MATOC Benefit-Cost Analysis White Paper

MATOC
Metropolitan Area Transportation Operations Coordination

June 2010

District Department of Transportation
Maryland Department of Transportation
metro
VDOT Virginia Department of Transportation

"Working together to reduce incident-related travel delays through improved coordination, cooperation, and information-sharing."

This report prepared by Sabra, Wang & Associates, Inc. under the Implementation Manager support contract with MWCOG and the guidance of the MATOC Steering Committee.

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1.0 EXECUTIVE SUMMARY

The National Capital Region (NCR) is a diverse, multi-jurisdictional region, which includes travel by automobile, transit, rail, carpool, bicycle and foot. Within the NCR, there are multiple transit services, rail lines and over 300 centerline miles of interstates, parkways, tollways and HOV/HOT lanes under the jurisdiction of many DOT agencies (Federal, State, local), including the Park Service, one District, two States, 36 municipalities, 16 counties, and multiple transit agencies and toll authorities. Because of the close proximity of these governing jurisdictions, an incident that affects a transportation system in one jurisdiction (e.g., interstate highway) often will affect traffic operations and other modes of travel in adjacent jurisdictions, and the likelihood of this occurring increases with the length of time it takes to detect, mobilize and fully mitigate the incident – programs that facilitate coordination via the timely sharing of accurate incident information among NCR agencies are anticipated to reduce incident duration and be of significant benefit to the public.

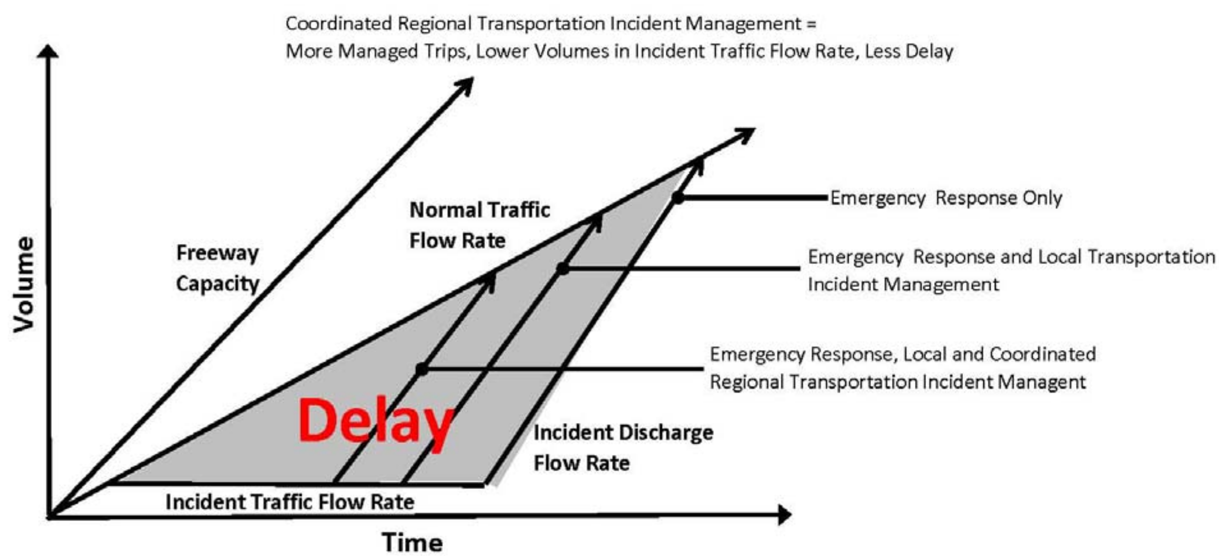
The Metropolitan Area Transportation Operations Coordination (MATOC) Program has an information-sharing mission to foster among transportation agencies a real-time situational awareness of transportation operations during regionally significant incidents that occur in the NCR. MATOC monitors, gathers and communicates accurate and timely incident and mobility information so that transportation agencies in the NCR may better coordinate their respective response activities to improve public safety (e.g., reduce secondary crashes), reduce travel delay and fuel consumption, and better inform the public, which allows individuals to make better informed travel decisions (e.g., defer or delay travel, take an alternate route or mode of travel). MATOC, however, does not usurp or override the policies or actions of other agencies, nor does it get involved in direct incident management or operational decision making, operation of service patrols, maintenance of traffic control systems, or snow removal.

Regional traffic incidents include incidents that have a significant impact on the transportation network in more than one jurisdiction; multiple minor incidents that create cascading additive impacts closely resembling that of a major incident; and severe weather that has an impact on the regional transportation network. Incidents of regional significance typically monitored by MATOC include traffic collisions, disabled vehicles, vehicle fires, hazardous materials incidents, medical emergencies, debris on roadway, road construction, weather events (e.g., thunderstorms, sleet and snow), or any combination of events that would propagate a regional transportation impact. In general, the more severe the incident, the longer its duration and impact to the traveling public.

Within the NCR, the average highway user spends 62 hours per year in congested traffic, 51% of which is non-recurring congestion caused by these traffic incidents. Interstate I-270 alone has an average of 7 incidents per day total both directions, end-to-end – 41% crashes and 59% non-crashes (e.g., disabled vehicles, police activity). On average, there are a total of 224 police-reported crashes per day on all roadways in the

NCR, and a percentage of these incidents are of such regional significance that MATOC involvement is warranted. For example, from December 1, 2009 to April 30, 2010, MATOC was involved with an average of 36 incidents per month.

It is well recognized that the coordinated sharing of incident and mobility information with potentially affected regional transportation agencies during traffic incidents has a positive effect in reducing the incident timeline in terms of detection, verification, information dissemination, response, clearance, and recovery. Programs that reduce the incident timeline and provide travelers with an earlier and regionally broader advance warning to modify their trips will reduce queue buildup, traffic delay and secondary crashes, which, in aggregate, will provide significant tangible benefits in terms of cost savings related to emissions, fuel consumption, value of time and safety. Modified trips in this context are considered trips made at a later time, on another route, by another mode, or cancelled. The following graphically illustrates this concept, where earlier incident detection and regionally broader coordination and notification by MATOC reduces the incident timeline (i.e., traffic delay and queuing) more than emergency response and local transportation incident management, which is the incremental benefit of MATOC:



This study uses traffic modeling techniques, the best available data, and engineering judgment to estimate loss of roadway capacity, vehicular queuing, travel delay, and costs (i.e., emissions, fuel consumption, value of time) associated with regionally significant traffic incidents for the purpose of quantifying benefits attributable to MATOC's real-time coordination and sharing of incident and mobility information among affected NCR transportation agencies during the incident timeline. The study uses procedures and methodologies that are commonly used and accepted in traffic engineering theory and practice, but attempts to maintain a straightforward and transparent approach. The study philosophy is to use reliable published data when available and, when assumptions are made, to be reasonable and conservative. The following sketch-planning analysis was used in this study to quantify the benefits attributable to the implementation of MATOC:

1. Identify Representative Case Studies. The study identified the following three incidents involving MATOC that occurred on major roadway facilities in the NCR:

    a. I-66 WB Bus Crash. On Friday, May 22, 2009 at approximately 4:45 PM, a multi-vehicle, rear-end crash (including two buses chartered for a school trip) occurred in the far left lane of WB I-66 just before the WB I-66 off-ramp to NB Nutley St. (MD 243) in Fairfax, VA. MATOC notified VDOT, Fairfax County, Maryland SHA CHART, Virginia Commuter, DDOT, and WMATA at key points during the incident timeline.

    b. I-495 EB IL Vehicle Fire. On Thursday, September 17, 2009 at approximately 3:00 PM, a vehicle fire occurred in the far left lane of the EB I-495 Inner Loop west of MD 187 in Montgomery County, MD. MATOC notified Maryland SHA CHART and VDOT at key points during the incident timeline.

    c. New York Avenue Shoulder Collapse. From 3:00 PM Friday, May 9 to 5:00 PM Sunday May 11, 2008, a storm sewer failure between the 1100 and 1200 blocks of New York Avenue (a major arterial link between DC 295 and I-395) caused a partial roadway collapse and the loss of the one or more travel lanes in the westbound direction into the District of Columbia, which is normally three lanes in the westbound direction. This inbound lane was closed for the entire weekend for emergency construction. MATOC coordinated the sharing of information among DDOT and Maryland SHA CHART.

2. Model Traffic Incidents. The study developed and calibrated a traffic model for each case study having MATOC involvement to reflect the actual incident timeline of events and the resulting primary queue length and duration reported by RITIS. Using each calibrated base model, the study conservatively adjusted the model's incident timeline of events (e.g., if and when DMS messages were posted) and the percent modified trips that would be expected if MATOC had not been involved – the independent variable being percentage and time of occurrence of modified trips.

3. Estimate Costs. The study estimated the costs of each incident with and, hypothetically, without MATOC in terms of emissions, fuel and value of time due to the resulting queue and traffic delay – the net benefit of MATOC for each incident being the difference in total cost of emissions, fuel and value of time (i.e., reduced emissions, fuel consumption, and wasted time).

4. Annualize Benefits. The study annualized the benefits of MATOC by conservatively estimating, based on historical data, how many incidents similar to the case studies would be expected to occur each year.

5. Determine the Benefit-to-cost Ratio. The study calculated the benefit-to-cost ratio as the ratio of the annualized benefits of MATOC to MATOC's annual operating cost.

Based on this conservative analysis, MATOC is demonstrated to have a benefit-to-cost ratio of 10:1. Note that this assessment is conservative as it does not include potential savings for reduced or eliminated secondary queues, secondary incidents or the potential delay reduction due to rubbernecking in the opposite direction. Also note that this assessment is conservative because the study does not attempt to quantify costs or benefits of the aggregate impacts of multiple simultaneous incidents being greater than the sum of their parts – an exacerbation effect.

The study concludes that MATOC has yielded positive benefits in cost savings associated with reduced traffic delay, reduced emissions and reduced fuel consumption. Although not directly evaluated in the analysis, it is also known through previous research of similar programs that MATOC indirectly improves the safety of incident responders and other motorists. At the current level of operation, it is expected that an even higher benefit-to-cost ratio would be realized with only a nominal percent increase in the occurrence of minor incidents and only a few additional major incidents in one year. Furthermore, MATOC benefits could be increased by providing supportive direct traveler information through, for example, a branded website for:

- real-time travel time information,
- trip planning,
- transit and toll information,
- notices/advisories (e.g., road closures), and
- information on additional arterials, local roadways and local transit service.

MATOC benefits can also be increased by developing standard operating procedures and action plans for recurring special events and major construction projects.

2.0 INTRODUCTION

2.1 Coordinated Regional Transportation Incident Management (CRIM)

2.1.1 What is CRIM

Traffic incidents lead to congestion when the traffic demand exceeds the reduced roadway capacity at the incident location. Nationally, traffic incidents account for approximately 60% of vehicle-hours lost to non-recurring congestion. Therefore, quick detection, response, and removal of incidents are essential to maximizing the efficiency of the existing traffic networks. It is widely accepted that these non-recurrent congestion problems can be reduced by the proper use of incident management procedures (source: *Evaluation of Incident Management Strategies, Final Report, November 2005, FHWA-NJ-2005-020, Ozbay, et. al.*).

Traffic incident management is defined as the "systematic, planned, and coordinated use of human, institutional, mechanical, and technical resources to reduce the duration and impact of incidents, and improve the safety of motorists, crash victims, and incident responders. These resources are also used to increase the operating efficiency, safety, and mobility of the highway by systematically reducing the time to detect and verify an incident occurrence, implementing the appropriate response, and safely clearing the incident, while managing the affected flow until full capacity is restored. (source: *Traffic Incident Management Handbook, 2000*). Coordinated regional incident management is the planned, coordinated effort between multiple agencies to deal with incidents and restore normal traffic flow as safely and quickly as possible. This effort makes use of technology, processes, and procedures to reduce incident duration and impact to:

- reduce incident detection, verification, response, and clearance times to quickly re-establish normal capacity and conditions;
- enhance safety for motorists and field/safety personnel;
- reduce the number of secondary crashes that occur as a result of the primary incident;
- reduce motorist costs, vehicle emissions, and business costs; and
- allow resources to resume non-incident activities.

Because so many entities and jurisdictions are involved in response efforts, rapid and effective traffic incident management relies on successful information sharing between public safety agencies, transportation agencies, and other public and private sector incident responders. Information sharing is critical for quick and appropriate response because the efforts have direct correlations to public safety and mobility.

Programs that promote and enhance information sharing allows multiple agencies to identify needed resources and provide coordinated regional incident management; it also provides the motoring public with information upon which to base their travel choices (source: *Information Sharing for Traffic Incident Management, Ingrid Birenbaum, FHWA-HOP-08-059, January 2009*).

The monitoring, detection and real-time dissemination of incident-related information to affected agencies in the NCR is vital. ***Better information dissemination allows travelers to make better decisions regarding departure time, mode choice, and route to take*** (source: *Information Sharing for Traffic Incident Management, Ingrid Birenbaum, FHWA-HOP-08-059, Final Report, January 2009*) – i.e., modified trips.

2.1.2 Objectives of Information Sharing TIM Programs

Through the efforts of the Federal Highway Administration's (FHWA) TIM Program-Level Performance Measures Focus States Initiative, participating states developed the following key objectives for traffic incident management program elements such as CRIM (source: *Information Sharing for Traffic Incident Management, Ingrid Birenbaum, FHWA-HOP-08-059, Final Report, January 2009*):

- Reduce incident notification time (defined as the time between the first agency's awareness of an incident and the time to notify needed response agencies).
- Reduce roadway clearance time (defined as the time between awareness of an incident and restoration of lanes to full operational status).
- Reduce incident clearance time (defined as the time between awareness of an incident and the time the last responder has left the scene).
- Reduce recovery time (defined as the time between awareness of an incident and restoration of impacted roadway(s) to "normal" conditions).
- Reduce time for needed responders to arrive on scene after notification.
- Reduce number of secondary incidents and severity of primary and secondary incidents.
- Develop and ensure familiarity with regional, multi-disciplinary TIM goals and objectives and supporting procedures by all stakeholders.
- Improve communications between responders and managers regarding the status of an incident throughout the incident.

- Provide timely, accurate, and useful traveler information to the motoring public on a regular basis during an incident.

- Regularly evaluate and use customer (road user) feedback to improve TIM program assets.

Additionally, the coordination and sharing of incident information at a regional level will:

- provide a single set of objectives for the entire incident – a collective approach to develop strategies to achieve incident objectives;

- improve information flow and coordination between all jurisdictions and agencies involved in the incident;

- enhance the understanding of joint priorities and restrictions by all agencies with responsibility for the incident; and

- optimize the combined efforts of all agencies as they perform their respective assignments to mitigate the impacts of the incident.

2.1.3 CRIM Implementation in the National Capital Region – MATOC

Safe, quick clearance of highway incidents — a foundation of both mature and developing traffic incident management program elements — depends on strong, coordinated multi-jurisdictional agency operations that are supported by integrated communications (source: *FHWA Open Letter to Transportation Professionals & Traffic Incident Management (TIM) Partners, Jeffrey A. Lindley, October 31, 2008*).

The National Capital Region (NCR) is a diverse, multi-jurisdictional transportation region, which includes travel by automobile, transit, rail, carpool, bicycle and foot. Within the NCR, there are multiple transit services, rail lines and over 300 centerline miles of interstates, parkways, tollways and HOV/HOT lanes under the jurisdiction of many DOT agencies (Federal, State, local), including the Park Service, one District, two States, 36 municipalities, 16 counties, and multiple transit agencies and toll authorities. Because of the close proximity of these governing jurisdictions, an incident that affects a transportation system in one jurisdiction (e.g., interstate highway) often will affect traffic operations and other modes of travel in adjacent jurisdictions, and the likelihood of this occurring increases with the length of time it takes to detect, mobilize and fully mitigate the incident – programs that facilitate coordination via the timely sharing of accurate incident information among NCR agencies are anticipated to reduce incident duration and be of benefit to the public.

The Metropolitan Area Transportation Operations Coordination (MATOC) Program was established in 2008 as a regional coordination initiative among the following primary stakeholders:

- National Capital Region Transportation Planning Board (TPB),
- District of Columbia Department of Transportation (DDOT),
- Maryland Department of Transportation (MDOT),
- Virginia Department of Transportation (VDOT), and
- Washington Metropolitan Area Transit Authority (WMATA).

Secondary stakeholders are those centers, agencies, and organizations representing local traffic management centers, state and local public safety agencies, local public information officers, and others linked to the management of major emergencies and dissemination of information, such as:

- US DOT,
- US Park Police,
- Maryland Transit Providers (e.g., MTA, Ride-On, The Bus),
- Virginia Transit Providers (e.g., PRTC, VRE),
- Maryland Local Jurisdiction DOTs (e.g., Montgomery, Prince George's),
- Virginia Local Jurisdiction DOTs (e.g., Fairfax, Loudoun, Arlington), and
- Metropolitan Washington Airport Authority (e.g., Dulles Toll Road).

MATOC has an information-sharing mission to foster among these NCR transportation agencies a real-time situational awareness of transportation operations during regionally significant incidents that occur in the National Capital Region (NCR). MATOC monitors, gathers and communicates accurate and timely mobility information so that the DOT agencies in the NCR may better coordinate their respective incident response activities to improve public safety, reduce travel delay and inform the public so that individuals can make better informed travel decisions. Program area coverage includes Northern Virginia, the District of Columbia and Suburban Maryland during weekday commuter peak hours and other periods, as needed, for special events (e.g., Nuclear Conference April 2010).

Regional traffic incidents include incidents that have significant impact on the transportation network in more than one jurisdiction; multiple minor incidents that create cascading additive impacts closely resembling that of a major incident; and severe weather that has an impact on the regional transportation network. Incidents of regional significance that MATOC typically monitors include traffic collisions, disabled vehicles, vehicle fires, hazardous materials incidents, medical emergencies, debris on roadway, road construction, weather events (e.g., heavy rain, thunderstorms, sleet and snow), and any combination of events that would propagate a regional transportation impact. For example, recent incidents having MATOC involvement include:

- snow removal on I-495 between SR 267 and the Tysons Area (December 2009);
- electrical fire and unrelated police investigation that closed the Pennsylvania Avenue overpass over Rock Creek Parkway and M Street in Georgetown (January 7, 2010);
- tractor trailer fire on Montrose Road (January 14, 2010);
- two Metro technicians struck and killed by a piece of track equipment near the Rockville Metrorail station requiring closure of the Red Line (January 26); and
- regional record-breaking snowstorms (February 5-12, 2010).

RITIS and other NCR transportation information sources are actively monitored by MATOC to identify transportation incidents on highways and major arteries. Some of the key information sources monitored by MATOC include:

6. Regional Integrated Transportation Information System (RITIS). RITIS is an automated system that supports MATOC activities by compiling real-time traffic and transit data from agencies around the region; consolidating the data into a common format; and enabling the data to be shared with participating agencies, the media and the public. RITIS is maintained by the Center for Advanced Transportation Technology laboratory at the University of Maryland. RITIS data originates from the native incident management systems of the Maryland SHA (CHART), DDOT (CAPTOP), VDOT (OpenTMS) and the service disruption data from WMATA.

7. Capital Traffic Operation Platform (CAPTOP). CAPTOP is an integrated system developed by the Traffic Service Administration of District Department of Transportation for traffic operation and management. CAPTOP consists of a traffic incident management subsystem and a roadway traffic information subsystem. The traffic incident management subsystem is designed to record traffic incident/event information, monitor incident status, facilitate incident management and offer timely incident reports.

8. Coordinated Highways Action Response Team (CHART). The CHART website provides detailed traffic information for the Maryland Department of Transportation. The website provides an interactive traffic map that displays incidents, congestion, road work, CCTV, DMS, HAR and weather station reporting.

9. CAPWIN. CAPWIN is an interoperable first responder data communication and information sharing network. CAPWIN's application suite enables incident management & coordination across agencies, regions, and public safety and

transportation disciplines. CAPWIN was developed for mobile-to-mobile as well as HQ-to-mobile (and vice versa) communications.

10. INRIX. INRIX is a subscription service of traffic speed and congestion data. The data can be used to identify real-time speed and congestion data as well as to perform comparative analyses of historical speed and congestion data.

11. WebEOC®. WebEOC links local, state, federal, volunteer, private and worldwide sources together, helping to facilitate coordination and decision-making for planning, training and emergency response, recovery and continuity of government and business operations.

In addition to the above sources of information, MATOC monitors VA's My511, WTOP Radio, Trafficland CCTV Console, COG RICCS Roam Secure Network, and the WMATA service disruption website.

Once identified, incidents are tracked and evaluated for the potential to become a regional event. Information that is received from NCR agencies and MATOC's situational awareness notification/update emails that are broadcast to NCR agencies are exchanged via telephone, email (e.g., Blackberry, PDA), paging, RICCS, CAPWIN, NAWAS, and WebEOC®. The following is an example of a typical "For Your Situational Awareness" email:

Subject: MATOC Situational Awareness: I-495 Ramp/Lane Closures at Telegraph Road.

For your situational awareness:

- *Incident: construction activities*
- *Location: I-495 East & West/I-95 North & South, at the Telegraph Road interchange, mile marker 176, in Fairfax County*
- *There will be lane and ramp closures this week on the Inner and Outer Loops, nightly, from 9pm to 5am, Monday, May 3rd, to Friday morning, May 7th, daily, from 9am to 3pm, Monday, May 3rd, to Thursday, May 6th, and 9am to noon, Friday, May 7th, weather permitting.*
- *During this time, the Capital Beltway will be narrowed to two lanes, between Van Dorn Street, Exit 173, and Telegraph Road, Exit 176. There will also be lane and ramp closures on Telegraph Road.*
- *Motorists are urged to use alternate routes to avoid delays in the area.*
- *Please see the release below, from the Woodrow Wilson Bridge Project for further information.*
- *MATOC will update, as needed, with congestion and traffic information throughout the week.*

Table 1 identifies the MATOC "For Your Situational Awareness" emails broadcast to stakeholders for incidents that occurred from November 17 to December 11, 2009.

Table 1. MATOC Notifications: November 17, 2009 through December 11, 2009

Date	Location and Description	Notifications Made
17-Nov	I-395 near Duke St, Accident, significant traffic delays	WMATA, DDOT, VA Transit
18-Nov	Suitland Pkwy, 2 accidents, one on Naylor Rd in MD, the other at Alabama Ave in DC with alternating lane closures (first left then right), significant delays	WMATA, MD SHA, DDOT, MD Transit
20-Nov	EB I-66 at I-495, TT accident with all lanes closed	VA Transit, WMATA, DDOT
24-Nov	OL I-495 past Connecticut Ave, vehicle accident, significant delays	MD Transit, WMATA, DDOT
2-Dec	EB I-66 at I-495, vehicle accident, significant delays	VA Transit, WMATA
3-Dec	WB I-66 at Dulles Toll Rd, vehicle accident, significant delays	DDOT, WMATA, VA Transit
3-Dec	SB US29 at Lockwood Dr, tree down, all SB lanes blocked	MD Transit, WMATA
4-Dec	WB US50 at Kenilworth Ave, overturned single unit truck, significant delays	DDOT, MD SHA, WMATA, MD Transit
7-Dec	NB I-295 at Malcolm X Blvd, vehicle accident, significant delays	MD SHA, WMATA, MD Transit, WWB
8-Dec	NY Ave (inbound) at Montana Ave, disabled vehicle, significant delays	MD SHA, WMATA, MD Transit
9-Dec	IL I-495 at Telegraph Rd, standing water, significant delays	MD SHA, DDOT, WMATA, VA & MD Transit, WWB
10-Dec	NY Ave (inbound) and Bladensburg Rd, signal timing issues, significant delays	WMATA, MD SHA, DDOT, MD Transit
10-Dec	IL I-495 at Telegraph Rd, construction, significant delays into MD	MD SHA, WMATA, DDOT, VA & MD Transit, WWB
10-Dec	IL I-495 at Gallows Rd, Accident, significant delays	MD SHA, WMATA, DDOT, VA & MD Transit, WWB
11-Dec	NB MD295 at MD198, accident, significant delays	MD Transit, WMATA
11-Dec	Pentagon City METRO, suspicious package, 2 stations closed	MD SHA, VDOT, DDOT, VA & MD Transit

MATOC's day-to-day operations are conducted by a Communication Facilitator whose primary role is to act as the "communications hub" among the stakeholders and affected local transportation and public safety agencies. The Facilitator and support staff are also responsible for developing, maintaining and using tools (e.g., Regional Integrated Information System – RITIS) and processes to facilitate coordinated operating agency responses and for working with key agency personnel on pre- and post-incident analyses to improve operating procedures. Specifically, MATOC:

- provides for the quick and reliable exchange of transportation system information among operating agencies in the NCR;
- enables agency operations' staff to more effectively and reliably coordinate with each other and their peers in other agencies when a major incident or emergency occurs;
- continually improves the region's ability to inform the public and manage the transportation system; and

- continually improves regional preparedness for effectively managing the transportation system in response to major incidents.

MATOC's typical daily activities include:

1. Review incident log, pass-on book, and squawk sheet (trouble reports, maintenance).
2. Monitor RITIS, scan for major incidents, incidents near jurisdictional boundaries and multiple incidents in relative close proximity.
3. Monitor email and voicemail for incident notification (RICCS and other automated notification services).
4. Monitor WTOP; listen to traffic reports, weather reports, and major news stories with potential regional impact.
5. Monitor WTOP Incident Map. Cross reference with RITIS information. Identify and follow up on discrepancies, especially those that indicate lane closure.
6. Monitor CAPWIN; check incidents and chat rooms, especially those relating to transportation and transit operations.
7. Monitor Trafficland CCTV Console (or WTOP cameras if no Trafficland account). Use cameras to help confirm incident and lane closures. Use upstream cameras to estimate queue.
8. Monitor INRIX (or MapQuest if INRIX not available) regional travel speed and congestion displays to help identify congestion, stopped traffic, and incidents not displayed in RITIS.
9. Monitor WebEOC(s).
10. Monitor National Warning System (NAWAS) radio for alerts and roll call.
11. Monitor scanner(s).
12. Monitor supplemental sites to enhance situational awareness, including:
    a. My511 – Virginia DOT interactive website.
    b. CHART – Maryland DOT interactive website.

c. WMATA service disruptions site – provides known bus and rail disruptions.

d. WMATA interactive mapping – can be used to display PID at all rail stations.

e. MARC and VRE interactive sites – Commuter rail real time tracking, shows delays.

f. Monitor construction projects as any incident, coupled with a work zone could have a regional impact.

It is important to note that MATOC does not usurp or override policies or actions of any of the participating agencies. Nor does MATOC get involved in direct incident management or operational decision making, operation of service patrols, maintenance of traffic control systems, or snow removal. MATOC's primary function in traffic incident management is to monitor, collect, analyze, synthesize, and coordinate the sharing of information among the stakeholders regarding incidents of regional significance and actions taken by the agencies involved.

2.1.4 Benefits of Traffic Incident Management

In the larger context of traffic incident management program elements, such as coordinated regional information sharing programs), several benefits are recognized by the industry (source: *Benefits of Traffic Incident Management, National Traffic Incident Management Coalition, 2006*):

1. Economic Savings. By reducing travel delay, fuel consumption, emissions, and secondary incidents, traffic incident management programs boost the national and regional economy.

2. Energy Conservation and Environmental Benefits. Shorter incident durations as a direct result of traffic incident management program elements reduce fuel consumption, fuel costs, and emissions.

3. Public Health and Safety Benefits. Effective traffic incident management programs reduce traffic congestion, which improves roadway safety and reduces crashes.

4. Reduced Mortality. Faster highway incident detection and response saves lives. Response time has a well-documented relationship to likelihood of crash survival. For seriously injured patients, arrival at the hospital within the "golden hour" after the crash is considered a strong predictor of patient outcome.

5. Reduced Patient Morbidity. Faster incident detection and response prevents injuries and reduces health care costs. Particularly in cases of head trauma or internal injury, faster EMS response can dramatically improve a crash survivor's prognosis and reduce the collateral costs to society.

6. Increased Customer Satisfaction. Effective traffic incident management programs increase public satisfaction with government services. Clearing the road after an incident ranked as the top priority among SHA functions in a 2006 statewide citizen survey by MDOT, with 98% of respondents ranking road clearance as "very important" (source: *Schaefer Center for Public Policy: The State Highway Administration Customer Survey Report, Draft Report 2 of 2 Results Sorted by Customer Order of Importance, SMT Review Data, Customer Satisfaction Survey Results, University of Baltimore, May 10, 2006*).

Additionally, (source: *ITS for Traffic Incident Management: Deployment Benefits and Lessons Learned, ITS US DOT, May 2007*) reports the following:

- traffic incident management reduces fuel consumption by about 1.2% annually, saving 2,600-7,700 gallons per incident;

- traffic incident management reduces incident duration by up to 65% and reduces secondary crashes by 30–50%;

- service patrol type programs have benefit-to-cost ratios ranging from 2:1 to 36:1;

- ITS technologies for traffic incident detection, verification, response, and communication are recognized as valuable tools by transportation professionals and are being used throughout the country: 32% of freeway miles are monitored by video to detect incidents, and 45% are served by service patrols; and

- traffic incident management on arterial streets is growing: 5% of arterial streets have video monitoring for detection, and 10% have service patrols.

2.1.5 Challenges in Assessing Benefits of CRIM

Qualitative results from other metro areas are in strong support of regional transportation incident management and make the case that such program elements should be prioritized and funded at the federal, state and local levels. Program elements that may fall under the general rubric of traffic incident management include development of unified policies, procedures, operations and/or communication systems among incident responders; the application of ITS technologies to traffic incidents; motorist assistance patrols; interdisciplinary training in traffic control, Unified Command (UC) and National Incident Management System (IMS); improved towing industry procedures and practices; and enhanced traveler information systems. Among these, motorist assistance patrols have the best documented cost and benefit data (source: *Benefits of Traffic Incident Management, National Traffic Incident Management Coalition, 2006*).

NCHRP Report 520, Sharing Information between Public Safety and Transportation Agencies for Traffic Incident Management (2004) reviews the effectiveness of information sharing programs, similar to MATOC, in nine metropolitan areas (i.e., Albany, Austin, Cincinnati, Minneapolis, Phoenix, Salt Lake City, San Antonio, San Diego, Seattle) that involve regional coordination of public safety, transportation, and other public and private sector entities. The study reported that most local officials interviewed strongly supported sharing traffic incident information and employing multi-agency teams to coordinate and manage traffic incidents. The consensus opinion among these officials was that information sharing provides strong benefits in supporting coordination and cooperation in planning for and managing traffic incidents. However, these opinions were based generally on anecdotes and experience rather than hard evidence. None of the metropolitan areas reported in the study formally quantified the benefits of information sharing, such as detection, notification, response, clearance time, responder safety, or other metrics of performance; however, some locations have conducted subjective and empirical assessments of traffic incident management benefits. For example, incident responders in San Antonio have estimated that joint training and planning activities of their CMT has resulted in a 40% decrease in incident clearance times. Ideally, to more precisely quantify CRIM benefits, more detailed monitoring of incident performance metrics is recommended, such as:

- a baseline, or control group, to provide a basis for comparing current performance with former arrangements;
- establishing more direct cause and effect relationships between information-sharing activities and benefits related to improved traffic flow or reductions in mortality or morbidity (e.g., queues, secondary incidents); and
- public education and media coverage about the costs of mobility and partnerships on a regional level working towards improved incident response and operations.

Although, no specific examples of benefit reporting was obtained that could highlight the performance measures and benefits attributable to information sharing between public safety agencies and transportation agencies, there is nevertheless a substantial, albeit un-quantified, benefit that is intuitively attributed to the coordinated regional sharing of information for the purpose of managing and mitigating traffic incidents.

2.2 Study Purpose and Objectives

Americans lose 3.7 billion hours and 2.3 billion gallons of fuel every year sitting in traffic. In 2004, trucks idling in traffic are estimated to have cost the trucking industry some 243 million hours, the equivalent of 17,000 work years, with a cost of $8 billion. To combat the country's growing transportation congestion problem, the U.S. Department of Transportation launched the National Strategy to Reduce Congestion on America's Transportation Network. One element of this initiative is to reduce incident-related congestion by promoting operational and technological improvements that increase incident response capabilities (source: *ITS for Traffic Incident Management: Deployment Benefits and Lessons Learned, ITS US DOT, May 2007*).

Traffic incidents account for about one-quarter of all congestion on U.S. roadways. For every minute that a freeway travel lane is blocked during a peak travel period, four minutes of travel delay results after the incident is cleared (source: *Benefits of Traffic Incident Management, National Traffic Incident Management Coalition, 2006*). Reduced incident-related travel delay is a key benefit of traffic incident management program elements. For example, the Maryland SHA Coordinated Highways Action Response Team (CHART), a robust incident management program that includes motorist assistance patrols, reduced average incident duration by 28% in 2008. CHART assisted in 21,586 lane blockage incidents where average incident duration in 2008 was approximately 25 minutes, compared to 35 minutes for similar incidents responded to by other agencies, reducing travel delay on major Maryland corridors by 32 million vehicle-hours (source: *University of Maryland and Maryland State Highway Administration, Performance Evaluation and Benefit Analysis for CHART – Coordinated Highways Action Response Team – Year 2008*).

Although traffic incident management programs address issues that are of vital concern to the public (e.g., congestion and travel delay, public health and safety, the nation's economic health, energy savings, public safety resources, responder safety, and citizen satisfaction with government services), decision-makers at all levels of government generally do not have incident management programs on their "radar screen," in part because the benefits of such programs have not been articulated succinctly and strongly. Before they vote for, or budget for, traffic incident management program elements (such as MATOC or CHART), public officials want to know the cost-benefits of the investments. While one can safely assume that no one wants "unsystematic, unplanned, uncoordinated" traffic incident management, the reality is that investment in the elements of traffic incident management programs must compete with other worthy public investment opportunities (source: *Benefits of Traffic Incident Management, National Traffic Incident Management Coalition, 2006*).

In recognition of the above information, the MATOC Steering Committee commissioned this study to:

- assess the benefits that are unique to the coordinated management of incidents affecting regional travel in the NCR;

- determine how regional coordination of major traffic incidents that span jurisdictional boundaries (e.g., DDOT, VDOT, MDOT) enhances existing local incident management and mobility savings (e.g., time, fuel, emissions); and

- determine the benefit-to-cost ratio of the MATOC Program.

The following example helps to illustrate MATOC's primary activities and benefits:

> *Consider a scenario where a tractor-trailer overturns on the Capital Beltway and catches fire, which closes the roadway for an extended period. The immediate scene of the incident is handled skillfully and responsibly by police, fire, transportation and other first-responder personnel (e.g., CHART). Following well-established local incident management procedures, they work to clear the incident as quickly as possible, while providing public safety and security at the scene. However, as time progresses, the incident begins to quickly impact the regional transportation system miles from the scene – generating major travel/transit delays and traffic back-ups that could span jurisdictional boundaries and affect thousands of people. It is not the primary responsibility of the on-scene first responders to address these faraway secondary "ripple effects," as they are too busy addressing the immediate needs at the scene of the incident. The MATOC Program staff act to mitigate these ripple effects by making real-time notifications to potentially impacted transportation agencies in local and adjacent regional jurisdictions (e.g., DDOT, VDOT, MDOT, WMATA) to help ensure roadway variable message signs, radio traffic reports, and other means are used to notify the traveling public to avoid the area or expect delays. When travelers alter their travel route to avoid the problem area or decide to defer their travel to a later time, congestion queuing, secondary crashes in backups, travel delay, fuel consumption, and the resulting air pollution are reduced. These savings become increasingly significant when dealing with multiple regional incidents that occur simultaneously in the NCR.*

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3.0 STUDY APPROACH AND METHODOLOGY

3.1 Approach

This study uses traffic modeling techniques, the best available data, and engineering judgment to estimate traffic incident capacity loss, queuing, travel delay, and costs (i.e., emissions, fuel consumption, value of time) for the purpose of conservatively estimating quantifiable benefits attributable to MATOC's coordinated sharing of information with affected agencies in the National Capital Region. The study uses procedures and methodologies that are commonly used and accepted in traffic engineering theory practice, but attempts to maintain a straightforward and transparent approach. The study philosophy is to use reliable published data when available and, where assumptions are made, to be reasonable and conservative.

Based on the review of literature, it is recognized that the coordinated sharing of information with affected agencies during regional traffic incidents will have a positive effect in reducing the time associated with the following elements of the incident timeline, as discussed in Appendix 7.2.2 (source: *Information Sharing for Traffic Incident Management, Ingrid Birenbaum, FHWA-HOP-08-059, Final Report, January 2009*):

- incident detection,
- incident verification,
- motorist information dissemination,
- incident response,
- incident clearance, and
- incident recovery.

Any program that can hasten the mitigation of the traffic incident and provide travelers in the region with an earlier advance warning to modify their trips will reduce queue buildup and traffic delay, which, in aggregate, will provide <u>significant</u> tangible benefits in terms of cost savings related to emissions, fuel consumption and value of time. Modified trips in this context are considered trips being made at a later time, on another route, by another mode, or trips cancelled.

A literature review was undertaken to research an appropriate study approach and methodology that could be used to quantify the benefits that can be attributed to the implementation of the MATOC program. It was determined to use the following sketch-planning analysis:

7. <u>Identify Representative Case Studies</u>. Identify three representative traffic incidents (i.e., bus crash, vehicle crash, shoulder collapse) occurring on major

roadway facilities in the National Capital Region (i.e., I-66, I-495, New York Avenue) that involved coordinated regional incident management by MATOC.

8. Model Traffic Incidents. Develop and calibrate a traffic model for each incident having MATOC involvement to reflect the actual incident timeline of events and the resulting primary queue length and duration reported by RITIS. Using these calibrated base models, conservatively adjust the incident timeline of events (e.g., if and when DMS messages are posted) and the percent modified trips that would be expected if MATOC had not been involved – the independent variable being percentage and time of occurrence of modified trips. For example, FHWA HOP-09-002 evaluated ITS (VMS/DMS) use in DC area work zones and documented an average of 52% diversion of mainline traffic volume with advanced traveler information.

9. Estimate Costs. Estimate the costs of each incident with and, hypothetically, without MATOC in terms of emissions, fuel and value of time due to the resulting queue and traffic delay – the net benefit of MATOC for each incident being the difference in total cost of emissions, fuel and value of time (i.e., reduced emissions, fuel consumption, and wasted time).

10. Annualize Benefits. Annualize the benefits of MATOC by conservatively estimating, based on historical data, how many times incidents similar to the case studies would be expected to occur each year.

11. Determine the Benefit-to-cost Ratio. Calculate the benefit-to-cost ratio as the ratio of the annualized benefits of MATOC to MATOC's annual operating cost.

Note that this assessment is conservative as it does not include potential savings for reduced or eliminated secondary queues, secondary incidents or the potential delay reduction due to rubbernecking in the opposite direction. Also note that this assessment is conservative because the study does not attempt to quantify costs or benefits of the aggregate impacts of multiple simultaneous incidents being greater than the sum of their parts – an exacerbation effect.

3.2 Model Selection and Development

3.2.1 *Highway Capacity Manual 2000* (HCM)

The selected case studies primarily occurred during the evening commuter peak hour on principal facilities (I-66, I-495, New York Avenue) – which, in the National Capital Region, are operating at or close to capacity. Thus, removing one or more lanes due to a traffic incident will assuredly create a bottleneck with a demand-to-capacity ratio greater than one – an oversaturated condition.

Using a conventional HCM analysis for analyzing freeways (e.g., I-66, I-495) operating at an oversaturated condition is not recommended. The HCM states that the literature does not sufficiently describe the effect of traffic incidents on speeds and hence on the speed-flow curve. Without a full speed-flow curve, the analyst is forced to use other methods or to work around this limitation of the model and should consider each capacity reduction in turn, from the simplest to the most difficult to deal with. The HCM further states that if the analysis is not concerned with speed (as in this study), capacity reduction could be modeled using proportioning factors. However, this idea was rejected because of the possibility of overestimating capacity reduction because there exists a lack of empirical data and supporting research, discussed in Appendix 7.3.2.2.

The HCM bottleneck, or queuing, analysis is directly applicable to analyzing impacts of traffic incidents on freeways, Interstates and other un-interrupted flow facilities. Generally, if the demand is greater than the new reduced capacity that is created by the traffic incident, a bottleneck is created, traffic that wishes to pass cannot do so, and a queue begins to form upstream. Since the bottleneck can only pass a flow equal to capacity (not demand) to the downstream lanes, the unmet demand is transferred to the next analysis time interval (usually 15-minutes), and the reduced flow rate through the bottleneck is propagated upstream in the form of a queue whose density depends on the severity of the bottleneck. Downstream of the bottleneck, traffic flow is metered at the bottleneck capacity rate. Only when the bottleneck effects clear (i.e., when demand drops or capacity is restored) does traffic flow on the downstream lanes increase to serve the unmet demand from the preceding analysis time interval. Given adequate time, the flows will catch up with demand, undersaturated operations will resume, and the queue will dissipate. This queuing analysis can be used to estimate traffic characteristics under traffic incident situations, including the estimation of maximum queue length, average queue length, maximum individual delay, average individual delay, and total delay. The inputs generally include normal capacity, traffic demand when the incident occurred, incident capacity, and the incident duration.

3.2.2 Maryland SHA Lane Closure Analysis Program (LCAP)

A queuing analysis model for analyzing traffic incidents was not found during the literature review; however, models that assess impacts of lane closures, such as in works zones, were evaluated for their applicability to this project. The Maryland State Highway Administration's (SHA) Lane Closure Analysis Program (LCAP) provides a structured method to analyze work zone impacts (e.g., bottlenecks, queue length and duration) associated with <u>hourly</u> volume variation and multiple lane closure scenarios. Although LCAP uses an hourly analysis time interval and will not determine costs associated with emissions, fuel consumption and value of time, its concept and framework was found to be applicable to assess the impact of traffic incidents – primary queue length and traffic delay resulting from the loss of capacity due to one or more lanes being closed.

In 2008, LCAP was successfully used in 20 projects as a means to mitigate traffic impacts (source: *Coordinating, Planning and Managing the Effects of Roadway Construction with Technology, April, 2009, RITA, US DOT*). Lane capacity in LCAP is customizable to include analysis criteria specific to the National Capital Region, and it is appropriate for assessing lane closures on uninterrupted flow facilities (e.g., freeways, interstates, arterials) that do not involve signalized intersections. The level of satisfaction of Maryland SHA staff is very high in terms of accuracy of travel times, traffic delays, and estimated queue lengths. The input data requirements depend on the roadway facility and the lane-closure scenario that is being analyzed. Output capabilities and calibration of parameters were found to be relatively easy (source: *Evaluation of Work Zone Enhancement Software, Organizational Results Research Report, University of Missouri for Missouri Department of Transportation, Final Report OR10-006, September 2009*).

The University of Maryland developed the following equation (which is used in LCAP) to determine reduced capacities at bottlenecks created by work zones in Maryland:

$$C_a = 1857 - 168.1N - 37L - 9HV + 92.7LD - 34.3WL - 106.1WI - 2.3WG * HV$$

where,

C_a	=	adjusted mainline capacity (vphpl)
N	=	number of closed lanes
L	=	location of closed lanes (right side = 1, otherwise = 0)
HV	=	proportion of heavy vehicles (%)
LD	=	lateral distance to open lanes (feet)
WL	=	work zone length (miles)
WG	=	work zone grade (%)
WI	=	work zone intensity (heavy = 1, light to medium = 0)

Based on the HCM bottleneck queuing analysis methodology, the University of Maryland equation, and the original framework of Maryland SHA’s LCAP program, a Microsoft Excel spreadsheet model was developed to analyze traffic incidents in 15-minute time intervals to determine queue length, queue duration, travel delay in queue, travel distance in queue, and the costs associated with emissions, fuel consumption and value of time.

3.2.3 Synchro/SimTraffic

Microscopic simulation models simulate the movement of individual vehicles based on car-following and lane-changing theories. Vehicles enter a transportation network using a statistical distribution of arrivals (a stochastic process) and are tracked through the network over brief time intervals (e.g., 1 second or a fraction of a second). Upon entry, each vehicle is assigned a destination, a vehicle type, and a driver type. In many microscopic simulation models, the traffic operational characteristics of each vehicle are influenced by vertical grade and other factors based on relationships developed in prior research. The primary means of calibrating and validating microscopic simulation models are through the adjustment of input parameters to reproduce output results.

Synchro/SimTraffic, a microscopic simulation model released by Trafficware of Sugarland, Texas, was selected for this project to model traffic incidents that occurred on interrupted-flow facilities (e.g., urban signalized arterials). Synchro/SimTraffic simulations can be used to simulate lane closures due to traffic incidents on signalized urban arterials. When using this type of modeling software, the model must be created and calibrated to reflect the bottlenecking, queue length, and queue duration of the traffic incident by adjusting lane configurations to simulate lane closures and adjusting traffic volumes to simulated trips being modified due to advance notification. To obtain outputs from the model, observations of simulations must be made (recording queue lengths and durations) or the output files must be read to determine the maximum queue length, etc. SimTraffic outputs total delay, delay/vehicle, stopped delay by turn movement, for arterials, and for the entire network; maximum queue, average queue, and 95-percentile queue by lane and by turn movement; and upstream block time, storage block time, and queuing penalty.

3.3 Cost Conversion Criteria

The following criteria were used to develop costs for emissions, fuel consumption, and value of time (source: *University of Maryland and Maryland State Highway Administration, Performance Evaluation and Benefit Analysis for CHART – Coordinated Highways Action Response Team – Annual Reports*; *Evaluation of the Benefits of a Real-Time Incident Response System, Andrey A. Petrov, et. al., University of Maryland, 2004*; and *Benefits of Traffic Incident Management, National Traffic Incident Management Coalition, 2006*):

EMISSIONS

Grams HC per veh-hour of delay in queue:	13.073
Grams CO per veh-hour of delay in queue:	146.831
Grams NOx per veh-hour of delay in queue:	6.261
Pounds CO2 per gallon of gasoline (car) burned:	19.560
Pounds CO2 per gallon of diesel (truck) burned:	22.380
Cost savings due to HC reduction (per ton):	$6,700
Cost savings due to CO reduction (per ton):	$6,360
Cost savings due to NOx reduction (per ton):	$12,875
Cost savings due to CO2 reduction (per ton):	$20.87

<u>FUEL CONSUMPTION</u>

Gallons of gasoline (car) consumed per veh-hour in queue:	0.1560
Gallons of diesel (truck) consumed per veh-hour in queue:	0.8500
Cost of gasoline:	$2.50/gal
Cost of diesel:	$2.60/gal

<u>VALUE OF TIME</u>

Cost of car occupant per veh-hour of delay in queue:	$26.58
Cost of truck driver per veh-hour of delay in queue:	$20.68
Cost of truck cargo per veh-hour of delay in queue:	$45.40

3.4 MATOC Annual Operating Cost

The Steering Committee has indicated that MATOC's annual operating cost is $1.2 million, as itemized below:

- Services: $360K
- Operations: $540K
  - Facilitator: $245K
  - Operator #1: $120K
  - Operator #2: $120K
  - Back-Up: $30K
  - Directs: $25K (including $8K for office space)
- RITIS Support: $150K
- Contingency $150K

4.0 CASE STUDIES

4.1 I-66 WB Bus Crash

This analysis compares actual mobility costs for an incident in which MATOC was involved for Coordinated Regional Incident Management (CRIM) versus potential costs for the same incident assuming only Local Incident Management (i.e., without MATOC) involvement. The independent variable in the analysis is percentage of trips modified. For example, FHWA HOP-09-002 evaluated ITS (VMS/DMS) use in DC area work zones and documented an average of 52% diversion of mainline traffic volume with advanced traveler information.

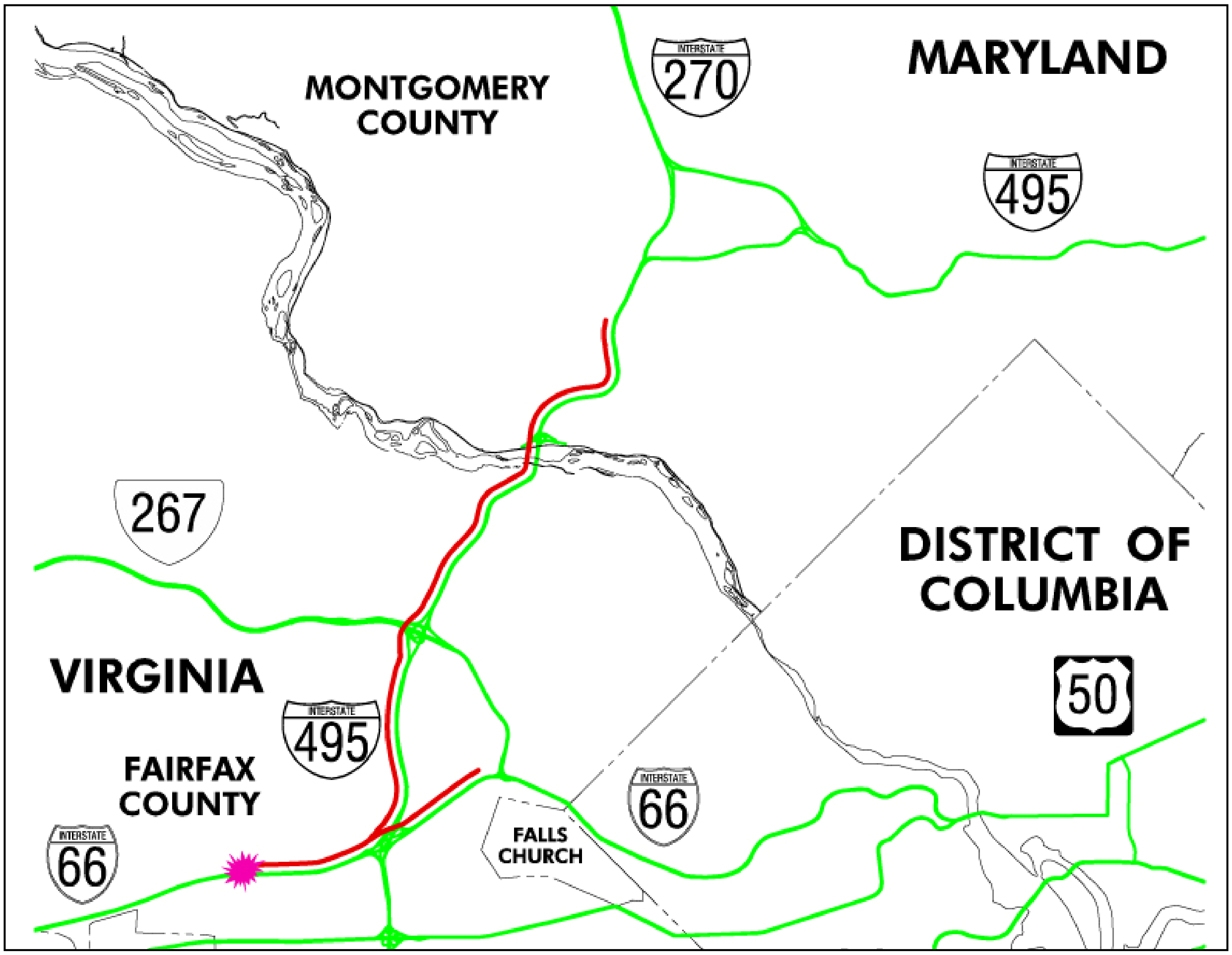
On Friday, May 22, 2009 at approximately 4:45 PM, a multi-vehicle, rear-end crash (including two buses chartered for a school trip) occurred in the far left lane of WB I-66 just before the WB I-66 off-ramp to NB Nutley St. (MD 243) at location N38°52'45.81" W77°15'07.80" in Fairfax, VA. The chronology of events with CRIM (i.e., with MATOC involvement) is shown in Table 2, and the resulting queue is illustrated in Figure 1.

Table 2. I-66 WB Bus Crash – Chronology of Events with CRIM

Clock Time	Elapsed Time (min)	Action	Lane Status
04:30 PM	---	[I-66 WB (3 Lanes+1 Shoulder Lane) (Begins 3:00 AM-Ends at 8:00 PM)]	4 Lanes Open / 0 Lanes Closed
04:45 PM	0:00	Two Buses Rear-End in Left-Most WB Lane	4 Lanes Open / 0 Lanes Closed
05:00 PM	0:15	Police/EMS Notified; MATOC notifies VDOT	3 Lanes Open / 1 Lane Closed
05:15 PM	0:30	EMS Task Force Equipment called to Scene; VDOT closes I-66/I-495 ramps; MATOC notifies CHART	3 Lanes Open / 1 Lanes Closed
05:30 PM	0:45	Three Lanes Needed for Equip/Services - Right Shoulder Used as Lane; CHART posts signs	1 Lanes Open / 3 Lanes Closed
07:00 PM	2:15	All Lanes Closed to Evacuate Injured-Buses-EMS Task Force; MATOC notifies Virginia Commuter, DDOT, WMATA	0 Lanes Open / 4 Lanes Closed
07:30 PM	2:45	Two Lanes Re-Opened To Traffic; MATOC send update emails; VDOT/Fairfax Co. monitor arterial congestion & bus delay	2 Lanes Open / 2 Lanes Closed
08:00 PM	3:15	(3-Lane Use After 8:00 PM)	2 Lanes Open / 1 Lane Closed
08:30 PM	3:45	Incident Cleared-Full Capacity Restored (3-Lane Use After 8:00 PM)	3 Lanes Open / 0 Lanes Closed
09:00 PM	4:15	RITIS Shows Normal Traffic Operations	3 Lanes Open / 0 Lanes Closed

Note: Modified trips assumed to begin at 10% at 5:15 PM and continue through the event peaking at 50% at 7:00 PM and reaching 0% modified trips at 9:00 PM.

Figure 1. I-66 WB Bus Crash – Illustration of Queues



Traffic volumes representing the day and location of the incident along westbound I-66 were developed based on historical 24-hour volume and classification machine counts obtained from VDOT and Sabra-Wang's record files. Figure 2 shows the diurnal distribution of traffic, and Figure 3 shows the percent modified trips used in the analysis.

A Microsoft Excel spreadsheet model was developed to calibrate a model to replicate the incident queue length and duration based on the University of Maryland LCAP capacity reduction equation discussed in Section 3.2.2, which demonstrated the following queue and traffic delay:

- 12.7-mile maximum queue length
- 3.8-hours duration of queue
- 9,490 vehicle-hours of delay in queue
- 173,730 vehicle miles of travel in queue

Figure 4 illustrates the cumulative queuing under CRIM conditions (i.e., with MATOC involvement).

Figure 2. I-66 WB Bus Crash – Diurnal Distribution of Traffic

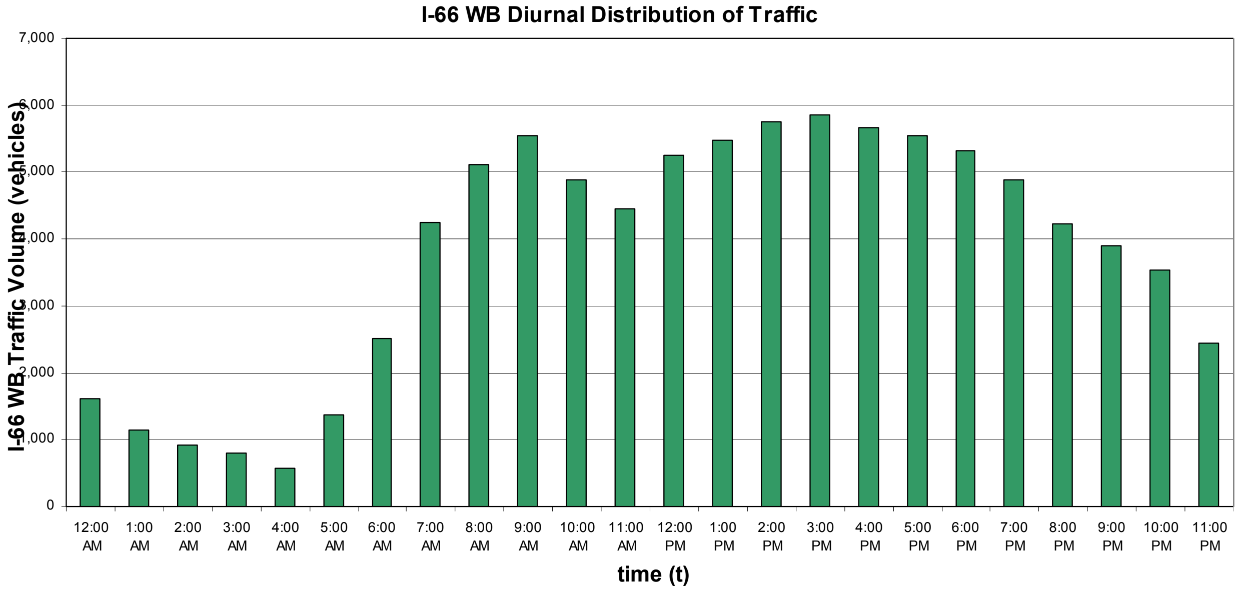


Figure 3. I-66 WB Bus Crash – Percent Modified Trips

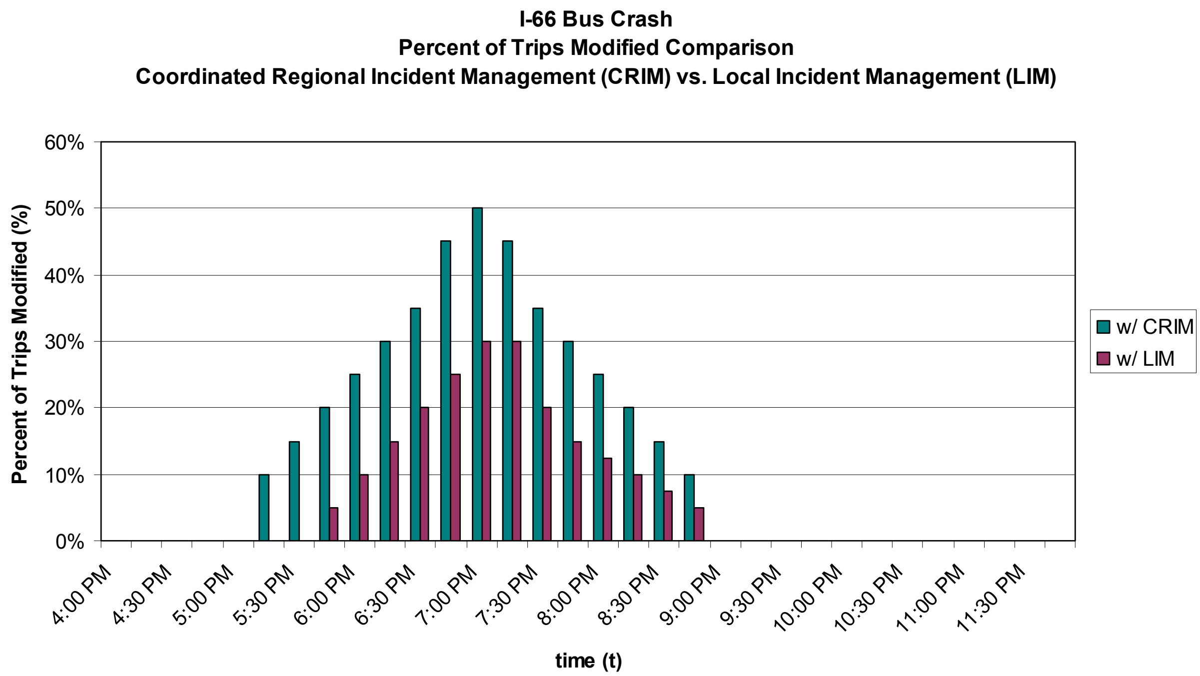
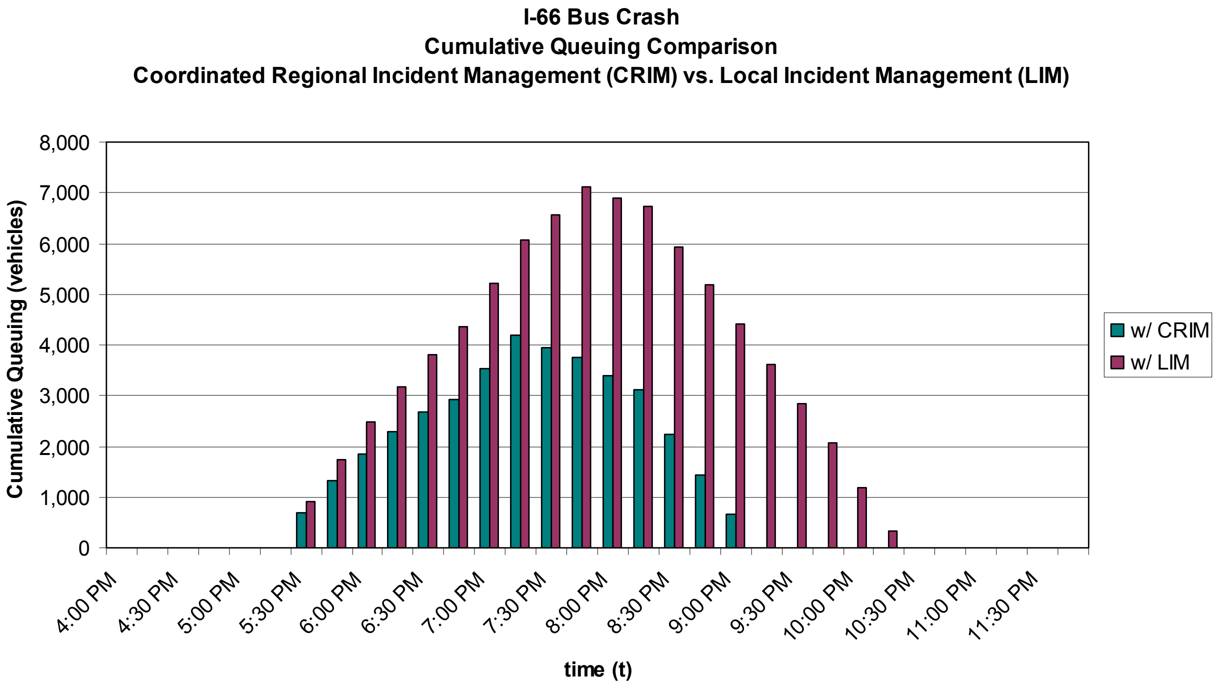


Figure 4. I-66 WB Bus Crash – Cumulative Queuing



Based on criteria that is consistent with the Maryland CHART procedures for evaluating costs of emissions, fuel consumption, and delay (see Section 3.3), the analysis of the incident with MATOC involvement resulted in the following costs:

- Emissions: $11,910 (HC $920; CO $9,770; NO_x $840; CO_2 $380)
- Fuel Consumption: $4,570 (Car $3,520; Truck $1,050)
- Value of Time: $323,700 (Car $292,350; Truck $31,350)
- Total: $340,180

The chronology of events in Table 3 then was assumed to take place for the same incident to represent mitigating the incident using LIM only (i.e., without MATOC coordination or action).

Using the previously calibrated Excel spreadsheet model, assuming the events in Table 3 and the percent modified trips for LIM in Figure 3, the incident was reanalyzed assuming the use of LIM only to mitigate the incident (i.e., without MATOC), which yielded the following queue and traffic delay:

- 21.6-mile maximum queue length
- 5.0-hours duration of queue
- 20,170 vehicle-hours of delay in queue
- 625,850 vehicle miles of travel in queue

Figure 4 illustrates the cumulative queuing under LIM conditions (i.e., without MATOC involvement).

Table 3. I-66 WB Bus Crash – Chronology of Events with LIM

Clock Time	Elapsed Time (min)	Action	Lane Status
04:30 PM	---	[I-66 WB (3 Lanes+1 Shoulder Lane) (Begins 3:00 AM-Ends at 8:00 PM)]	4 Lanes Open / 0 Lanes Closed
04:45 PM	0:00	Two Buses Rear-End in Left-Most WB Lane	4 Lanes Open / 0 Lanes Closed
05:00 PM	0:15	Police/EMS Notified	3 Lanes Open / 1 Lane Closed
05:15 PM	0:30	EMS Task Force Equipment called to Scene	3 Lanes Open / 1 Lanes Closed
05:30 PM	0:45	Three Lanes Needed for Equip/Services - Right Shoulder Used as Lane; VDOT closes I-66/I-495 ramps; CHART Notified	1 Lanes Open / 3 Lanes Closed
06:00 PM	1:15	All Lanes Closed for Additional Hour - Safety Over Operations	0 Lanes Open / 4 Lanes Closed
07:00 PM	2:15	Evacuate Injured-Buses-EMS Task Force	0 Lanes Open / 4 Lanes Closed
07:30 PM	2:45	One Lane Re-Opened To Traffic	1 Lanes Open / 3 Lane Closed
08:00 PM	3:15	Two Lanes Re-Opened To Traffic	2 Lanes Open / 1 Lanes Closed
08:30 PM	3:45	Incident Cleared-Full Capacity Restored (3-Lane Use After 8:00 PM)	3 Lanes Open / 0 Lanes Closed
11:00 PM	6:15	Normal Traffic Operations	3 Lanes Open / 0 Lanes Closed

Note: Modified trips assumed to begin at 5% at 5:45 PM and continue through the event peaking at 30% at 7:00 PM and reaching 0% modified trips at 9:00 PM.

Based on criteria consistent with the Maryland CHART procedures for evaluating costs of emissions, fuel consumption, and delay (see Section 3.3), the analysis of the incident without MATOC involvement resulted in the following costs:

- Emissions: $25,310 (HC $1,950; CO $20,760; NO_x $1,790; CO_2 $810)
- Fuel Consumption: $9,700 (Car $7,470; Truck $2,230)
- Value of Time: $688,000 (Car $621,360; Truck $66,640)
- Total: $723,010

Table 4 shows a comparison of modeling the incident under CRIM (i.e., with MATOC involvement) and LIM (i.e., without MATOC involvement) conditions. Based on the results of this analysis, it can be seen that MATOC contributed to a total savings of $382,830 in terms of emissions, fuel consumption, and the value of time. Note that this assessment is conservative as it does not include potential savings for reduced or eliminated secondary queues, secondary incidents or the potential delay reduction due to rubbernecking in the opposite direction.

Table 4. I-66 WB Bus Crash – CRIM/LIM Queue, Delay, and Costs

Measure of Effectiveness/Cost	Coordinated Regional Incident Management	Local Incident Management
Max Queue Length (miles)	12.7	21.6
Queue Duration (hours)	3.8	5.0
Queue Delay (vehicle hours)	9,490	20,170
Queue Travel (Vehicle Miles)	173,730	625,850
Cost ($) – Total Emissions	11,910	25,310
Cost ($) – Greenhouse Emissions	10,990	23,360
Cost ($) – Excess Fuel	4,570	9,700
Cost ($) – Lost Time	323,700	688,000
Cost ($) – TOTAL	340,180	723,010
Total Benefit ($) = $723,010 - $340,180 = $382,830		

4.2 I-495 EB IL Vehicle Fire

This analysis compares actual mobility costs for an incident in which MATOC was involved for Coordinated Regional Incident Management (CRIM) versus potential costs for the same incident assuming only Local Incident Management (i.e., without MATOC) involvement. The independent variable in the analysis is percentage of trips modified. For example, FHWA HOP-09-002 evaluated ITS (VMS/DMS) use in DC area work zones and documented an average of 52% diversion of mainline traffic volume with advanced traveler information.

On Thursday, September 17, 2009 at approximately 3:00 PM, a vehicle fire occurred in the far left lane of the EB I-495 Inner Loop west of MD 187 at location N39°00'51" W77°07'33" in Montgomery County, MD. The chronology of events with CRIM (i.e., with MATOC involvement) is shown in Table 5, and the resulting queue is illustrated in Figure 5. The following is the account of events as obtained from the MATOC Communication Facilitator (MCF):

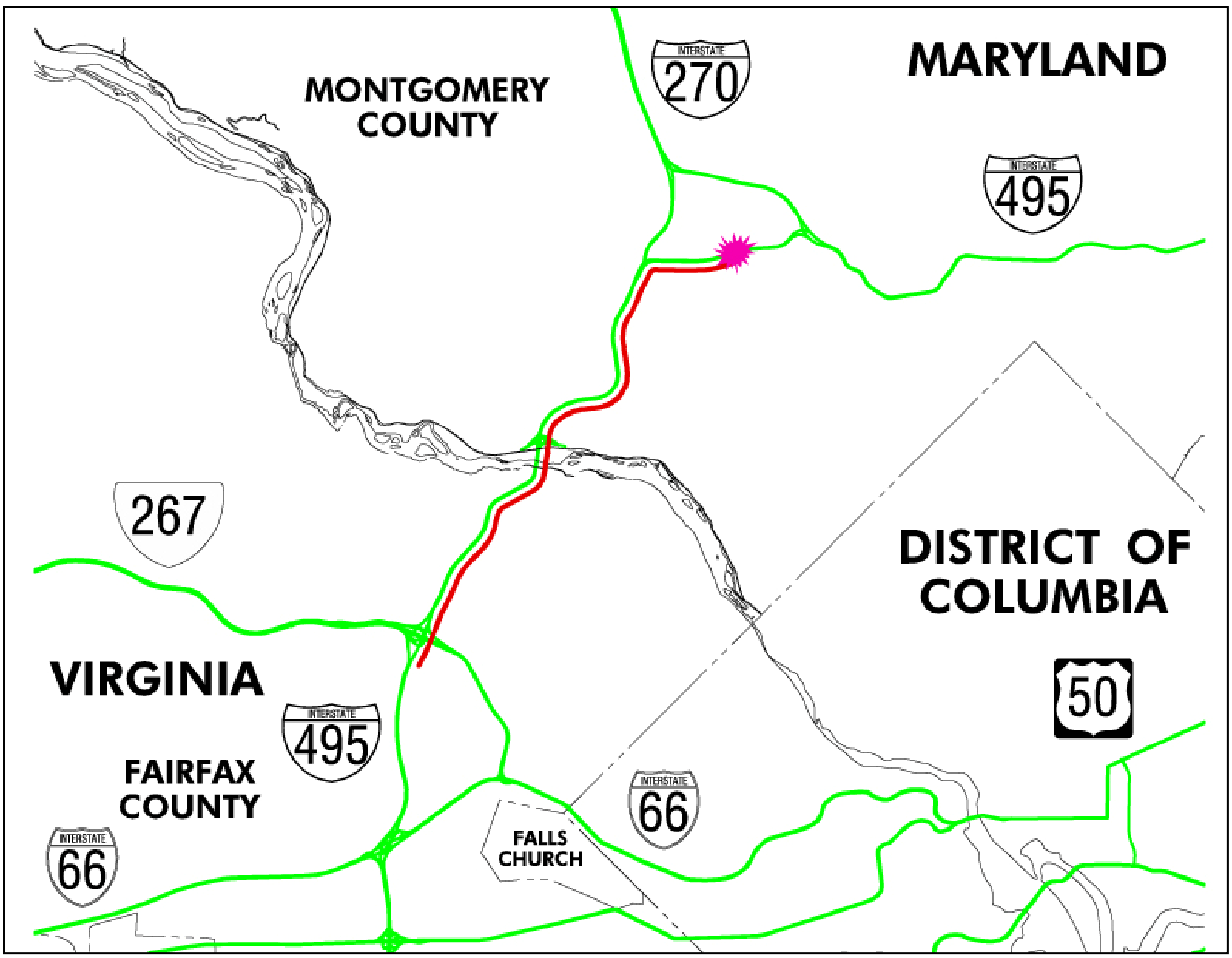
> *The MATOC Communication Facilitator (MCF) learned of the auto fire while monitoring the WTOP traffic report. RITIS displayed an auto fire with all lanes blocked. The traffic cameras confirmed that all lanes were blocked with apparatus and the vehicle involved. It was 3:30 PM and Thursday evening rush is historically the worst peak period in the Washington area. There was no indication in RITIS that VDOT had been notified. There was no indication that MD SHA had displayed their Variable Message Sign (VMS). The VA state line is 5 miles from the incident. INRIX displayed congestion that was well into Virginia. The MCF called VDOT and spoke to the I-495 operator and advised of the incident and the current congestion. The MCF asked if VDOT could post an appropriate DMS, and VDOT advised that they would. The MCF received a message stating that VDOT posted signs on I-95 in Springfield, on I-66 in Fairfax and the one portable sign VDOT had on I-495. The MCF called MD SHA TOC 3 and advised of the VDOT DMS. The MCF then learned that the vehicle fire would have 2 of 3 lanes blocked for a while and passed this information onto VDOT. The MCF then monitored the incident until it was cleared and passed the update on to VDOT as the lanes reopened. RITIS indicated that MD SHA TOC 3 posted its DMS at 4:19 pm, and VDOT posted its DMS at 4:02 pm.*

Table 5. I-495 EB IL Vehicle Fire – Chronology of Events with CRIM

Clock Time	Elapsed Time (min)	Action	Lane Status
03:00 PM	0:00	Vehicle Fire in Left EB Lane I-495 IL West of MD 187	3 Lanes Open / 0 Lanes Closed
03:15 PM	0:15	State Police, Fireboard, CHART 9301 notified of Vehicle fire; MATOC Notifies CHART based on info from WTOP traffic report	2 Lanes Open / 1 Lanes Closed
03:30 PM	0:30	State Police Arrived; RITIS displays all lanes blocked	0 Lanes Open / 3 Lanes Closed
03:45 PM	0:45	Fireboard Arrived; RITIS indicates VDOT had not been notified	0 Lanes Open / 3 Lanes Closed
04:00 PM	1:00	CHART 9301 arrived; MATOC notifies VDOT; VDOT Posts DMS Message; No RITIS indication that SHA had display DMS	1 Lanes Open / 2 Lanes Closed
04:15 PM	1:15	Towing Co arrived; MDSHA TOC 3 posted DMS message	1 Lanes Open / 2 Lanes Closed
04:45 PM	1:45	State Police, Fireboard, CHART & Tow Departed	2 Lanes Open / 1 Lanes Closed
05:15 PM	2:15	RITIS Shows Normal Traffic Operations	3 Lanes Open / 0 Lanes Closed

Note: Modified trips assumed to begin at 10% at 4:00 PM and continue through the event peaking at 40% at 4:45 PM and reaching 0% diversion at 6:15 PM.

Figure 5. I-495 IL Vehicle Fire – Illustration of Queues



Traffic volumes representing the day and location of the incident along eastbound I-495 were developed based on historical 24-hour volume and classification machine counts obtained from Maryland SHA and Sabra-Wang's record files. Figure 6 shows the diurnal distribution of traffic, and Figure 7 shows the percent modified trips used in the analysis.

A Microsoft Excel spreadsheet was developed to calibrate a model to replicate the incident queue length and duration based on the University of Maryland LCAP capacity reduction equation discussed in Section 3.2.2, which demonstrated the following queue and traffic delay:

- 9.1-mile maximum queue length
- 2.3-hours duration of queue
- 4,260 vehicle-hours of delay in queue
- 60,960 vehicle miles of travel in queue

Figure 8 illustrates the cumulative queuing under CRIM conditions (i.e., with MATOC involvement).

Based on criteria that is consistent with the Maryland CHART procedures for evaluating costs of emissions, fuel consumption, and delay (see Section 3.3), the analysis of the incident with MATOC involvement resulted in the following costs:

- Emissions: $5,370 (HC $410; CO $4,390; NO_x $380; CO_2 $190)
- Fuel Consumption: $2,280 (Car $1,530; Truck $750)
- Value of Time: $149,610 (Car $127,090; Truck $22,520)
- Total: $157,260

The chronology of events in Table 6 then was assumed to take place for the same incident to represent mitigating the incident using LIM only (i.e., without MATOC coordination or action).

Using the previously calibrated Excel spreadsheet model, assuming the events in Table 6 and the percent modified trips for LIM in Figure 7, the incident was reanalyzed assuming the use of LIM only to mitigate the incident (i.e., without MATOC), which yielded the following queue and traffic delay:

- 10.2-mile maximum queue length
- 2.5-hours duration of queue
- 5,080 vehicle-hours of delay in queue
- 80,000 vehicle miles of travel in queue

Figure 8 illustrates the cumulative queuing under LIM conditions (i.e., without MATOC involvement).

Figure 6. I-495 IL Vehicle Fire – Diurnal Distribution of Traffic

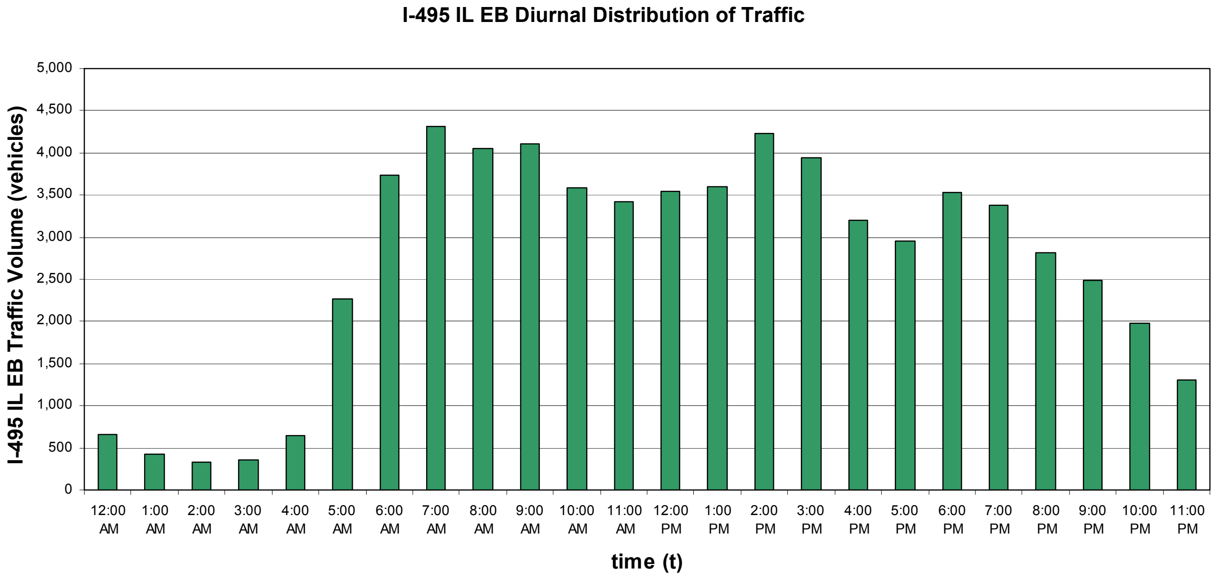


Figure 7. I-495 IL Vehicle Fire – Percent Modified Trips

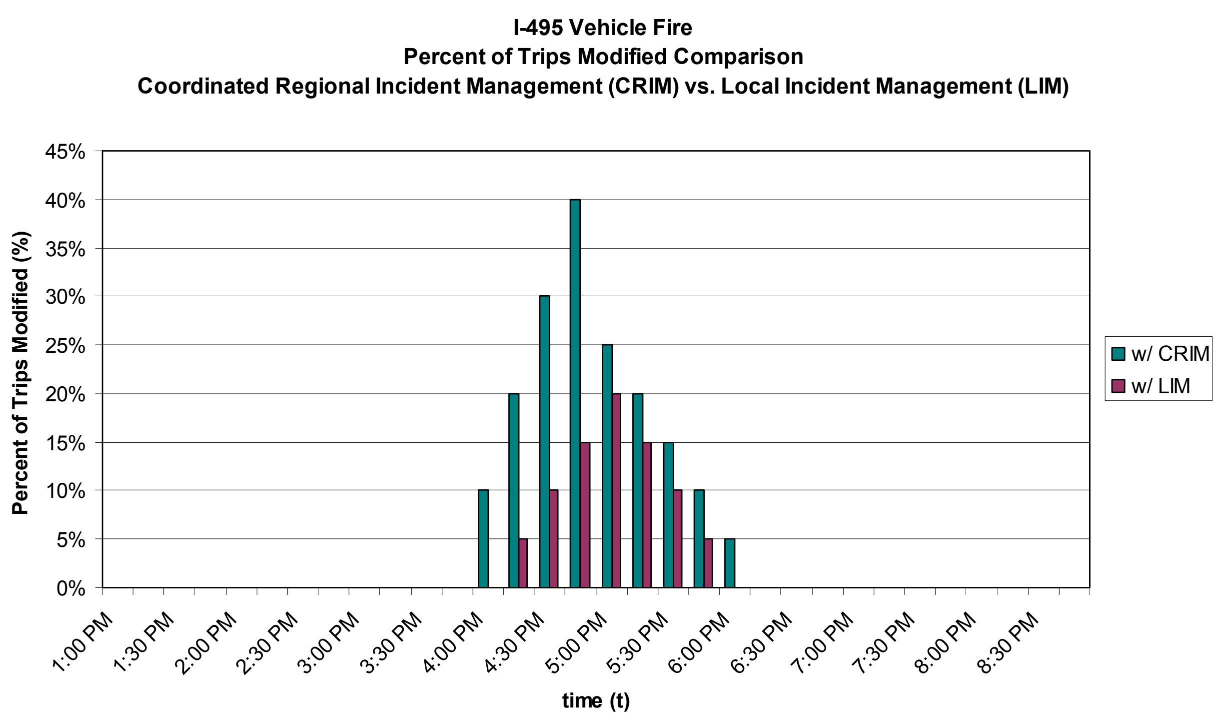


Figure 8. I-495 IL Vehicle Fire – Cumulative Queuing

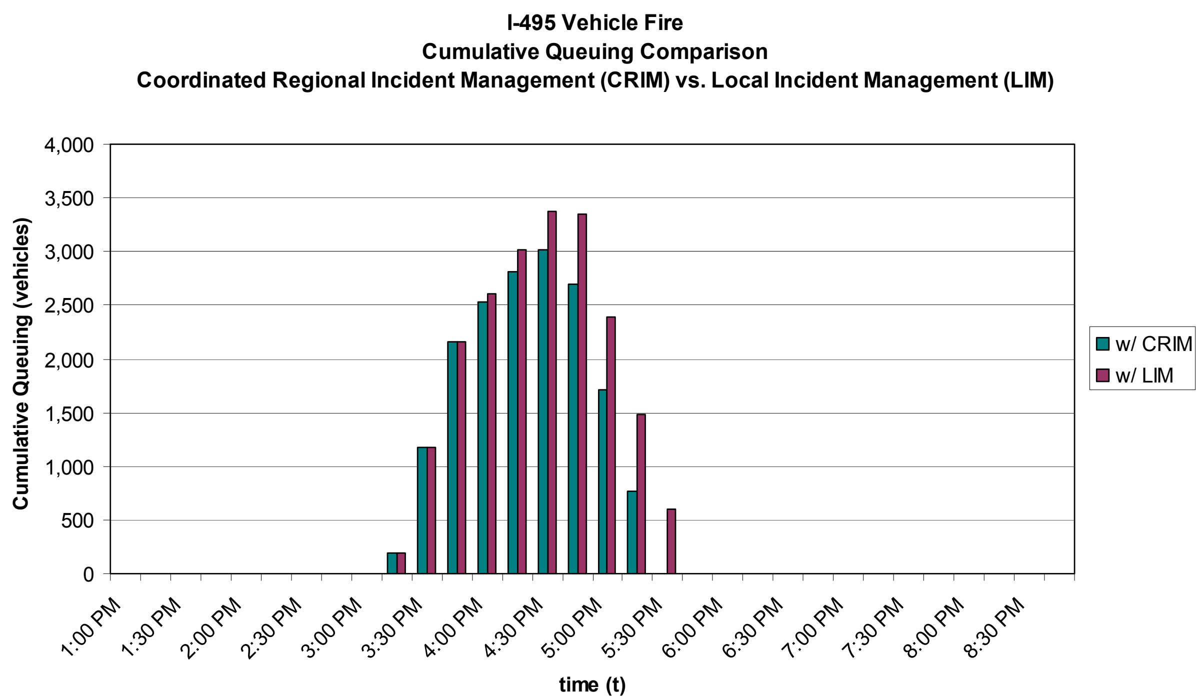


Table 6. I-495 EB IL Vehicle Fire – Chronology of Events with LIM

Clock Time	Elapsed Time (min)	Action	Lane Status
03:00 PM	0:00	Vehicle Fire in Left EB Lane I-495 IL West of MD 187	3 Lanes Open / 0 Lanes Closed
03:15 PM	0:15	State Police, Fireboard, CHART 9301 notified of Vehicle fire	2 Lanes Open / 1 Lanes Closed
03:30 PM	0:30	State Police Arrived	0 Lanes Open / 3 Lanes Closed
03:45 PM	0:45	Fireboard Arrived	0 Lanes Open / 3 Lanes Closed
04:00 PM	1:00	CHART 9301 arrived	1 Lanes Open / 2 Lanes Closed
04:15 PM	1:15	Towing Co arrived; MDSHA TOC 3 posted DMS message	1 Lanes Open / 2 Lanes Closed
04:45 PM	1:45	State Police, Fireboard, CHART & Tow Departed	2 Lanes Open / 1 Lanes Closed
05:30 PM	2:15	Normal Traffic Operations	3 Lanes Open / 0 Lanes Closed

Note: Modified trips assumed to begin at 5% at 4:15 PM and continue through the event peaking at 20% at 5:00 PM and reaching 0% diversion at 6:15 PM.

Based on criteria consistent with the Maryland CHART procedures for evaluating costs of emissions, fuel consumption, and delay (see Section 3.3), the analysis of the incident without MATOC involvement resulted in the following costs:

- Emissions: $6,400 (HC $490; CO $5,230; NO_x $450; CO_2 $230)
- Fuel Consumption: $2,720 (Car $1,820; Truck $900)
- Value of Time: $178,400 (Car $151,550; Truck $26,850)
- Total: $187,520

Table 7 shows a comparison of modeling the incident under CRIM (i.e., with MATOC involvement) and LIM (i.e., without MATOC involvement) conditions. Based on the results of this analysis, it can be seen that MATOC contributed to a total savings of $30,260 in terms of emissions, fuel consumption, and the value of time. Note that this assessment is conservative as it does not include potential savings for reduced or eliminated secondary queues, secondary incidents or the potential delay reduction due to rubbernecking in the opposite direction.

Table 7. I-495 IL Vehicle Fire – CRIM/LIM Queue, Delay, and Costs

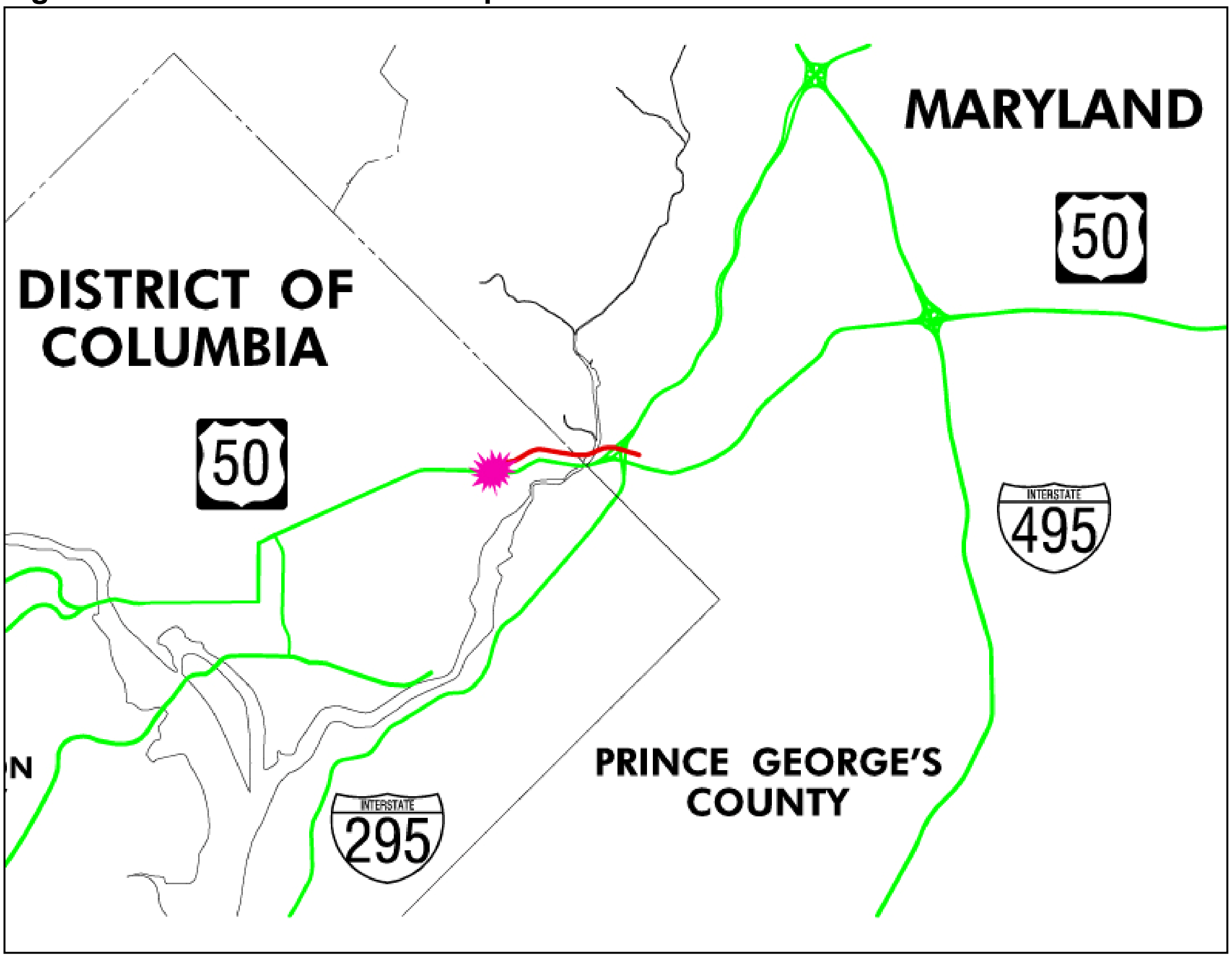
Measure of Effectiveness/Cost	Coordinated Regional Incident Management	Local Incident Management
Max Queue Length (miles)	9.1	10.5
Queue Duration (hours)	2.3	2.5
Queue Delay (vehicle hours)	4,260	5,080
Queue Travel (Vehicle Miles)	60,960	80,000
Cost ($) – Total Emissions	5,370	6,400
Cost ($) – Greenhouse Emissions	4,960	5,910
Cost ($) – Excess Fuel	2,280	2,720
Cost ($) – Lost Time	157,260	187,520
Cost ($) – TOTAL	164,910	196,640
Total Benefit ($) = $196,640 - $164,910 = $30,260		

4.3 New York Avenue Shoulder Collapse

From 3:00 PM Friday, May 9 to 5:00 PM Sunday May 11, 2008, a storm sewer failure between the 1100 and 1200 blocks of New York Avenue (a major arterial link between DC 295 and I-395) caused a partial roadway collapse and the loss of the one or more travel lanes in the westbound direction into the District of Columbia, which is normally three lanes in the westbound direction. This inbound lane was closed for the entire weekend for emergency construction. DDOT stationed traffic control officers, revised signal timing, and posted portable VMS advising travelers of major delays, and Maryland SHA CHART posted DMS messages on US 50 WB and I-495/95 NB and SB.

Based on data obtained from DDOT (e.g., signal timing, traffic volume data), a Synchro/SimTraffic network was developed to model the incident to encompass the largest area of impact with respect to queuing. The model was calibrated to reflect the actual queue length and duration of the incident (see Figure 9). Volumes that were used for the 1-hour simulation runs were based on the highest hour within the duration of the incident. The CRIM evaluation of the actual incident (i.e., with MATOC involvement) was calibrated using a 35% reduction in traffic volumes due to modified trips. The hypothetical LIM evaluation (i.e., without MATOC involvement) assumed a 15% reduction in traffic volumes due to modified trips.

Figure 9. NY Ave Shoulder Collapse – Illustration of Queues



Although the performance measure and costs shown in Table 8 and Table 9 are based on the single-highest volume hour of the event, it is necessary to determine which additional hours within the approximate 48-hour incident duration would also be affected and become a physical bottleneck where the demand exceeds the new reduced capacity. To establish this threshold, a reduced interrupted-flow arterial capacity of 650 passenger cars per hour per lane was used as determined based on current HCM methods and procedures. Hours that exceeded this threshold are identified in Figure 10.

In aggregation, using a ratio of the lower-volume hour to the highest-volume hour together with the hourly costs shown in Table 9, the total event benefit is estimated to be $294,700 (see Figure 10).

It should be noted that, for the purpose of performing the benefit-cost analysis, this incident will be considered a normal regional event using the single highest hourly cost.

Table 8. NY Ave Shoulder Collapse – CRIM/LIM SimTraffic Model Results

Measure of Effectiveness/Cost	Coordinated Regional Incident Management	Local Incident Management
Total Delay (hr)	3,248	4,237
Total Travel Time (hr)	3,527	4,435
Fuel Used (gal)	2,437	2,919
HC Emissions (g)	42,461	55,390
CO Emissions (g)	476,907	622,123
NO_x Emissions (g)	20,336	26,528
CO_2 Emissions (g)	21,797,147	26,108,277
Delay per Transit Bus (hrs)	0.25	0.35

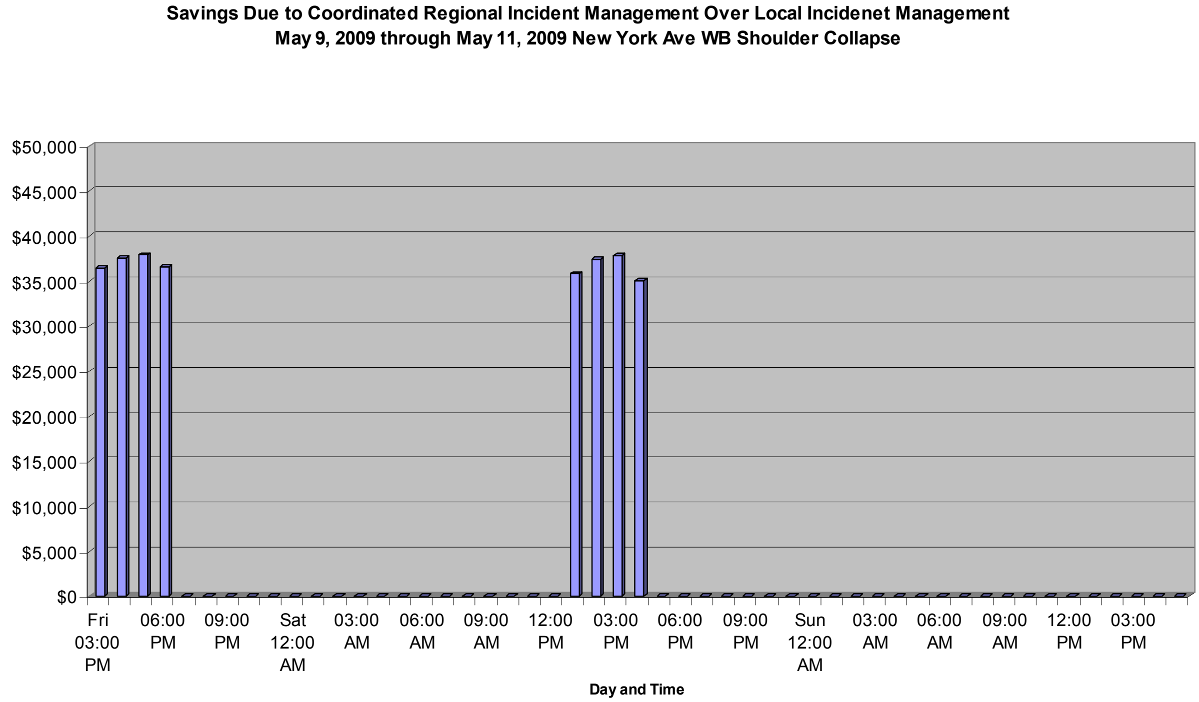
Note: Results from single-highest 1-hour SimTraffic simulations.

Table 9. NY Ave Shoulder Collapse – CRIM/LIM Queue, Delay, and Costs

Measure of Effectiveness/Cost	Coordinated Regional Incident Management	Local Incident Management
Max Queue Length (miles)	1.75	2.65
Queue Delay (vehicle hours)	3,248	4,237
Cost ($) – Total Emissions	4,410	5,750
Cost ($) – Greenhouse Emissions	4,100	5,340
Cost ($) – Excess Fuel	6,110	7,310
Cost ($) – Transit Passengers	6,860	9,600
Cost ($) – Lost Time	110,790	144,530
Cost ($) – TOTAL	128,170	167,190
Total Benefit ($) = $167,190 - $128,170 = $39,020		

Note: Results from single-highest 1-hour SimTraffic simulations.

Figure 10. NY Ave Shoulder Collapse – Cumulative Benefits



5.0 DETERMINATION OF BENEFIT-TO-COST RATIO

An average of 224 police-reported crashes per day occur in the National Capital Region (sources: *DDOT SHSP, MHSO, VDOT, NHTSA*), and a percentage of these non-recurring traffic incidents are of such regional significance that MATOC involvement is warranted. For example, for the period from December 1, 2009 to April 30, 2010, MATOC reported that it was involved with an average of 36 incidents per month.

For the purpose of conservatively estimating the benefit-to-cost ratio of MATOC involvement, it is assumed that MATOC is typically involved in approximately 20 minor incidents (e.g., I-495 vehicle fire) and one major freeway, arterial or transit incident (e.g., I-66 bus crash) of regional significance per month. As such, the benefits for one year of MATOC operation would be as follows:

- Benefit of Minor Incident: $30,260 (I-495 vehicle fire) x 20 x 12 = $7.3 million/year
- Benefit of Major Incident: $382,830 (I-66 bus crash) x 1 x 12 = $4.6 million/year
- Total Annual Benefit: $7.3 million + $4.6 million = $11.9 million/year
- Benefit-to-cost Ratio: $11.9 million / $1.2 million (which includes RITIS) = 10:1

Traffic incident management programs, such as motorist assistance patrols, have been shown to have a benefit-to-cost ratio in the range from 2:1 to 36:1 (source: *ITS for Traffic Incident Management: Deployment Benefits and Lessons Learned, ITS US DOT, May 2007*). MATOC, using this conservative analysis, is demonstrated to have a benefit-to-cost ratio of 10:1. Note that this assessment is conservative as it does not include potential savings for reduced or eliminated secondary queues, secondary incidents or the potential delay reduction due to rubbernecking in the opposite direction.

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6.0 SUMMARY AND CONCLUSIONS

The evaluation results show that MATOC has yielded positive benefits in cost savings associated with reduced traffic delay, reduced emissions and reduced fuel consumption. Although not directly evaluated in the analysis, it is also known through previous research of similar programs that MATOC indirectly improves the safety of incident responders and other motorists. At the current level of operation, it is expected that an even higher benefit-to-cost ratio would be realized with only a nominal percent increase in the occurrence of minor incidents and only a few additional major incidents in one year. Furthermore, MATOC benefits could be increased by providing supportive direct traveler information through, for example, a branded website for:

- real-time travel time information,
- trip planning,
- transit and toll information,
- notices/advisories (e.g., road closures), and
- information on additional arterials, local roadways and local transit service.

MATOC benefits can also be increased by developing standard operating procedures and action plans for recurring special events and major construction projects.

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Appendix

Appendix: Synthesis of Research on Traffic Congestion, Incidents and Their Effects

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7.0 APPENDIX: SYNTHESIS OF RESEARCH

7.1 Traffic Congestion

Traffic congestion relates to an excess of vehicles on a portion of roadway at a particular time resulting in speeds that are slower – sometimes much slower – than normal or "free flow" speeds. Congestion often means stopped or stop-and-go traffic. Congestion is the result of the following root causes (as shown in Figure 11), which often interact with one another (source: *http://www.ops.fhwa.dot.gov/congestion_report; Traffic Congestion and Reliability: Trends and Advanced Strategies for Congestion Mitigation, FHWA, Cambridge Systematics, TTI, September 2005*):

1. Physical Bottlenecks ("Capacity") – recurring. Capacity is the maximum amount of traffic capable of being handled by a given highway section. Capacity is determined by a number of factors: the number and width of lanes and shoulders; merge areas at interchanges; and roadway alignment (grades and curves).

2. Traffic Control Devices – recurring. Intermittent disruption of traffic flow by control devices such as poorly timed signals contribute to congestion and travel time variability.

3. Traffic Incidents – non-recurring temporary bottleneck. Traffic incidents are events that disrupt the normal flow of traffic, usually by physical impedance in the travel lanes or rubbernecking. Events such as vehicular crashes, breakdowns, and debris in travel lanes are the most common form of traffic incidents.

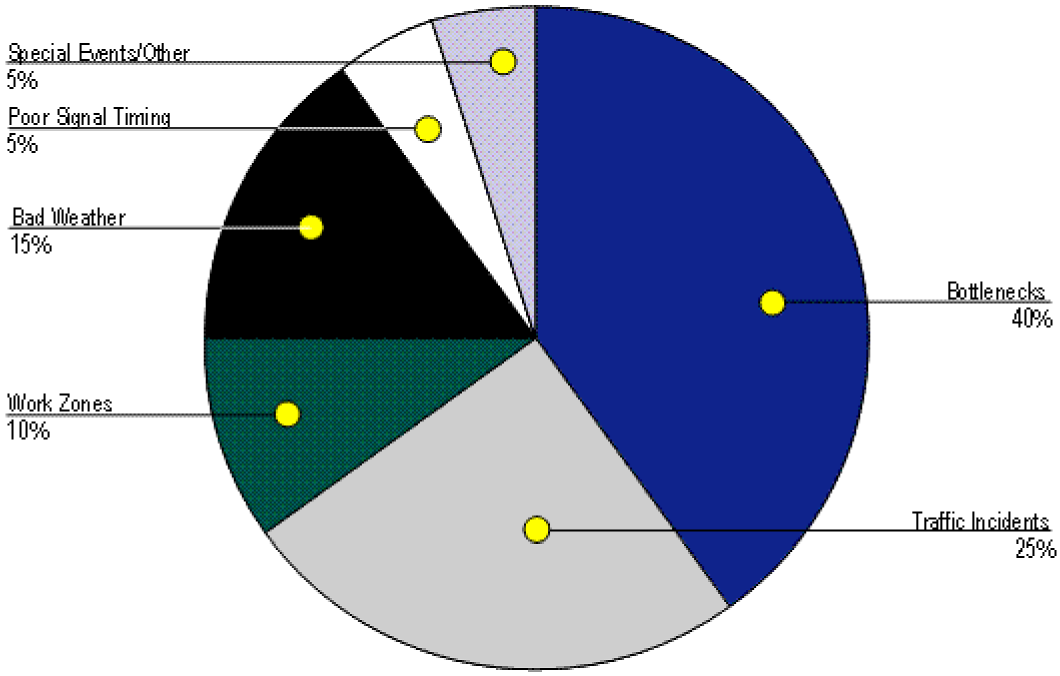
4. Work Zones – non-recurring temporary bottleneck. Work zones are construction activities on the roadway that result in physical changes to the highway environment. These changes may include a reduction in the number or width of travel lanes, lane "shifts," lane diversions, reduction, or elimination of shoulders, and even temporary roadway closures.

5. Weather – non-recurring. Environmental conditions can lead to changes in driver behavior that affect traffic flow.

6. Special Events – non-recurring. Special events are a special case of demand fluctuations whereby traffic flow in the vicinity of the event will be radically different from "typical" patterns. Special events occasionally cause "surges" in traffic demand that overwhelm the system.

Only the first and second causes contribute to recurring congestion (i.e., they are tangible in design and function, and therefore, candidates for remediation). The remaining sources are non-recurring and random.

Figure 11. Causes of Traffic Congestion – National Summary



(Source: http://www.ops.fhwa.dot.gov/aboutus/opstory.htm; Traffic Congestion and Reliability: Trends and Advanced Strategies for Congestion Mitigation, FHWA, Cambridge Systematics, TTI, September 2005)

The interaction between these root causes is complex and varies greatly from day-to-day and highway-to-highway, and some events can cause other events to occur. For example:

- congestion from a traffic incident can shift traffic to other highways or cause travelers to leave later, go to other destinations, or choose not to go at all;
- high congestion levels can lead to an increase in traffic incidents due to closer vehicle spacing and overheating of vehicles during summer months; and
- the traffic turbulence and distraction to drivers caused by an initial crash can lead to secondary crashes.

"Rubbernecking" (see Appendix 7.3.4) past traffic incidents that do not require a lane closure, or simply driving into sun glare, often results in slowdowns even though excess traffic demand may not be present. The mere act of one or more lead vehicles slowing creates a rippling effect; a shock wave that reverberates back to vehicles that are following. In other words, this slowing could be the result of a traffic confluence or the rubbernecking. The slowing reduces room to maneuver, which self-perpetuates the shock wave. The problem begins to clear once past the incident, as vehicles begin to accelerate away, and maneuvering room downstream of the incident increases (source: *http://ops.fhwa.dot.gov/bn/index.htm ; FHWA Office of Operations Traffic Bottlenecks*).

The average highway user in the National Capital Region (NCR) spends 62 hours per year in congested traffic, 51% of which is caused by non-recurring congestion (i.e., traffic incidents). The cost of this non-recurring congestion is estimated to be $1.35 billion and 45 million gallons of wasted fuel (source: *2009 Urban Mobility Report, Texas Transportation Institute, July 2009*). There is an average of 224 police-reported, vehicle-related crashes per day on all roadways, freeway and non-freeway, in the NCR. Interstate I-270, for example, has an average of 7 incidents per day (total both directions, end-to-end), which includes 41% crashes and 59% non-crashes (e.g., disabled vehicles, police activity). In general, the more severe the incident, the longer its duration and impact to the traveling public.

7.2 Traffic Incidents

7.2.1 Incident Classification

In general, a traffic incident is a period of impact due to a vehicle crash, breakdown or special traffic event in which normally flowing traffic is interrupted. The incident can vary in severity from a breakdown on the shoulder, to roadway blockage from a multi-vehicle crash, to a regional evacuation from a natural or man-made disaster. The scale of the incident influences the scope of the response in terms of information needs, agencies involved and resources needed to manage the incident. This non-recurring congestion results in a reduction in roadway capacity or an abnormal increase in traffic demand. Normal operations of the transportation system are disrupted. Incidents are a major source of roadway congestion, contributing to millions of hours of delay and productive hours wasted as well as causing a direct negative effect on roadway safety and operations (source: *Information Sharing for Traffic Incident Management, Ingrid Birenbaum, FHWA-HOP-08-059, Final Report, January 2009*). Incidents are classified in the *FHWA Manual on Uniform Traffic Control Devices* based on duration, each with unique traffic control characteristics and needs:

1. Major Incident. Major incidents are typically those involving hazardous materials, fatal traffic crashes involving numerous vehicles, and other natural or man-made disasters. These traffic incidents typically involve closing all or part of a roadway facility for a period exceeding 2 hours. Traffic control is implemented.

2. Intermediate Incident. Intermediate incidents typically affect travel lanes for a time period of 30 minutes to 2 hours, and usually require traffic control on the scene to divert road users past the blockage. Full roadway closures might be needed for short periods during traffic incident clearance to allow traffic incident responders to accomplish their tasks. Traffic control is implemented.

3. Minor Incidents. Minor incidents are disabled vehicles and minor crashes that result in lane closures of less than 30 minutes. On-scene responders are typically

law enforcement and towing companies, and occasionally highway agency service patrol vehicles. Diversion of traffic into other lanes is often not needed or is needed only briefly. It is not generally possible or practical to set up a lane closure with traffic control devices for a minor traffic incident.

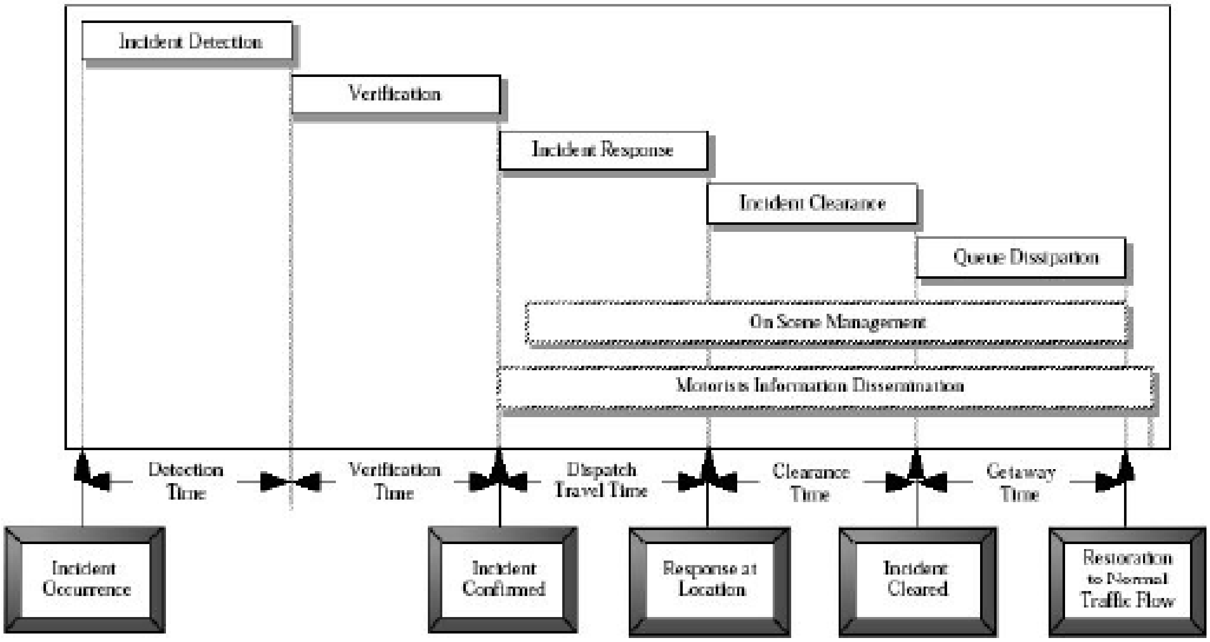
7.2.2 Incident Timeline

There are generally five key phases that are recognized on the traffic incident timeline. When changes to operational or technological processes are implemented to enhance the management of the incident (e.g., quicker detection, coordinated information sharing), the overall duration of an incident can be shortened and, thus, its negative impacts reduced. Key elements that have been identified to shorten the incident timeline are: implementation of intelligent transportation systems (ITS), inter-agency coordination, and improvements derived from after-action reviews. Figure 12 presents the temporal distribution of the phases of the incident timeline. As can be seen in Figure 12, on-scene traffic management (which involves site management and traffic management) and motorist information dissemination commence during the incident response phase and continue throughout the incident impact period. The phases of the incident timeline are as follows (source: *Information Sharing for Traffic Incident Management, Ingrid Birenbaum, FHWA-HOP-08-059, Final Report, January 2009*; *Evaluation of Incident Management Strategies, Final Report, November 2005, FHWA-NJ-2005-020, Ozbay, et. al.*):

1. Incident Detection. The crash or incident occurs, and traffic queues begin to build from lane blockages or "rubbernecking" (see Appendix 7.3.4). The earlier responding agencies become aware of an incident, the more quickly resources can be sent to resolve the situation. Automating this process through the use of detection equipment removes the reliance of human detection, whether by law enforcement/ emergency personnel notification or cell phone calls from passing motorists. This is the first time someone in an official capacity learns of the incident and has an opportunity to follow a response plan.

2. Incident Verification. Once an incident is detected and a response agency (transportation management center or law enforcement) is aware of an incident, the location, scope, and impact of the event must be verified quickly so that the appropriate resources can be sent out to the scene. Verification through closed-circuit television cameras or video from other sources is extremely useful, because it eliminates the time needed to send a person to the scene for verification. Scene images can often be shared with multiple responding partners so that all can take appropriate action.

Figure 12. Temporal Distribution of the Phases of a Traffic Incident



(source: Evaluation of Incident Management Strategies, Final Report, November 2005, FHWA-NJ-2005-020, Ozbay, et. al.)

3. Motorist Information Dissemination. Motorist information involves activating various means of disseminating incident-related information to affected motorists. Media used to disseminate motorist information includes the following: commercial radio broadcasts, highway advisory radio (HAR), variable message signs (VMS), telephone information systems, in-vehicle or personal data assistant information or route guidance systems, commercial and public television traffic reports, and Internet/on-line services. Motorist information needs to be disseminated as soon as possible and beyond the time it takes to clear an incident. Such information should be disseminated until traffic flow is returned to normal conditions. This may take hours if an incident occurs during a peak period and has regional impacts.

4. Incident Response. Incident response resources are called for and then arrive. They can include law enforcement, transportation agency resources, wreckers, hazardous material clean-up specialists, specialty equipment, etc. Having the personnel with appropriate resources and training arrive quickly is critical. Pre-established routes or wrong-way access to a site while following a law enforcement pilot vehicle are examples of ways response vehicles may avoid traffic queues that grow quickly after an incident occurs.

5. Site Management. Site management is the process of effectively coordinating and managing on-scene resources to remove the incident and reduce the impact on traffic flow. Ensuring the safety of response personnel, incident victims, and other motorists is the foremost objective of incident site management. Site management encompasses the following activities: accurately assessing

incidents; properly establishing priorities; notifying and coordinating with the appropriate agencies and organizations; using effective liaisons with other responders; and maintaining clear communications. Effective incident site management can be facilitated by regional coordination and information sharing.

6. Traffic Management. Traffic management involves the application of traffic control measures in areas affected by an incident. Traffic management in the context of an incident may include: establishing point traffic control on-scene; managing the roadway space (opening and closing lanes, blocking only the portion of the incident scene that is needed for safety, staging and parking emergency vehicles and equipment to minimize impact on traffic flow); deploying appropriate personnel to assist in traffic management (e.g., state police, local police, and service patrols); actively managing traffic control devices (including ramp meters, lane control signs, and traffic signals) in affected areas; and designating, developing, and operating alternate routes.

7. Incident Clearance. Once the area is declared safe (e.g., from fire, hazardous material, etc. which are priority), the incident response team can get to work. The response team must have the right equipment available so that scene clearance and temporary repair work, if needed, can begin to re-open the roadway. This time is lengthened if equipment is missing. Changes to the clearance component of the incident timeline may be addressed during multi-agency sessions where stakeholders can discuss lessons learned. Development of agreements, execution of tabletop exercises, and discussion of after-action reviews are also extremely helpful in reducing incident clearance times. Sharing automated information using clear communication and cooperative work are extremely helpful in reducing incident clearance times.

8. Incident Recovery. When the incident is finally cleared and the roadway is re-opened, time is needed for queues to dissipate. Recovery time is the period from the re-opening of all lanes to the resumption of normal traffic flow. This time is largely dependent upon the length of the queue from the incident; an accepted estimate is that for every minute of lane closure, four minutes of recovery time is needed once lanes are re-opened. If fewer vehicles join the waiting traffic stream and possibly divert to other roadways or modes, they do not become part of the incident queue, in turn shortening the time needed to resume normal conditions. Traveler information services, partnerships with the media, and ITS information dissemination devices placed in advance of the queue help travelers make route decisions that can keep them from driving unwittingly into an incident queue for an unknown period of time. Because travelers in the regional jurisdictions themselves have a part in controlling this part of the incident timeline, the information they receive must be coordinated, accurate, timely and reliable. Any reduction in detection, response (i.e., dispatch and travel time), and clearance time reduces the total incident duration.

7.3 Negative Effects of Traffic Incidents

7.3.1 General

In general, traffic incidents have the following negative effects:

- Wasting time of motorists and passengers ("opportunity cost"). As a non-productive activity for most people, congestion reduces regional economic health.

- Delays, which may result in late arrival for employment, meetings, and education, resulting in lost business, disciplinary action or other personal losses.

- Inability to forecast travel time accurately, leading to drivers allocating more time to travel "just in case," and less time on productive activities.

- Wasted fuel increasing air pollution and carbon dioxide emissions (which may contribute to global warming) owing to increased idling, acceleration and braking. Increased fuel use may also, in theory, cause a rise in fuel costs.

- Wear and tear on vehicles as a result of idling in traffic and frequent acceleration and braking, leading to more frequent repairs and replacements.

- Stressed and frustrated motorists, encouraging road rage and reduced health of motorists.

- Blocked traffic may interfere with the passage of emergency vehicles traveling to their destinations where they are urgently needed.

- Spillover effect from congested main arteries to secondary roads and side streets as alternative routes are attempted.

- Pollution caused by slow moving traffic, which is exacerbated if heavy diesel vehicles are part of the traffic flow.

7.3.2 Capacity Reduction

7.3.2.1 Definition of Capacity (Freeway)

For uninterrupted-flow facilities such as freeways, the *Highway Capacity Manual 2000* (HCM) defines freeway capacity as the maximum hourly rate at which persons or vehicles can reasonably be expected to traverse a point or uniform section of a lane or roadway during a given time period under prevailing roadway, traffic and control conditions. During this time period, typically 15 minutes, the freeway must be operating under “ideal conditions.” When these ideal situations are not present, such as during a traffic incident, the capacity of the freeway is reduced.

Freeway capacity at free-flow speeds greater than or equal to 70 mph is considered to be 2,400 passenger cars per hour per lane (pcphpl). A number of factors affect free-flow speed: number of lanes, lane width, lateral clearance, etc. Under base traffic and geometric conditions, freeways will operate with capacities as high as 2,400 pcphpl for freeways with free-flow speeds of 70 mph or greater. As the free-flow speed decreases, there is a slight decrease in capacity. For example, the capacity of a basic freeway segment with a free-flow speed of 55 mph is expected to be 2,250 pcphpl (source: *Highway Capacity Manual 2000 Exhibit 23-2*).

In addition, the HCM categorizes traffic flow on a basic freeway segment into the following types, which represent different freeway conditions:

1. Undersaturated Flow. Undersaturated flow represents traffic flow that is unaffected by upstream or downstream conditions. This flow is generally defined within a speed range of 55 mph to 75 mph at low to moderate flow rates and a range of 45 mph to 65 mph at high flow rates.

2. Queue Discharge Flow. Queue discharge flow represents traffic flow that has just passed through a bottleneck and is accelerating back to the free-flow speed of the freeway. This flow type is generally defined within a narrow range of flows, 2,000 to 2,300 passenger cars per hour per lane (pcphpl), with speeds ranging from 35 mph up to the free-flow speed of the freeway section. Studies suggest that the queue discharge flow rate from the bottleneck is lower than the maximum flows observed before breakdown. A typical value for this drop in flow rate is approximately 5%.

3. Oversaturated Flow. Oversaturated flow represents traffic flow that is influenced by the effects of a downstream bottleneck. Traffic flow in the congested regime can vary over a broad range of flows and speeds depending on the severity of the bottleneck. Queues may extend several thousand feet to tens of miles upstream from the bottleneck. On freeways, vehicles move slowly through a queue, with periods of stopping and movement.

Based on the above, it is reasonable to define incident capacity as the minimum 15-minute oversaturated flow at the upstream of a bottleneck created by the traffic incident.

7.3.2.2 Capacity Reduction Due to Incidents

Capacity reduction due to vehicular crashes or vehicle breakdowns are generally short-lived, ranging from less than one hour before they can be cleared (for a minor fender-bender involving only passenger vehicles) to as long as 12 hours (for a major incident involving fully loaded tractor-trailer rigs). For example, the mean duration of a traffic incident was 37 minutes, with just over half of the incidents lasting 30 minutes or less and 82% of the incidents lasting one hour or less (*source: Giuliano, G. Incident Characteristics, Frequency, and Duration on a High Volume Urban Freeway, Transportation Research, Vol. 23A, No. 5, 1989, pp. 387-396*). When trucks were involved, however, the duration was longer; crashes involving trucks lasted 63 minutes on the average (source: *Highway Capacity Manual 2000*).

At the scene of the traffic incident, it is important to recognize that the physical capacity of the freeway at the time of the incident has been abruptly reduced, creating a temporary point of constraint or “bottleneck.” At the bottleneck, it is likely that one or more lanes would be partially or entirely blocked by stopped vehicles, debris or emergency response vehicles. The percent of original capacity available at the incident scene intuitively would be the ratio of the number of lanes available after the incident occurred to the number of lanes that were available before the incident occurred. For example, a three-lane (in one direction) freeway has an incident that shut down one lane – percent original capacity = (3-1)/(3) = 66%. Note, however, that the loss of capacity is likely to be greater than simply this proportion of original capacity that is physically blocked. For example, a four-lane (in one direction) freeway having two lanes blocked due to the incident retains only 25% of its original capacity (see Table 10). The additional loss of capacity over the 50% (i.e., (4-2)/(2)) reduction due to the loss of lanes arises because drivers slow down to look at the incident (i.e. rubbernecking) while they are abreast of it and are slow to react to the possibility of speeding up to move through the incident area. Rubbernecking also promotes reduced capacity in the opposite direction in which the incident occurred (see Appendix 7.3.4).

Table 10. Proportion of Freeway Capacity Available Under Incident Conditions

Number of Freeway Lanes by Direction	One Lane Blocked	Two lanes Blocked	Three Lanes Block
2	0.35 (0.49)	0.00 (0.00)	NA (NA)
3	0.49 (0.64)	0.17 (0.29)	0.00 (0.00)
4	0.58 (0.72)	0.25 (0.45)	0.13 (0.20)

Notes:

1. *(Excerpt from Highway Capacity Manual 2000 Exhibit 22-6 reported sources: Reiss, R.A., and W. M. Dunn, Jr. Freeway Incident Management Handbook, Report FHWA-SA-91-056. FHWA, 1991; Gordon, R. L., et. al. Traffic Control Systems Handbook, Report FHWA-SA-95-032, FHWA, 1996*)
2. *The values in parentheses (#.##) represent resulting proportions from analyzing the I-66 bus crash using the capacity reduction equation developed by the University of Maryland for the Maryland SHA (see Section 3.2.2).*

As discussed in the HCM, the behavior of traffic streams during and immediately after the occurrence of an incident is not well understood. The relationships among speed, density, and flow may be discontinuous at the point of capacity and the maximum queue departing flow rate may be less than capacity under stable flow. Various observations of freeway queue departing flow rate range from 1,800 pcphpl to 2,400 pcphpl. Goolsby (source: *Goolsby, M.E., Influence of Incidents on Freeway Quality of Service, Presented at 50th TRB Annual Meeting, Jan, 1971*) estimated that an incident blocking one out of three lanes will reduce traffic flow by an average of 50%, an incident blocking two out of three lanes will reduce traffic flow by an average of 79%, and an incident blocking the shoulder lane out of three lanes will reduce traffic flow by 33%.

A study conducted by Ling Qin (source: *Characterization of Accident Capacity Reduction, Research Report No. UVACTS-15.0-48, National ITS Implementation Research Center, September 2001*) reported that the research supporting the subject criteria shown in Table 10 (HCM Exhibit 22-6) was not found through literature review, including the references provided in the HCM. Furthermore, Ling Qin (2001) postulates that because the HCM criteria is fairly consistent with Goolsby's (1970 results), it is possible that Goolsby's (1970) results is one of the founding works. Ling Qin's (2001) research showed that incident capacity reduction with one lane out of three lanes blocked is 63%, and incident capacity reduction with two lanes out of three lanes blocked is 77% (source: *Characterization of Accident Capacity Reduction, Research Report No. UVACTS-15.0-48, National ITS Implementation Research Center, September 2001*), which is somewhat consistent with Goolsby (1970).

7.3.3 Traffic Delay

Traffic delay due to congestion is generally referred to as the difference between the actual travel time and the free-flow time along the roadway facility. Delay is either "recurrent" and "non-recurrent." Recurrent delay is delay experienced in everyday travel based on historical data. Non-recurrent delay is delay caused by an event or incident and can be divided into two distinct periods – immediate delay and residual delay. Immediate delay is the part of the total delay that is incurred during the incident. Residual delay is the part of the total incident delay that is sustained after the incident has cleared. It is estimated that 60% of all freeway delay is attributed to incidents producing non-recurrent delay (source: *An Analysis on the Impact of Rubbernecking on Urban Freeway Traffic, Research Report No. UVACTS-15-0-62, National ITS Implementation Research Center, August 2004*).

The effect of an incident on traffic is illustrated in Figure 13. The horizontal axis represents elapsed time, and the vertical axis represents traffic volume (arrival and departure). The slope of the lines in Figure 13 represents traffic-flow rate. When an incident occurs, the actual traffic flow after the incident location decreases due to the reduction of the roadway capacity. As soon as the incident is cleared, the traffic flow is higher than regular demand due to the vehicles waiting behind the incident site.

However, the traffic flow is constrained by the maximum capacity of the roadway at the incident location. If the traffic before the incident site is diverted to alternative routes, delays are expected to be reduced due to lower traffic demand. This delay reduction due to traffic diversion (i.e., modified trips) is shown by the dotted area in Figure 13 (source: *Evaluation of Incident Management Strategies, Final Report, November 2005, FHWA-NJ-2005-020, Ozbay, et. al.*).

7.3.4 Rubbernecking

In general, rubbernecking means to look about or stare with exaggerated curiosity. Individuals driving in the same as well as the opposite direction of travel in which the crash occurred are often distracted by the incident. It is the curiosity of the event that leads to distraction, which causes a reduction in vehicular speed. This reduction in vehicular speed begins to create congestion and possibly secondary incidents.

In the same direction of travel in which the crash occurred, rubbernecking will cause a loss of capacity somewhat greater than that physically remaining after a shoulder or lane has been removed from use due to a crashed or disabled vehicle. This added loss of capacity arises because drivers slow to look at the incident while they are abreast of it and are slow to react to speeding up to move through the incident area.

The affect of rubbernecking is also responsible for reducing capacity in the opposite direction of travel in which the crash occurred. Few quantitative studies of this effect have been published, but experience suggests that it depends on the magnitude of the incident, including the number of emergency vehicles present. The reduction may range from 5% for a single-car accident and one emergency vehicle to 25% for a multi-vehicle accident with several emergency vehicles present (source: *Highway Capacity Manual 2000*). In addition, resent research on the impact of traffic in the opposite direction indicates that about 10% of crashes caused rubbernecking in the opposite direction, the average delay caused by this rubbernecking is 107 vehicle-hours in the opposite direction of travel, and the average capacity reduction is in the opposite direction of travel is 12.7% (source: *An Analysis on the Impact of Rubbernecking on Urban Freeway Traffic, Research Report No. UVACTS-15-0-62, National ITS Implementation Research Center, August 2004*).

Figure 13. Total Delay Due to a Traffic Incident

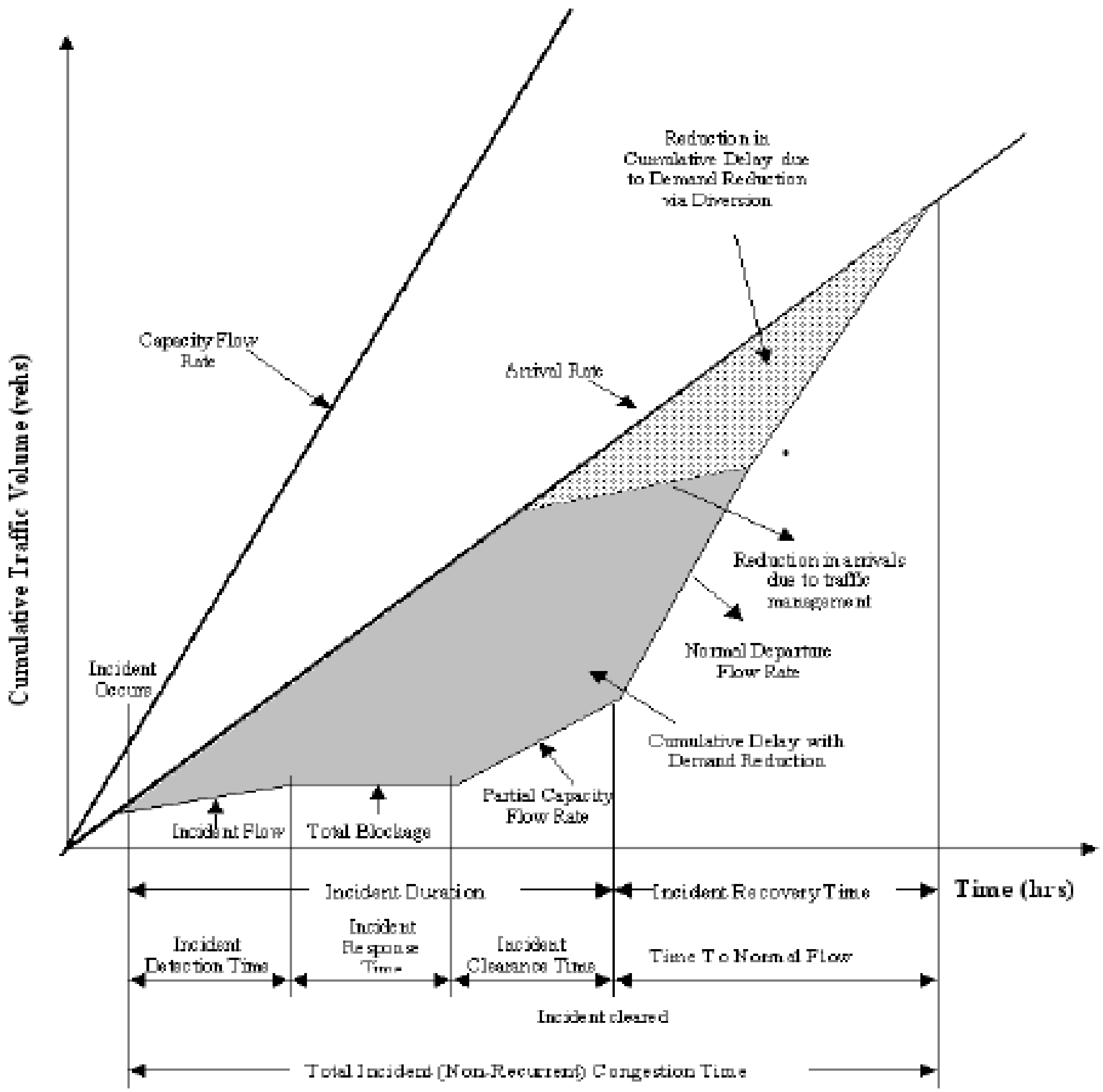


Figure 2. Total delay due to an incident [4]

* This line is a straight line, which is parallel to the "Capacity Flow Rate" line.

(source: Evaluation of Incident Management Strategies, Final Report, November 2005, FHWA-NJ-2005-020, Ozbay, et. al.)

7.3.5 Secondary Incidents

Incident management programs, such as coordinated regional information sharing operations, prevent secondary incidents by reducing the duration of traffic incidents, and by publicizing the incident using changeable message signs and traveler information systems (source: *Benefits of Traffic Incident Management, National Traffic Incident Management Coalition, 2006*). Consider the following:

- Secondary crashes due to congestion resulting from a previous crash are estimated to represent 20% of all crashes (source: Federal Highway Administration Office of Operations Webpage, "Traffic Incident Management," www.ops.fhwa.dot.gov/aboutus/one_pagers/tim.htm).

- Traffic incident management reduces secondary crashes by 30% to 50%. (source: *ITS for Traffic Incident Management: Deployment Benefits and Lessons Learned, ITS US DOT, May 2007*).

- During the incident timeline of a primary incident, the likelihood of a secondary crash increases by 2.8% for each minute the primary incident continues to be a hazard, which is due primarily to the dramatic evolving change in traffic conditions (e.g., the rapid spreading of queue length, the substantial drop in traffic speed, rubbernecking) (source: *Karlaftis, Latoski, Richards, Sinha: "ITS Impacts on Safety and Traffic Management: An Investigation of Secondary Crash Causes," ITS Journal, 1999, Vol. 5, pp.39-52*).

- A 1995 analysis of collision statistics on several arterials and expressways in California showed that secondary crashes represent an increase in collision risk of over 600% (source: *Intelligent Transportation Systems Impact Assessment Framework: Final Report, Volpe National Transportation Systems Center, September 1995*).

- Maryland's CHART incident management program resulted in an estimated 233 fewer secondary incidents in 2008 (source: *University of Maryland, College Park and Maryland State Highway Administration, Performance Evaluation of CHART – Coordinated Highways Action Response Team – Year 2008*).

- According to a study conducted by Minnesota Department of Transportation, secondary crashes account for 13% of all crashes occurred during peak hours (source: I-35 Incident Management and the Impact of Incidents on Freeway Operation, Minnesota Department of Transportation, January 1982).

- On arterial streets between the hours of 6:00 AM and 10:00 PM, up to 15% of all crashes may have been caused by previous incidents (source: *Raub, R.A., Schofer, J. L., Managing Incidents on Urban Arterial Roadways, Paper TRB 76th Annual Meeting, 1997*).

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Appendix

Appendix: Glossary

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8.0 APPENDIX: GLOSSARY

1. Analysis Period/Time Interval. A single time period during which a capacity analysis is performed on a facility. If the demand exceeds capacity during an analysis period, consecutive analysis periods can be selected to account for initial queue from the previous analysis period also referred to as time interval.

2. Annual Average Daily Traffic (AADT). The total volume of traffic passing a point or segment of a facility in both directions for one year divided by the number of days in the year.

3. Arterial. A signalized street that primarily serves through-traffic and that secondarily provides access to abutting properties with signal spacing of two miles or less.

4. Base Condition. The best possible characteristics in terms of capacity for a given type of facility, that is, further improvements would not increase capacity, a condition without hindrances or delays.

5. Basic Freeway Segment. A length of freeway facility whose operations are unaffected by weaving, diverging, or merging.

6. Bottleneck. A road element on which demands exceed capacity.

7. Breakdown. The onset of a queue development on a freeway facility.

8. Breakdown Flow. Also called forced flow, occurs either when vehicles arrive at a rate greater than the rate at which they are discharged or when the forecast demand exceeds the computed capacity or a planned facility.

9. Calibration. The process of comparing model parameters with real-world data to ensure that the model realistically represents the traffic environments. The objective is to minimize the discrepancy between model results and measurements or observations.

10. Capacity. The maximum hourly rate at which persons or vehicles can reasonably be expected to traverse a point or uniform section of a lane or roadway during a given time period under prevailing roadway, traffic, and control conditions.

11. CAPTOP. Capital Traffic Operation Platform.

12. CAPWIN. Capital Wireless Information Net.

13. CCTV. Closed Circuit Television.

14. CHART. Coordinated Highways Action Response Team (Maryland SHA).

15. CMT. Congestion Management Team.

16. COG (Council of Governments) RICCS Roam Secure Network. A software application used to send emergency alerts, notifications and updates to account holders.

17. CRIM. Coordinated Regional (Transportation) Incident Management.

18. Critical Density. The density at which capacity occurs for a given facility, usually expressed as veh per mile per lane.

19. Critical Speed. The speed at which capacity occurs for facility, usually expressed as miles per hour.

20. DC. District of Columbia.

21. DDOT. District Department of Transportation.

22. Delay. The additional travel time experienced by a driver, passenger or pedestrian.

23. Demand-to-Capacity Ratio. The ratio of demand flow rate to capacity for a traffic facility.

24. Density. The number of vehicles on a roadway segment averaged over speed, usually expressed as veh per mile per lane.

25. DMS. Dynamic Message Sign.

26. EMS. Emergency Medical Services.

27. FHWA. Federal Highway Administration.

28. Flow Rate. The equivalent hourly rate at which vehicles pass a point on a lane, computed as the number of vehicles passing the point divided by the time interval in which they pass, expressed as vehicles per hour

29. Free-Flow Speed. The average speed of passenger cars over a basic freeway segment under conditions of low volume.

30. Freeway. A multilane, divided highway with a minimum of two lanes for the exclusive use of traffic in each direction and full control of access with out traffic disruption.

31. HAR. Highway Advisory Radio.

32. HCM. Highway Capacity Manual.

33. HOT. High Occupancy Toll.

34. HOV. High Occupancy Vehicle.

35. IMS. Incident Management System.

36. Incident. Any occurrence on a roadway that impedes the normal flow of traffic, such as accidents, debris, disabled vehicles, and hazardous material spills.

37. Incident Delay. The component of delay that results from an incident, compared with the no-incident condition.

38. INRIX. Subscription service of traffic speed and congestion data.

39. Interrupted Flow. A category of traffic facilities characterized by traffic signals, stop signs, or other fixed causes or periodic delay or interruption to the traffic stream.

40. ITS. Intelligent Transportation System.

41. Jam Density. The density at which congestion stops all movement of vehicles, usually expressed as veh pre mile per lane.

42. LCAP. Lane Closure Analysis Program.

43. LIM. Local (Transportation) Incident Management.

44. MARC. Maryland Area Regional Commuter.

45. MATOC. Metropolitan Area Transportation Operations Coordination.

46. MCF. MATOC Communication Facilitator.

47. MHSO. Maryland Highway Safety Office

48. Microscopic Model. A mathematical model that captures the movement of individual vehicles.

49. MTA. Maryland Transit Administration.

50. NAWAS. National Warning System.

51. NCR. National Capital Region.

52. NHTSA. National Highway Traffic Safety Administration.

53. NIMS. National Incident Management System.

54. Oversaturation. A traffic condition in which the arrival flow rate exceeds capacity.

55. Passenger-Car Equivalent. The number of passenger cars displaced by a single heavy vehicle of a particular type under specified roadway, traffic and control conditions.

56. pcphpl. passenger car per hour per lane.

57. PID. Passenger Information Display.

58. Prevailing Conditions. The geometric, traffic, and control conditions during the analysis period.

59. PRTC. Potomac and Rappahannock Transportation Commission.

60. Queue. A line of vehicles 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 joining the rear of the queue are usually considered part of the queue. The internal queue dynamics can involve starts and stops. A faster-moving line of vehicles is often referred to as a moving queue or a platoon.

61. Queue Carryover. The queued vehicles left over from the analysis period due to demand exceeding capacity.

62. Queue Discharge. A flow with high density and low speed in which queued vehicles start to disperse. Usually denoted as level-of-service (LOS) F.

63. Queue Discharge Flow. A traffic flow that has passed through a bottleneck and is accelerating to the free-flow speed of the freeway.

64. Residual Queue. The unmet demand at the end of the analysis period, resulting from operation while demand exceeded capacity.

65. RITIS. Regional Integrated Transportation Information System .

66. Rubbernecking. To look about or stare with exaggerated curiosity.

67. Service Flow Rate. The maximum hourly rate at which vehicles reasonably can be expected to traverse a point or uniform segment of a lane or roadway during a given time period (usually 15 min) under prevailing roadway, traffic,

environmental, and control conditions, while maintaining a designated level of service; expressed as vehicles per hour per lane.

68. Service Measure. A specific performance measure used to assign a level of service to a set of operating conditions for a transportation facility.

69. Service Volume. The maximum hourly rate at which vehicles reasonably can be expected to traverse a point or uniform segment of a roadway during an hour under specific assumed conditions while maintaining a designated LOS.

70. SHA. Maryland State Highway Administration

71. Shock Wave. The compression wave that moves upstream through traffic as vehicles arriving at a queue slow down abruptly, or the decompression wave of thinning traffic hat moves downstream from the point of a capacity reduction on a freeway.

72. SHSP. Strategic Highway Safety Plan.

73. Simulation Model. A computer program that uses mathematical models to conduct experiments with traffic events on a transportation facility or system over extended periods of time.

74. Stochastic Model. A mathematical model that employs random variables for at least one input parameter (e.g., SimTraffic).

75. TIM. Traffic Incident Management.

76. Trafficland CCTV Console. This subscription service allows the user to set up a console of numerous camera feeds.

77. Total Delay. The sum of all components of delay for any lane group, including control delay, traffic delay, geometric delay, and incident delay.

78. TPB. Transportation Planning Board.

79. Traffic Condition. A characteristic of traffic flow, including distribution of vehicles types in the traffic stream, directional distribution of traffic, lane use distribution of traffic, an d type of driver population on a given facility.

80. Traffic Delay. The component of delay that results when the intersection of vehicles causes drivers to reduce speed below the free-flow speed.

81. Travel Time. The average time spent by vehicles traversing a highway segment, including control delay, in seconds per vehicle or minutes per vehicle.

82. UC. Unified Command.

83. Undersaturation. A traffic condition in which the arrival flow rate is lower than the capacity or the service flow rate at a point or uniform segment of a lane or roadway.

84. Uninterrupted Flow. A category of facilities that have no fixed causes of delay or interruption external to the traffic stream; e.g. freeways and unsignalized section of multilane highways.

85. Unmet Demand. The umber of vehicles on a facility that have not been served at any point in time as a result of operation in which demand exceeds capacity, in either the current or previous analysis period.

86. VA's My511. The My511 website provides detailed traffic information for the Virginia Department of Transportation.

87. Validation. Determining whether the selected model is appropriate for the given conditions and for the given task, it compares model prediction with measurements or observations.

88. VDOT. Virginia Department of Transportation.

89. VMS. Variable Message Sign.

90. Volume. The number of vehicles passing a point on a lane, roadway, or other traffic-way during some time interval, often one hour, expressed vehicles

91. Volume-to-Capacity Ratio. The ratio of flow rate to capacity for the transportation facility.

92. VRE. Virginia Railway Express.

93. WebEOC®. WebEOC links local, state, federal, volunteer, private and even worldwide sources together, helping to facilitate coordination and decision-making for planning, training and emergency response, recovery and continuity of government and business operations.

94. WMATA. Washington Metropolitan Area Transit Authority.

95. Work Zone. A segment of highway in which maintenance and construction operations impinge on the number of lanes available to traffic or affect the operational characteristics of traffic flowing through the segment.

96. WTOP Radio. Provides frequent traffic reports and breaking news.