Module 4: Traffic Operations

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Purpose

This module builds on the information provided in Module 3, “Application of ITS to Transportation Management Systems.” Module 4 focuses specifically on the application of intelligent transportation systems (ITS) in traffic operations and how transportation facility owners, operators, and stakeholders use ITS technologies described in the previous module to manage and operate transportation systems.

The primary focus is how ITS tools and capabilities support traffic operations. This module also looks at transportation system programs, policies, and practices that implement ITS technologies to deliver effective traffic operations. A primary goal of this module is to increase understanding of how technology and processes can be used to provide the capabilities and data essential to effectively manage transportation resources through partnerships, policies, agency interactions, and personal interactions enabled by ITS technologies.

Objectives

After completing this module, you should be able to:

- Understand how ITS technologies and tools are used to effectively operate the transportation system.
- Understand the role of data in traffic operations.
- Recognize that management and operation of traffic is a core mission of transportation organizations.
- Understand how ITS contributes to comprehensive transportation systems management and operations.
- Develop performance goals that lead to improved traffic operations.

Introduction

Highway applications of ITS have roots in highway safety and efficiency initiatives dating back more than 50 years. Today’s transportation/traffic management centers (TMCs), also called transportation/traffic operations centers (TOCs), represent a central hub for the integration of ITS applications on highways and major arterials to support real-time management and operations. This module examines how highway operating agencies incorporate, integrate, and manage an array of ITS applications to address traffic safety and reliability focused on both recurring and nonrecurring congestion.
Traditionally, the mission and emphasis of state and local departments of transportation (DOTs), and other organizations responsible for highways, was primarily on building and maintaining the roads and related facilities that they were responsible for. Over the years, agencies have shifted their focus to include increasing emphasis on effectively operating and managing the systems to maximize efficiency and minimize additional capacity requirements. This transition is not easy because it involves rethinking almost every aspect related to how agencies carry out their mission and how the agencies themselves are structured. Advancements in ITS applications provide the tools, capability, and data that agencies need to support this shift.

The mission, responsibilities, and needs of state and local jurisdictions can be quite different. The division of responsibilities for highways and traffic operations varies significantly from place to place. In many cases, state DOTs have primary responsibility for Interstate Highways and local agencies are responsible for other types of roadways. North Carolina and Virginia are examples where the state is responsible for all highways and associated traffic control, with only a few exceptions.

In regions where responsibilities are shared among multiple agencies, operations centers tend to be structured and operated to support the needs and responsibilities of state agencies. However, a growing number of local agencies have, or plan to develop, local, fully functional TMCs, which are organized and operated to support the responsibilities of local agencies. Advanced ITS applications provide the means for state and local TMCs to work together, coordinate activities, and share information when the need arises.

The primary focus of TMCs has been on freeway management, incident management, and traveler information. Although this may remain their primary function, a growing number of centers are finding ways to interact, share information, and collaborate with other agencies that engage in activities and/or have responsibilities that impact roadway operations. Snow removal and emergency response are examples.

As discussed in Module 3, congestion includes both recurring and nonrecurring congestion, as shown in Figure 1. The 40 percent due to bottlenecks, along with the 5 percent poor signal timing, collectively, are what we call recurring congestion. As seen in the figure, the leading cause of nonrecurring congestion is traffic incidents.
Almost all of the other causes can be mitigated by better operational strategies. Even congestion due to bad weather can be mitigated by ITS, as will be discussed later in this module. Dealing with more severe emergencies usually presents orders of magnitude increase in challenges, and improved operational planning, preparation, and response can help mitigate many of the impacts incurred with severe emergencies.

A number of Federal Highway Administration (FHWA) programs focus on supporting ITS applications that reduce recurrent and nonrecurrent congestion. These programs include Traffic Incident Management, Planned Special Events Traffic Management, Work Zone Management, Road Weather Management, Congestion Mitigation, Active Transportation and Demand Management, Arterial Management, Access Management, Operations Asset Management, Traffic Signal System Management, Corridor Traffic Management, Bottleneck Mitigation, Freeway Management, Travel Demand Management, Tolling and Pricing, Value Pricing Pilot Program, and Congestion Mitigation. Other related programs include Traffic Analysis Tools, Planning for Operations, Performance Management, and Facilitating Integrated ITS Deployment. Applications of most of these programs are discussed in this module. The FHWA Office of Operations website http://ops.fhwa.dot.gov/program_areas/programareas.htm includes more detailed information about these programs.

There are other Federal ITS programs in other administrations of the USDOT, notably the Federal Transit Administration (FTA), the Research and Innovative Technologies Administration (RITA), which houses the ITS Joint Program Office (JPO), and the Federal Motor Carrier Safety Administration.
Planning for Operations
Traditional planning processes have focused on capital improvements to highways. As agencies move toward a performance-based management approach, there is an increasing interest in developing effective measures to integrate operational improvements in the planning process and encourage thinking beyond the physical construction of facilities and infrastructure. According to FHWA, “Planning for Operations includes three important aspects:

1. Regional transportation operations collaboration and coordination activity that facilitates Regional Transportation Systems Management and Operations.
2. Management and operations considerations within the context of the ongoing regional transportation planning and investment process.
3. The opportunities for linkage between regional operations collaboration and regional planning.

Linking planning and operations is vital to improving transportation decision-making and the overall effectiveness of transportation systems. Coordination between planners and operators helps ensure that regional transportation investment decisions reflect full consideration of all available strategies and approaches to meet regional goals and objectives.3

Planning for operations must necessarily be part of the long-range planning effort, and this planning process needs to be expanded beyond planning and funding the installation of more infrastructure. Specifically, planning for operations ensures the long-term, adequate, and reliable source of funds for day-to-day operations and maintenance of the infrastructure.

Transportation Systems Management and Operations
FHWA defines TSM&O as "an integrated program to optimize the performance of existing multimodal infrastructure through implementation of systems, services, and projects to preserve capacity and improve the security, safety, and reliability of our transportation system." Their Regional Concept for Transportation Operations suggests some examples of TSM&O strategies as follows:4

- Traffic incident management.
- Traveler information services.
- Traffic signal and arterial management.
- Transit priority systems.
- Freight management.
- Road weather management.
A key to the success of TSM&O programs is the establishment of processes that allow effective applications of TSM&O strategies, such as the integration of TSM&O into the planning process, the use of systems engineering, standardization and documentation, and performance management.

As an example, the Florida DOT began planning to implement TSM&O on a broader scale in the mid-2000s. As a first step, FDOT formed a TSM&O Leadership Team based in the central office, with membership from all the district secretaries. The team developed a strategic plan framework and workshop guidelines for use by the districts (see www.dot.state.fl.us/trafficoperations/TSMO/TSMO-home.shtm). The initial scope was somewhat limited and was focused on ultimately integrating freeway and arterial traffic management in Broward County. FDOT’s TSM&O Strategic Plan and other resources can be downloaded from www.dot.state.fl.us/trafficoperations/TSMO/TSMO-home.shtm.

Others states and regions, such as Maryland’s Coordinated Highways Action Response Team, CHART, (see www.chart.state.md.us/) and Washington state’s program (see their Grey Notebook at www.wsdot.wa.gov/accountability/), are promoting TSM&O as well.

**Regional Operations**

Technologies, procedures, planning, and preparation to support the management of recurring and nonrecurring congestion across jurisdictions are essential. Experience has clearly illustrated that providing venues for representatives of partner agencies to meet and discuss common concerns and needs not only improves interagency coordination, but also helps to build relationships that significantly enhance common policies and practices, as well as effective coordination, for example, when incidents occur.

Regional transportation systems management and operations (RTSMO) focuses on fostering relationships and building cooperation among agencies that share responsibility for managing and operating transportation systems in a region. RTSMO provides a means of sharing resources, information, experience, successes, problems, and mutual needs with stakeholder agencies in the broader region.

FHWA has a wealth of documentation on this subject, including:

- “Regional Concept for Transportation Operations: A Tool for Strengthening and Guiding Regional Transportation Operations Collaboration and Coordination,”
A key product of such RTSMO activities is a regional ITS architecture, required of all Federally-funded ITS projects.

A regional approach to traffic operations provides an effective means of reaching stakeholders to identify needs, opportunities, and enhancements to existing ITS systems, which may be supported by ITS technologies. Regional organizations can form working groups or subcommittees to focus on ITS solutions and develop and maintain regional ITS architectures and plans.

**Integrated Corridor Management**

As discussed in Module 3, “Application of ITS to Transportation Management Systems,” integrated corridor management (ICM) applies strategies and advanced technologies to coordinate and integrate transportation operations among agencies to increase overall system throughput and enhance the mobility, reliability, and safety of corridor users. ICM may include freeways, arterials, parking, public transit, and freight facilities. The following projects are examples of ICM applications that include interstate, state, and local facilities in coordination with public transit to maximize system efficiency and reliability.

**San Diego I-15 ICM Demonstration Project**

San Diego, CA, typically experiences significant traffic congestion during peak travel periods, and the city has a limited number of high-occupancy vehicle (HOV) and high-occupancy toll (HOT) lanes, and also has limited transit capacity. The San Diego ICM application demonstration corridor includes I-15 from State Route 52 in San Diego to State Route 78 in Escondido. The San Diego Association of Governments (SANDAG) is the lead agency, accompanied by the California Department of Transportation (Caltrans), the City of San Diego, the City of Escondido, the City of Poway, the Metropolitan Transit System, and the North County Transit District.

The following are existing ITS assets the San Diego Pioneer Site will leverage in its ICM demonstration:
• Dynamic ramp metering
• Dynamic message signs (DMS)
• Dynamic variable pricing along 21-miles of managed lanes

San Diego plans to evaluate the following ICM strategies in the I-15 corridor:

• En route traveler information
• Pretrip traveler information
• Transit signal priority
• Freeway-coordinated ramp metering
• Signal coordination on arterials with freeway ramp metering
• Congestion pricing on managed lanes
• Physical bus priority on arterials
• Increased HOV occupancy requirements

The ICM strategies planned for demonstration in this project include:

• Real-time traveler information about traffic and travel times, public transit, and parking availability.
• A smart transportation management system to leverage ITS investments in the corridor and combine road sensors, video, and traveler information to reduce congestion.
• Coordination of incident management efforts along the corridor.
• Traffic signal timing and coordination along the corridor, including ramp metering.
• A decision support system to provide operators with real-time simulation, predictive algorithms, analysis modeling, and enhanced control.

Even though this demonstration is not completed, it is included due to the breadth of ICM applications planned. See also [www.youtube.com/watch?v=c9nqWXL5avo/](http://www.youtube.com/watch?v=c9nqWXL5avo/).

**Dallas ICM Demonstration Task**

The Dallas, TX, area is currently populated by 6 million people and is growing by 1 million every 7 years. Travel demand and congestion in this area continue to grow. The Route 75 ICM Corridor in Dallas is the highest volume and most critical transportation corridor in the region. It has major employment centers, and although there isn’t room for expansion of the corridor, it will be impacted by major construction planned in the surrounding area.

Transit availability and capacity are being increased in the region to accommodate expected growth. Other ongoing improvements include enhanced park-and-ride facilities and deployment of ITS elements. Dallas will also add managed lanes and explore value-pricing strategies.
The Dallas ICM site covers the Route 75 corridor from downtown Dallas to State Highway No. 121, with the North Dallas Toll Way to the west and various arterials to the east as their corridor. The Dallas Area Rapid Transit Authority is the lead agency, accompanied by the City of Dallas, the City of Richardson, the City of Plano, the City of University Park, the Town of Highland Park, the North Central Texas Council of Governments, the North Texas Toll Way Authority, and the TxDOT Dallas District.

The following are ITS assets that the Dallas ICM site will leverage:

- On the freeway network:
  - Route 75 Corridor fully instrumented in 2009
  - DalTrans Transportation Management Center—The TMC integrates TxDOT, DART, and Dallas County Sheriff’s Department
  - CCTV cameras
  - Detectors
  - DMS with posted travel times.
  - Mobility assistance patrol

- On the arterial network:
  - Connected traffic signals
  - 9-1-1 integration with traffic signal system
  - Surveillance cameras that are tied to wrecker services
  - Arterial DMS
  - Traffic signal priority

Dallas plans to evaluate the following ICM strategies in the Route 75 corridor:

- Managed lane strategy
- Earlier dissemination of traveler information
- Route diversion to parallel frontage roads for minor incidents
- Route diversion to frontage road and strategic arterials for major incidents including signal retiming along the arterials
- Mode diversion Red Line light rail transit (LRT) for major incidents
- Combined route and mode diversion strategy that diverts travelers to frontage roads, strategic arterials, and Red Line LRT
- LRT smart parking system
- Added parking and valet system

To evaluate the benefits of the proposed ICM, the Dallas site used three modeling tools to look at how the ICM would work in the real world under simulated conditions. By integrating the results of the travel-demand modeling, a mesoscopic-simulation model, and a microscopic-simulation model, Dallas has been able to look at where bottlenecks could occur and where travel times are unacceptable.
The ICM strategies planned for demonstration include:

- Real-time traveler information about traffic and travel times, public transit, and parking availability.
- Information collected by detectors on the current travel conditions on freeways, frontage roads, arterial streets, light-rail Red Line, Red Line park-and-ride lots, and managed lanes in the corridor.

A decision support system will help operators select the appropriate combination of ICM strategies to apply to different operational conditions.

**TMC Operations Overview**

Module 3, “Application of ITS to Transportation Management Systems,” provides a description of the features and capabilities provided by TMCs, and how they are organized. This module addresses how the capabilities provided by TMCs support operations activities and, more significantly, how the managers and operators of the TMC use its components—sensors, closed-circuit television (CCTV), dynamic message signs (DMS), ramp meters, highway advisory radio (HAR), and road weather management subsystems (RWMS) and software—to manage traffic and respond to incidents and emergencies.

TMCs are traditionally owned and operated by state DOTs and major cities responsible for managing freeway traffic through ITS subsystems. The principal function of a TMC is traffic management through surveillance, monitoring, and control, either indirectly via traveler information applications or directly through lane control and ramp metering.

**Planning TMC Operations and Maintenance**

A key element of planning for operations is to ensure the successful design, implementation, operation, and maintenance of TMCs. This planning should start from completed ITS studies and initiatives for the region, such as the regional ITS architecture, strategic deployment plan, concept of operations (ConOps), and operations and management plans.5

A TMC ConOps presents a high-level description of system capabilities based on agreed vision, goals, identified needs, and high-level functional requirements, as outlined in FHWA’s guidance on producing and implementing TMC ConOps documents.6 This forms the basis for defining the detailed requirements and producing a high-level design. The ConOps also identifies the TMC stakeholders, spatial and temporal coverage of the TMC, and required resources (e.g., hardware, software, facilities, and personnel). Developing a ConOps document forms a solid basis for establishing TMC operations and management procedures, acquiring and utilizing resources, and interfacing with TMC stakeholders. The stakeholders include other public agencies, private-sector service providers, the general public, and the media.
The TMC Business Planning and Plans Handbook produced by FHWA’s Pooled Fund Study provides guidelines for developing TMC business plans. The establishment of a business plan is recommended to provide a roadmap that agencies follow to establish goals and objectives, and the steps to achieve them. A properly implemented TMC business plan establishes justification for sustainable funding through ongoing performance measurement and reporting of outcomes. In addition, the business plan helps identify the current and desired state of the TMC and the key gaps that need to be addressed to reach the desired level of operational effectiveness. The plan includes an analysis of the strengths, weaknesses, opportunities, and threats (SWOT analysis) of TMC implementation scenarios. The plan also identifies the expected benefits; the associated funding requirements and financial strategy; and the requirements for establishing partnerships, organization and management structure, and personnel needs.

TMCs require significant funds for implementation, operation, and maintenance, which can affect and limit their implementation. Adequate staffing and operation plans are required for effective TMC operations. The majority of agencies run TMCs with public-sector staff; however, some agencies have found it challenging to staff and train personnel to effectively operate the TMC. These agencies often outsource the TMC operations to private-sector companies. FHWA has developed a Handbook for Developing a TMC Operations Manual to assist agencies in establishing their operation plans.

In general, the evolving culture of planning for operations looks at tools like life-cycle implications, asset management, value engineering, and TSM&O, which are occupying more significant places in transportation.

**TMC Operations**

Figure 2 summarizes the typical activities that TMCs perform in support of traffic operations for the types of traffic conditions indicated. For the purposes of this discussion, it is assumed that the TMC is responsible for freeway operations. Note that the field network communications and device controller infrastructure, as well as the TMC software, are common to all resources; thus, they are not mentioned in the figure. Understandably, all of the resources mentioned in the figure might not be present in all TMCs.

**Figure 2. Transportation Management Center Operations**

<table>
<thead>
<tr>
<th>Operating Condition</th>
<th>Operational Function</th>
<th>Operational Method</th>
<th>Resources Used</th>
<th>Desired Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>All conditions</td>
<td>Surveillance</td>
<td>Visual monitoring</td>
<td>CCTV, video wall, workstations, video tours</td>
<td>Maximum visual coverage of network</td>
</tr>
<tr>
<td>Operating Condition</td>
<td>Operational Function</td>
<td>Operational Method</td>
<td>Resources Used</td>
<td>Desired Result</td>
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<tr>
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</tr>
<tr>
<td>Sensor monitoring</td>
<td>Electronic detectors</td>
<td>Maximum sensor coverage of network, capture traffic characteristics</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vehicle probes</td>
<td>Safety service patrol, road watchers</td>
<td>Detect and verify incidents timely</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Traffic control/ influence</td>
<td>Traveler information</td>
<td>DMS, PCMS, HAR, 511, media feed</td>
<td>Inform public of conditions for self-decisions</td>
<td></td>
</tr>
<tr>
<td>Traffic control/ influence</td>
<td>Ramp metering</td>
<td>Lane signals, DMS, PCMS</td>
<td>Increase roadway capacity</td>
<td></td>
</tr>
<tr>
<td>Traffic control/ influence</td>
<td>Variable speed limits</td>
<td>Speed limit DMS</td>
<td>Stabilize flow</td>
<td></td>
</tr>
<tr>
<td>Sensor monitoring</td>
<td>RWMS</td>
<td>Detect adverse weather</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Visual monitoring</td>
<td>CCTV, video wall, workstations, video tours</td>
<td>Detect and verify adverse weather</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Visual monitoring</td>
<td>CCTV, video wall, workstations, video tours</td>
<td>Detect and verify incident, dispatch response, notify other responders</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sensor monitoring</td>
<td>Electronic detectors</td>
<td>Incident detection algorithms alert for potential incident</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Incident notification</td>
<td>Police, PSAP</td>
<td>Initiate response</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Patrol vehicles</td>
<td>Safety service patrol, road watchers</td>
<td>Detect incidents, SSP respond and assist</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Traveler information</td>
<td>DMS, PCMS, HAR, 511, website, media feed, social media</td>
<td>Encourage diversions and trip time changes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operating Condition</td>
<td>Operational Function</td>
<td>Operational Method</td>
<td>Resources Used</td>
<td>Desired Result</td>
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<tr>
<td>---------------------</td>
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</tr>
<tr>
<td>Ramp metering</td>
<td>Ramp signals, queue detectors</td>
<td>Ramp metering</td>
<td>Smoothen merging, effect increased diversion</td>
<td></td>
</tr>
<tr>
<td>Speed advisory</td>
<td>Speed advisory DMS</td>
<td>Speed advisory DMS</td>
<td>Calming of speeds and reduced lane changing</td>
<td></td>
</tr>
<tr>
<td>Variable speed limits</td>
<td>Speed limit DMS</td>
<td>Speed limit DMS</td>
<td>Reduce limit to safe speed</td>
<td></td>
</tr>
<tr>
<td>Lane use control</td>
<td>Lane signals</td>
<td>Lane signals</td>
<td>Open/close lanes as appropriate</td>
<td></td>
</tr>
<tr>
<td>Maintenance of traffic</td>
<td>DMS, PCMS</td>
<td>DMS, PCMS</td>
<td>Safe, free flow past maintenance and other road work</td>
<td></td>
</tr>
<tr>
<td>Queue warning</td>
<td>DMS, PCMS</td>
<td>DMS, PCMS</td>
<td>Safe, free flow past maintenance, other road work, and incidents</td>
<td></td>
</tr>
<tr>
<td>Work zone and main- tenance activities</td>
<td>Traffic control/influence</td>
<td>Traveler information</td>
<td>DMS, PCMS, HAR, 511, website, media feed, social media</td>
<td>Safe, free flow past maintenance and other road work, or diversion of route</td>
</tr>
</tbody>
</table>

A key to successful traffic operations is the interagency, multiple-disciplinary integration of the TMC and other agencies. This is often referred to as the 4-Cs (communication, cooperation, coordination, and consensus). In particular, managing routine traffic, traffic incidents, and even transportation emergencies is greatly enhanced by agencies practicing the 4-Cs together. This is most effective when centers like the TMC, public safety answering point (PSAP), and/or emergency operations center (EOC) are colocated, or at least in close two-way communication and able to share data, information, and images. For example, most traffic incidents are first detected by a cellular telephone call that is received at a PSAP. Data integration between TMC databases and public safety computer-aided-dispatch databases facilitates quicker and more appropriate response by secondary responders and provides better traffic- and incident-related information to public safety agencies. For another example, information seen on camera can be actively provided to responders (e.g., police, fire, other emergency services, and maintenance), and responders can directly request resources. For more information, visit: [www.ops.fhwa.dot.gov/eto_tim_pse/technologies/data.htm](http://www.ops.fhwa.dot.gov/eto_tim_pse/technologies/data.htm).

Some TMCs manage arterial traffic signal systems, and more will in the future. The primary reason for the separation between freeway and arterial operations is the absence of software systems that fully integrate the two types of operations. The trend toward more integrated traffic management will eventually drive more functional integration of freeway and arterial operations. The development of nonproprietary
software that handles both facility types is unlikely in the near future for technical and institutional reasons.

A useful report, titled Impacts of Technology Enhancements on Transportation Management Center Operations and produced by the Transportation Management Center Pooled Fund Study (TMC PFS), provides guidance to TMC managers on how to position themselves operationally in anticipation of future technology changes and advancements (see www.ops.fhwa.dot.gov/publications/fhwahop13008/index.htm). The study was undertaken for the following reasons:¹⁰

- Pressure on TMCs has never been greater because of:
  - Technology options increasing exponentially.
  - The rapid pace of technology innovation.
  - The public’s expectation of timely and accurate information.

- This is a time of challenge and opportunity for TMCs because of:
  - The proliferation of wireless communication.
  - The rise of social media.

The study identified eight top trends and issues affecting technology impacts on TMC operations. The first four trends originated from within the transportation field itself and the others from outside the transportation field. The trends are:

- A nimble service-oriented program mindset and organizational structure.
- Active transportation and demand management (ATDM) concept and toolkit.
- Accommodating toll and other pricing operations in TMCs.
- Performance monitoring and management.
- Automation tools and related tools to increase efficiency.
- Involvement of third parties in data collection, data analysis, and provision of traveler information.
- Mobile communications and wireless networks.
- Social media for traveler information and crowdsourcing.

The study identifies 80 strategies that address the eight trends, gives examples, and includes checklists to assist in implementation of the strategies.

An excellent video depicting various scenarios in a futuristic TMC, the, TMC of the Future (http://itsa.org/knowledgecenter/knowledge-center-20), was produced by the Intelligent Transportation Society of America (ITSA) for the 2008 ITS World Congress. The video features the future use of what was called Vehicle-Infrastructure Integration (VII) and is now referred to as Connected Vehicles (CV). The CV program is still in the research and development stage, so its use in the TMC is largely futuristic; however, one of the key elements is the use of probe data for traffic flow characteristics, which is already commonplace. Notice that the TMC in the video also operates arterial systems
and provides integrated corridor management, currently being implemented across the country. The video addresses integration with other transportation modes and services, such as transit and parking, and even discusses congestion pricing.

**System Monitoring**

Effective traffic operations require the system to be fully functional. This is accomplished by monitoring the system components. System monitoring has two aspects: 1) monitoring the system for the purposes of traffic management, and 2) monitoring to assess the health of the system itself. This section deals with the latter.

In this case, the TMC software monitors the incoming data, images, and other media from the field devices that are used for routine traffic management and incident detection, verification, notification, and dispatch. Within the TMC itself, the software automatically monitors the status of its key processors, servers, video displays, communications, and all the other assorted equipment, including the software itself, needed to maintain a high level of operational efficiency. Equally importantly, these form the core of data and information used for performance management.

It is essential to monitor the system to evaluate its success in achieving its mission. Typically, the TMC software will have modules that automatically monitor the various components to detect and report failures or other anomalies that need to be brought to the operators’ attention. In legacy systems, this is generally achieved through periodic polling of the devices to sense expected responses, monitoring data streams for continuity, and using other diagnostic techniques. As device sophistication increases, devices may do more self-diagnostics, pushing health information to the central system. The results from the monitoring are used for instant failure reporting, as well as providing system performance measures over time.

From a traffic operations perspective, this process is essential because it enables the TMC operators, managers, and maintenance team to allow the system to perform its tasks in managing traffic and providing situational awareness to the traveling public. System monitoring helps ensure the following:

- **System reliability**—Helps to ensure system robustness and overall reliability.
- **Efficiency**—The TMC and field equipment are operating at or above specifications and performing their expected functions properly.
- **Effectiveness**—The ITS is achieving its program goals and objectives from an operational perspective.
- **Accountability**—Enables managers to be confident that the investment in ITS is being nurtured and protected through proper operation the vast majority of the time, or contrarily, that problems exist that need to be addressed.
Congestion Management

A simple law of traffic physics is that when traffic demand approaches the roadway capacity, the quality of service rapidly diminishes; and when demand exceeds capacity, traffic flow breaks down completely. The array of processes, tools, and practices used to mitigate the resulting congestion is referred to as congestion management—namely, managing the situation in a manner to avoid or minimize the negative impacts of congestion. This section covers methods for mitigating recurring congestion—congestion that occurs on a regular basis due to traffic demand exceeding roadway capacity on virtually a daily basis.

Module 3 covered the physical aspects of technology-enabled applications used to manage recurring congestion, such as advanced traveler information systems (ATIS), active traffic management (ATM), ramp metering, etc. This section deals more with strategies for using these tools to manage the congestion.

For freeway facilities, strategically there are only two ways to avoid this congestion: 1) reduce the demand, or 2) increase or enhance the efficient operation of the roadway. The remainder of this section deals primarily with both strategies.

Travel Demand Management Strategies

There are a number of programmatic strategies for reducing traffic demand by encouraging changes in traveler behavior (additional information can be found at www.ops.fhwa.dot.gov/tdm/index.htm).

- Implementing programs that promote alternative travel modes, such as transit use, ride sharing, and associated ATDM services, or encourage nonmotorized travel.
- Encouraging flexible work times, telecommuting, and the use of satellite work places.
- Applying real-time ATIS that encourages drivers to use alternate routes, change trip times, or effect other behavioral changes.

These programs are implemented through marketing campaigns and ATDM technology. Another approach is through the use of pricing incentives, or disincentives, such as:

- Congestion pricing strategies, including high-occupancy toll lanes, in which the fees for the use of express travel lanes vary by the number of persons in the vehicle, the time of day, and the level of congestion in the HOT lane(s) and general-use lanes.
- Parking management in which fees for parking spaces vary by the number of persons in the vehicle, the time of day, location, and sometimes parking lot utilization.
• Access management in which access to whole areas, such as the center core of a city, is limited. This is more popular in Europe and Asia, but U.S. cities are considering this approach.

**Other Active Transportation and Demand Management**

ATDM programs involve the use of strategies, tools, and resources to dynamically manage, control, and influence traffic flow and travel demand of transportation facilities. ATDM goes beyond ATM, discussed in Module 3, to include demand management. ATDM strategies are designed to modify conditions, possibly in combination with predicting conditions, to achieve operational objectives, such as preventing or delaying breakdown conditions, improving safety, promoting sustainable travel modes, reducing emissions, or maximizing system efficiency. FHWA established the FHWA ATDM program to develop guidance, analysis techniques, case studies, and research to support improved planning, analysis, design, implementation, operation, and evaluation of ATDM.¹⁰

All of these strategies use technology tools, such as electronic toll or fee collection, but the ITS tools are basic. The more strategic application of ITS lies in the operational efficiency enhancement realm.

**Operational Efficiency Enhancement Strategies**

This discussion focuses on operational efficiencies that can be considered instead of fixed, permanent, physical roadway capacity improvements. It considers how ITS can be applied to enhance operations and make better use of the actual capacity through traffic flow improvement strategies. TSM&O strategies increase or enhance operation of existing roadway capacities.

The following strategies—most of which constitute ATM—can be applied to improve the operation and/or stabilize flow of traffic on limited-access highways.

- **Metering traffic onto freeways:** By spacing merging traffic, there is less queuing in the acceleration lane and smoother merges, which allows more stable flow past the ramp and increases throughput. Freeway mainline speeds can be increased by as much as 50 percent due to ramp metering.¹¹ Ramp meters are used extensively in Arizona, California, Illinois, Minnesota, Texas, Utah, Virginia, and Wisconsin, and more recently in Florida and Georgia.

- **Reversible lanes:** Having reversible, or contraflow lanes permits otherwise unused capacity in the off-peak direction to be used in the peak direction of flow. This use of the existing roadway requires ITS devices to facilitate the operation through lane control signals, remote-controlled gates, CCTV, and sensors. Reversible roadways like the Shirley Highway in northern Virginia leading into Washington, DC, and I-5 north of both San Diego, CA, and Seattle, WA, have proven effective. Contraflow lanes are generally restricted to buses, such as the approach to the Lincoln Tunnel leading into New York City, although the
contraflow lane on the Long Island Expressway also permits (or at least has in the past permitted) taxis carrying passengers.

- Movable median barriers to accommodate peak period demand: Functionally, this is similar to contraflow, but instead of shifting traffic to the other side of a median, the median itself is moved, effectively adding a lane to the peak direction. Houston, TX, has successfully used this technique for years. Again, lane control signals and portable changeable message signs (PCMSs) can help with this technique; although there is less need since the lanes are usually separated by pavement lane lines and barriers.

- Automated toll collection: Electronic toll collection (ETC) is the standard for toll systems. Vehicles with transponders are able to pass through toll plazas at low speed without stopping, or in many cases at highway speeds. This greatly improves traffic operations in the toll plaza. A number of the larger ETC systems (e.g., E-ZPass in the northeast, eastern seaboard, and Midwest, and SunPass in Florida) are currently working to make their systems interoperable so that each system’s transponders will work in the other’s area. Led by Ontario Highway 407 in Toronto, Canada, tolling systems are now increasingly turning to open road tolling (ORT), or free-flow tolling, and have no cash collection at all. Non-toll-tag vehicles can be identified by license number, and the owner is sent a bill for the toll, usually with a small surcharge.

- Managed lanes: New lanes or existing HOV lanes are converted to HOT lanes that operate as toll lanes using ETC (or even ORT) for single-occupant vehicles (SOVs) or even low-occupant vehicles. Carpools of two- or three-plus occupants generally may use the HOT lanes for free, thus encouraging demand shift to HOVs, while SOVs are charged a variable toll that is dependent on the time of day, level of congestion in the general-use lanes, and occupancy of the HOT lanes. Shifting demand from the general-use lanes to the HOT lanes makes better use of the available capacity in the HOT lanes while improving flow for all. HOT lanes operate or are under construction in more than 20 locations nationally (see Traffic Congestion–Road Pricing Can Help Reduce Congestion, but Equity Concerns May Grow, Report to U.S. House of Representatives, Government Accounting Office, January 2012 at www.gao.gov/assets/590/587833.pdf).

- Hard-running shoulder: As discussed in Module 3, some locales allow buses and, in some cases, general, mixed traffic to use the shoulder lane during peak periods. The name comes from the fact that the shoulders often need to be upgraded to normal travel-lane strength for use as traffic lanes. This treatment uses ITS devices, like lane control signals and DMS. Figure 3 shows the hard-running shoulder on I-66 in Fairfax County, VA, and a close-up of the sign and lane control signal.
• Work zone management: Work zones are areas of reduced capacity. Efficient management of these areas is essential for efficient traffic operations and safety, as discussed in greater detail later in this module.

• Variable speed limits: An element of ATM, variable speed limits that reflect the realistic speeds indicated by the onset of congestion can have a leveling effect and reduce erratic lane changing, increasing smoother traffic flow and throughput. Speed limits are displayed using special DMSs that closely resemble the official speed-limit sign. (Note that these DMSs must be legislatively authorized to be enforceable.) A similar effect may be achieved through variable speed advisory signs, which do not have to be legislatively enabled or enforced.


**TMC Congestion Management Strategies**

TMCs are directly or indirectly involved in many aspects of mitigating nonrecurring congestion. Here are some examples:

- Use ATIS to the fullest. This is covered in more detail in the next section, so suffice it to say here that TMC managers and operators can use their ATIS tools to maximize the dissemination of useful traveler information by all channels, particularly the DMS, 5-1-1, HAR, and media. The latter may be overlooked by TMCs, but the Georgia DOT feels so strongly about the media as an arm of its NaviGAtor ATIS that it employs a media liaison, whose only function is to ensure that timely and accurate information is provided to the media.

- Scan CCTV images to look for signs of breakdown, such as a smoking vehicle, debris on the roadway, dangerous or excessive vehicular maneuvers, or anything that might lead to an incident. That said, most TMCs do not have a sufficient number of operators to focus on camera scans, even using camera tours; rather, they more commonly use system performance measures. Figure 4 shows an innovative approach used by Florida District 4’s TMC in Broward County in which the entire section of I-95 and I-75 in its control area are projected on the wall. Currently, it displays the speed profile (average speed) of the traffic on the two interstates so that operators can quickly identify hot spots. Taking proactive action before a suspected incident occurs is a successful means of preventive maintenance.

**Arterial Network Congestion Management Strategies**

While some of the foregoing applies to arterial networks, arterial system managers have less direct control over their facilities, so their strategies differ. As the flow regime changes, the operational objectives change as well. In most cases, the only direct control operators have on the system is signal timing; however, they can use signal timing to achieve different operational objectives. For example, as demand (equal to
volume until saturation is reached) increases, the objective may change from free flow, to vehicular throughput, and finally to queue management.

For freeways with ramp metering, traffic is queued where it has the least impact on the system, as long as the queue doesn’t interfere with the upstream signalized intersection, in which case the metering rate is increased. For purely arterial networks, gating strategies can do the same thing; again, the strategy is to store the queues where they have the least impact.

Similar to freeway systems, operational efficiency enhancements can be used on surface streets—either arterial highways or city streets—as follows:

- **The timing of traffic signals**—This strategy has been used nationally for many years; however, many cities and counties need to review and update the timing to accommodate changing demand patterns, as reported in the National Traffic Signal Report Card periodically published by the National Transportation Operations Coalition (NTOC), see [www.ite.org/reportcard/](http://www.ite.org/reportcard/). It has been shown that coordinating signals to accommodate progression of platoons of vehicle is a highly cost-effective method of increasing throughput and reducing delay, stops, and fuel consumption. As already noted, newer adaptive signal control technology (ASCT) strategies can reduce the retiming issue and be even more effective, since they can adjust cycle-by-cycle in near real-time. As noted earlier, traditional control strategies are still needed when ASCT fails, becomes untenable, or doesn’t meet the current operational objectives, such as maximizing progressive throughput.

- **Turn restrictions at key intersections**—This strategy eliminates signal phases (usually left turns) that take time away from the primary through movements. While inconvenient for some, forcing rerouting or other actions, the overall operation of intersections is greatly enhanced. These subsystems use traffic signals and sometimes DMS. Note that this treatment may require shifts in traffic patterns/individual movements whenever restricting specific movements.

- **Reversible lanes**—Just as on freeways, some cities use reversible lanes on arterials for the same reason. This is done daily for congestion management in Washington, DC, and for special sporting events in Jacksonville, FL.

- **Transit signal priority**—This uses sensors and/or transponders to detect buses approaching an intersection and special control software to either extend the green time, if already green, on the bus phase or to shift from opposing phases to green for the bus phase. This is a demand management strategy for encouraging the use of buses, and has been demonstrated not to interfere unreasonably with other traffic, thus improving overall throughput.
• Signal timing for crossings—Too often when trains, drawbridges, emergency vehicles, or other modes preempt signals and block traffic, signal timing continues as if the blockage has not occurred. Signal timing should be adjusted to accommodate rerouting. Again, ASCT strategies might react to this situation automatically.

A good example of an aggressive arterial network management program is Operation Green Light in Kansas City (see www.marc.org/transportation/ogl/).

FHWA has a program called Improving Traffic Signal Management and Operations. For information, see http://ops.fhwa.dot.gov/publications/fhwahop09055/sigopsmgmt_V.htm.

Advanced Traveler Information

The pioneers of ITS realized that transportation system users were an essential part of the ITS universe; in fact, the most important one. However, unlike other elements of ITS, the transportation professional has little direct control over users as each one is an independent entity who observes situations from the perspective of his or her parochial needs, and makes and executes decisions more or less independently. So the most effective thing the transportation profession can do is inform travelers in the best possible manner to enable them to make informed, and hopefully safe, decisions. This is accomplished through ATIS.

Most of this discussion of ATIS applies primarily to freeway systems. Some may impact arterial systems, but generally to a lesser degree.

The goal of ATIS is for travelers to have more information at their disposal to help them make more informed travel decisions about mode, route, departure time, and activity choices. A benefit of these better decisions can often be safer and more efficient traffic operations. For example, in the highway sector:

• Provide pretrip information through radio and TV traffic reports, websites, navigation maps, and information service provider (ISP) feeds that might enable travelers to change their travel mode, change the trip departure time, or change the route of the trip, to avoid an incident or normal congestion, thus reducing traffic demand in the affected area.

• Provide en route information through DMS, radio traffic reports, GPS (global-positioning system) navigation maps, and ISP feeds to a smartphone. This

A recent survey by Florida DOT District 6 (Miami-Dade Co. and south) found that 92 percent of freeway/turnpike drivers read DMS at least weekly, 97 percent said these signs provide accurate traffic alerts, and 78 percent reported a willingness to alter their route based on DMS postings. Use of 5-1-1 increased in the past year and 22 percent of respondents were more willing to change their departure times as a result of 5-1-1 information. (Source: Rodriguez, J., "Miami Drivers Reported Travel Benefits from Using Dynamic Message Signs," SunGuide® Disseminator, Florida DOT, January 2013.)
information enables travelers to change their trip plans en route or even abandon the trip to avoid an incident or normal congestion, thus reducing traffic demand in the affected area. Even if the traveler does not change any trip plans, just knowing the nature of congestion, perhaps with some indication of travel time or incident location, can reduce drivers’ frustration and anxiety, making them safer drivers that are less prone to take unnecessary chances, such as excessive lane changing.

- On managed lanes, current HOT pricing is conveyed by DMS, allowing SOV drivers to make a decision to use the HOT lanes, thus relieving demand in the general-purpose lanes.

Traveler information for transit passengers can inform them of the arrival of the next vehicle and provide transfer information. Although this may not immediately impact traffic operations, this type of traveler information makes travelers more comfortable and confident about using mass transit, thereby encouraging them to continue to do so and not add vehicles to the highways. Some ICM concepts include transit as well, particularly bus rapid transit systems.

There is a full range of traveler information provider systems and services. A summary of these technologies, along with advantages and disadvantages is given in Table 1.

**Table 1. Characteristics of Traditional Traveler Information Techniques**

<table>
<thead>
<tr>
<th>Technology</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
</table>
| Posting of messages on DMS     | • Point and advanced information to the most-affected drivers
• Efficiently changed
• Modern full-matrix signs can use graphics and color to enhance messages | • Doesn’t reach drivers off the highway
• Fixed location
• Old signs difficult to read
• Not always widely trusted |
| Posting of messages on PCMSs   | • Point (and possibly advanced) information to most-affected drivers
• Can be deployed to unplanned situations/incidents | • Takes time to deploy for unexpected events
• Not efficiently changed (unless remotely controlled)
• Sometimes difficult to read |
| 5-1-1 (voice, automated)       | • Widely available
• Efficiently updated
• Widely accepted
• Can be accessed in route
• Can be (partially) financed by sponsorships or advertising | • Must be proactively accessed
• Encourages phone use while driving
• Language issues, particularly in interactive voice recognition (IVR) |
| Call taker                     | • Highly responsive and effective
• Personalized | • Rarely used today, but popular where they are
• Encourages phone use while driving
• More expensive than IVR |
<table>
<thead>
<tr>
<th>Technology</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Website (TMC or 5-1-1)</td>
<td>• Widely available</td>
<td>• Not universally accessible; must be proactively accessed via computer or mobile device</td>
</tr>
<tr>
<td></td>
<td>• Efficiently updated</td>
<td>• Encourages mobile device use while driving</td>
</tr>
<tr>
<td></td>
<td>• Can be automated (e.g., speed maps)</td>
<td>• Language issues</td>
</tr>
<tr>
<td></td>
<td>• User can view selected CCTV images</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Can be partially financed by sponsorships or advertising</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Widely accepted</td>
<td></td>
</tr>
<tr>
<td>Media – radio traffic reports</td>
<td>• Widely available</td>
<td>• Must be proactively accessed</td>
</tr>
<tr>
<td></td>
<td>• Can be efficiently updated</td>
<td>• Always maintaining timely and accurate information</td>
</tr>
<tr>
<td></td>
<td>• Widely accepted (many say this is their primary mode)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Can be accessed in route</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Financed by the media</td>
<td></td>
</tr>
<tr>
<td>Media – TV traffic reports</td>
<td>• Widely available</td>
<td>• Must be proactively accessed</td>
</tr>
<tr>
<td></td>
<td>• Can be efficiently updated</td>
<td>• Always maintaining timely and accurate information</td>
</tr>
<tr>
<td></td>
<td>• Can show station-selected CCTV images</td>
<td>• Not available en route</td>
</tr>
<tr>
<td></td>
<td>• Widely accepted (many say this is primary mode)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Can be accessed pre-trip</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Financed by the media</td>
<td></td>
</tr>
<tr>
<td>Airborne spotting and reporting</td>
<td>• Widely available</td>
<td>• Must be proactively accessed</td>
</tr>
<tr>
<td></td>
<td>• Agile relocation</td>
<td>• Getting timely air time for incidents (unless it is a continuous traffic reporting station)</td>
</tr>
<tr>
<td></td>
<td>• Efficiently updated</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Widely accepted</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Can be accessed en route</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Financed by the media</td>
<td></td>
</tr>
<tr>
<td>Kiosks and display signs</td>
<td>• Popular with older, less tech-savvy, and ADA users</td>
<td>• Limited availability (e.g., transit terminals, rest stops, and other fixed locations)</td>
</tr>
<tr>
<td></td>
<td>• Provides peace of mind for transit riders</td>
<td>• Timely and accurate updates</td>
</tr>
<tr>
<td></td>
<td>• Transfers/connection information for transit users</td>
<td></td>
</tr>
</tbody>
</table>

In recent years, the proliferation of smartphones and other mobile devices (e.g., digital tablets and pads), the expanding use of social media, and the increasingly wide-spread use of vehicle probe data collection techniques have led to a number of truly advanced traveler information services. Some services collect data to be used by other traveler information providers. Table 2 summarizes these.
<table>
<thead>
<tr>
<th>Technology</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Point (i.e., fixed location) data collection systems</td>
<td>• Passive, nonintrusive, and nonthreatening</td>
<td>• Requires additional infrastructure deployment</td>
</tr>
<tr>
<td></td>
<td>• Reasonably accurate for travel times and inferred speeds</td>
<td>• Must funnel processed information through public or private agency at a cost</td>
</tr>
<tr>
<td>Probe vehicle tracking</td>
<td>• Ubiquitous supply of probes</td>
<td>• Some concern for invasion of privacy</td>
</tr>
<tr>
<td></td>
<td>• More easily deployed in rural areas and areas not covered by ITS</td>
<td>• Requires additional infrastructure deployment</td>
</tr>
<tr>
<td></td>
<td>• Useful for incident detection in such areas</td>
<td>• Must funnel processed information through public or private agency at a cost</td>
</tr>
<tr>
<td>Commercial traveler information services</td>
<td>• Use a variety of data sources, including probe vehicles</td>
<td>• Sometimes paid by subscription</td>
</tr>
<tr>
<td></td>
<td>• Feeds data to navigation maps in near real time</td>
<td>• Encourages cell phone or mobile device use while driving</td>
</tr>
<tr>
<td></td>
<td>• Navigation maps show alternative routes</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Can direct information to subscriber via cell phone (voice or text) or social media</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Well trusted</td>
<td></td>
</tr>
<tr>
<td>Social media – situation reporting</td>
<td>• Expands number of eyes on the highway</td>
<td>• Encourages cell phone or mobile device use while driving</td>
</tr>
<tr>
<td></td>
<td>• Free for all users</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Increasingly used by traffic and emergency managers to inform travelers about incidents and emergencies</td>
<td></td>
</tr>
<tr>
<td>E-mail alerts</td>
<td>• Low cost</td>
<td>• Paid by subscription</td>
</tr>
<tr>
<td></td>
<td>• Highly customizable</td>
<td>• Not as effective for en route alerts</td>
</tr>
<tr>
<td>In-vehicle telematics (including personal navigation devices)</td>
<td>• Expanding market</td>
<td>• Paid by subscription</td>
</tr>
<tr>
<td></td>
<td>• Combines advantages of several techniques</td>
<td>• Demonstrated, but not widely deployed</td>
</tr>
<tr>
<td></td>
<td>• Great potential for growth beyond simple traveler information</td>
<td>• Marketing and software integration issues</td>
</tr>
</tbody>
</table>

There is a great deal of potential benefit that can be derived from using third-party data services (e.g., real-time travel times on DMS, website traffic information, conducting historical analyses, etc.). A number of commercial traffic ISPs provide services to both individual travelers and/or agencies as follows:¹²

- Satellite radio provides traffic data in many metropolitan areas.
- A firm provides navigation data to in-vehicle devices in a number of areas.
- A probe vehicle tracking firm provides incident data.
A firm provides real-time, historical, and predictive traffic information for many U.S. cities.

A firm provides traffic flow data, incident data, and construction data in a number of areas.


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**Road Weather Management**

Traffic operations understandably deteriorate during inclement weather conditions. Automation of data collection of such conditions enables facility managers to respond to adverse conditions in a more timely and efficient manner.

As noted in Module 3, a road weather management (RWM) system (formerly called road weather information systems, RWIS, and also weather responsive transportation management systems, WRTM) consists of a set of sensors, or environmental sensor stations (ESS), that can detect and report a number of environmental measures that affect roadway operations, such as air and roadway surface temperature, wind direction and speed, the presence of falling or suspended particulates, and fuel emissions (technically not road weather information, but in the family).

RWM strategies include advisory applications that provide warning and other information to travelers, control strategies to regulate or optimize the transportation system, and treatment strategies to ensure that facilities are clear of obstructions. For these purposes, there is a need for supporting technologies, including weather surveillance, monitoring and prediction; information dissemination; and, decision support, control and treatment to improve safety, mobility, and productivity of the transportation system.13

Figure 5 presents a framework of RWM.14
A successful RWM program requires both prevailing and predicted weather and traffic information thus the data required to derive this information needs to be collected from multiple sources. A FHWA study on integrating weather in TMC operations provides assistance on identifying and integrating the required data in TMC operations. As part of the study, a self-evaluation and planning guide was developed to help traffic management centers evaluate their weather integration needs and develop appropriate implementation strategies. The guide’s aim is to assist the TMCs in identifying their weather conditions, weather impacts, current level of weather integration in the TMC, and the needs for enhanced integration.

Integrating weather information into TMC operations allows the development and use of decision support to better manage the traffic under adverse conditions, dispatch maintenance crews, and respond appropriately and in a timely manner to weather-induced problems. Decision support built on integrated weather and traffic information allows more proactive rather than reactive management.

Transportation agencies should ensure that travelers receive timely, accurate, and relevant weather and transportation system information. These agencies disseminate messages on precipitation, visibility, wind, and extreme weather events to travelers using DMS, HAR, websites, 5-1-1 traveler information weather systems, and other methods. The FHWA RWMP conducted a study that evaluated the current state of the practice in communicating weather-related traffic advisory and control information to the public, and recommended ways to improve those practices. The study produced a set of guidelines for communicating road weather information that meets the needs of travelers under different conditions and delivered in an understandable, useful, and effective manner.

Perhaps the most common use of RWM is in cold climates and/or mountainous regions where snow and ice are commonplace. Maintenance operators use the data from strategically placed ESS units to determine the optimal time to deploy dispensing trucks and/or snow plows and to determine the best treatment strategy—for example, whether to use brine, salt, or sand. This enables maintenance operators to avoid premature or incorrect deployments, thus saving valuable materials and minimizing vehicle-operating-cycle times.

Maintenance staffs increasingly use fleet management systems to locate their vehicles, including where they have and have not yet plowed. In many regions, weather conditions can vary considerably from place to place. RWM may be used to help prioritize where to send equipment. This is all helpful to traffic operations because it makes the mitigation actions more efficient, maintaining traffic flow in as orderly a fashion as possible under the circumstances. Winter maintenance activities are also being addressed in TMC concepts of operation and functional requirements in these regions.

RWM technologies are also used to detect conditions that may be hazards, such as high winds or flooding, and impact roadway operations. Sensor systems are used to detect other conditions that cause reduced visibility, such as fog, smoke, blowing dust or sand, and blizzard (white-out) conditions on roadways. Wind-speed sensors on some roadways and on bridges alert TMCs when they should consider issuing travel advisories for trucks and other large vehicles and, when winds are particularly high, these sensors may indicate the need to close bridges to all traffic.

FHWA Best Practices for Road Weather Information Systems Version 2.0 gives a number of examples as follows:17

- Sections of I-75 in Tennessee are prone to foggy conditions that have led to major multivehicle crashes. The Tennessee DOT has installed ESS units in the fog-prone areas. Transportation and public safety officials are notified when visibility degrades. The TMC has standard operating procedures (SOPs) that are triggered by the deteriorating conditions, resulting in mitigation actions ranging from activating DMS to alerting travelers of the hazard to closing the highway in the most severe conditions. Similar actions have been taken in Florida as a result of several major smoke/fog-related crashes.

- Washington State DOT employs RWM as part of a system to monitor conditions on Snoqualmie Pass, where winter road closures due to snow and snow-related visibility are common in winter.

- The Seaside Flood Warning Detection System was installed on Highway No. 101 in Oregon when severe winter flooding occurs. District maintenance staff previously did not have advanced warning of an impending flood situation, so motorists experienced standing water on the roadside without any prior warning. This project provides advanced warning to the public and reduces the

• Arizona has a severe blowing dust problem, so the DOT installed the Arizona Dust Warning System to alert travelers (see http://ops.fhwa.dot.gov/weather/best_practices/casestudies/003.pdf).

ESS units can be used in areas prone to high winds as a tool to help law enforcement decide when to close, and later reopen, bridges. An example from northeast Florida follows.
In northeast Florida, the North Florida Transportation Planning Organization (TPO) financed a project to install 22 ESS units on all major bridges in the region. These report primarily wind speed and direction via a National Oceanographic and Atmospheric Administration (NOAA) satellite that down-feeds to a vendor (Microcom Design), thence to the TMC in Jacksonville. TMC operators share the data with the Florida Highway Patrol (FHP) Joint Regional Communications (i.e., dispatch) Center (JRCC), in which a TMC satellite workstation is co-located, and to the four coastal county EOCs, who make the actual decisions to close and open bridges. The purpose of all this is three-fold:

- The sensors tell TMC operators when they should begin issuing warnings and alerts using the various ATIS media, thus alerting travelers to be aware of high winds, and possibly foresee bridge closures and take evasive action. This includes a direct feed to the media to enable them to broadcast the alert for high winds on a more localized basis.

- Local law enforcement officers, assisted by Florida Highway Patrol (FHP) Troopers if needed, are responsible for deciding to close bridges when wind speeds reach or exceed 40 mph. Without the ESS data, officers have to station themselves on the bridge and use hand-held wind gauges. This is an inefficient use of officers’ time during obviously serious conditions. Having the data enables the EOCs to dispatch them when conditions actually near the threshold.

- Similarly, the officers are relieved to perform other emergency duties as winds subside, and are alerted to improved conditions enabling them to open the bridge sooner.

- Standard operating procedures are for at least one unit to station itself at each end of the bridge when closed and one officer stationed at the crest of the bridge to monitor wind speed. That typically means at least three officers/units per closure. With 15 bridges in the coastal area, that means at least 45 officers can be tied up in bridge duty. It is hoped that soon the sensors can be relied upon to replace the third officer, allowing him/her to work on other emergency duties.

All of this enhances traffic operations during bad weather conditions, as well as helping the local law enforcement (and sometimes supporting FHP) to use their assets more efficiently.

Information in this example provided by Peter Vega, FDOT ITS Engineer.
Additionally, a number of DOTs subscribe to commercial weather forecasting companies that provide timely, location-specific forecasts that are reputedly better than the National Weather Service. This is possible because these companies draw their data from multiple sources, including the Weather Service, and fuse the results. At least one such company even has its own regionally located professional forecasters who are available for real-time consultation by clients.

Incident Management

The introduction to this module indicated that nonrecurring congestion accounts for about 50 percent of all congestion. Traffic incident management (TIM) is a structured, programmatic approach to reduce the impact of highway incidents on transportation system reliability and safety. Incidents include any unplanned event that affects traffic operations, ranging from flat tires or spilled loads to injury accidents or hazardous material spills. These incidents can impact the highway for minutes, hours, or days, and the time it takes the system to recover to normal operating conditions can be as much as five times the duration of the actual incident duration.

TIM has become an extremely important national program. Some years ago an interdisciplinary group formed the National Traffic Incident Management Coalition (NTIMC) (see http://ntimc.transportation.org/Pages/default.aspx) to focus a broad array of agencies and associations on TIM. The key accomplishment of NTIMC was the creation of a National Unified Goal (NUG) for TIM, which has been formally endorsed by 20 national agencies, organizations, and associations. The NUG’s three primary objectives are:

- Responder safety
- Safe, quick clearance
- Prompt, reliable, interoperable communications

Accompanying the goals are 18 strategies that TIM agencies are advised to adopt. The full list can be found at the NTIMC website on the NUG tab on the left.

FHWA has a TIM Program that sponsors a number of information exchange and training programs. This information can be accessed at www.ops.fhwa.dot.gov/eto_tim_pse/index.htm.

Another excellent TIM training tool was developed by the I-95 Corridor Coalition. The I-95 Corridor Coalition (see www.i95coalition.net/) has developed a comprehensive, computer-based training program for first responders. The TIM Core Competencies Training Module focuses on applying the I-95 Corridor Coalition’s quick clearance principles to highway traffic incidents. This approximately hour-long course covers basic scene safety and traffic management core competencies through a series of instructional
videos followed by quizzes, and can be used as standalone training for anyone with access to the Internet. (See www.i95vim.com/).

**Interagency, Multijurisdictional Traffic Incident Management Teams**

Many regions have found it useful to form an interagency, multijurisdictional TIM team. The team can operate as a unit to create TIM plans and concepts of operations that identify stakeholders and their respective roles and responsibilities in incident management, and continue to function as a mechanism for practicing the 4-Cs, sharing new techniques, cross-training, and conducting post-incident assessments through regular, on-going meetings, perhaps monthly or bimonthly. The members of the TIM team can, and generally should to the extent practical, represent all of the stakeholders listed in Figure 6.18

**Figure 6. Traffic Incident Management Stakeholders**

<table>
<thead>
<tr>
<th>Category</th>
<th>Stakeholder</th>
</tr>
</thead>
<tbody>
<tr>
<td>Federal Agencies</td>
<td>Federal Highway Administration (FHWA)</td>
</tr>
<tr>
<td></td>
<td>Federal Emergency Management Agency (FEMA)</td>
</tr>
<tr>
<td></td>
<td>Federal Transit Administration (FTA)</td>
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<tr>
<td></td>
<td>Federal Motor Carrier Safety Administration (FMCSA)</td>
</tr>
<tr>
<td></td>
<td>National Highway and Traffic Safety Administration (NHTSA) EMS Office</td>
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<tr>
<td></td>
<td>U.S. Fire Administration</td>
</tr>
<tr>
<td></td>
<td>Department of Defense (DOD)</td>
</tr>
<tr>
<td>State Agencies</td>
<td>State DOT (and neighboring states in certain regions), including at least:</td>
</tr>
<tr>
<td></td>
<td>• Traffic Engineering/Operations Office and ITS Sections of DOT</td>
</tr>
<tr>
<td></td>
<td>• Planning Office</td>
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<tr>
<td></td>
<td>• Maintenance Office</td>
</tr>
<tr>
<td></td>
<td>• Safety Office</td>
</tr>
<tr>
<td></td>
<td>• Motor Carrier Compliance Office</td>
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<tr>
<td></td>
<td>State Police or Patrol</td>
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<td></td>
<td>Department of Law Enforcement</td>
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<td></td>
<td>Department of Environmental Protection (DEP)</td>
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<tr>
<td></td>
<td>Division of Emergency Management (DEM)</td>
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<tr>
<td></td>
<td>Law Enforcement Communication/Dispatch Centers</td>
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<td></td>
<td>State Emergency Operation Center (SEOC)</td>
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<tr>
<td></td>
<td>Regional organizations</td>
</tr>
<tr>
<td>Local Agencies</td>
<td>Law enforcement (police and sheriffs)</td>
</tr>
<tr>
<td></td>
<td>Fire rescue</td>
</tr>
<tr>
<td></td>
<td>Emergency medical services (EMS)</td>
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<td></td>
<td>Metropolitan Planning Organizations (MPOs)</td>
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<tr>
<td></td>
<td>Medical Examiner/Coroner</td>
</tr>
<tr>
<td></td>
<td>City and county public works and traffic engineering</td>
</tr>
<tr>
<td></td>
<td>Emergency Operation Centers (EOCs)</td>
</tr>
<tr>
<td></td>
<td>County 9-1-1 Public Safety Answering Points (PSAPs)</td>
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<tr>
<td></td>
<td>Transit agencies</td>
</tr>
<tr>
<td>Authorities</td>
<td>Expressway Authorities</td>
</tr>
<tr>
<td>Category</td>
<td>Stakeholder</td>
</tr>
<tr>
<td>--------------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Transportation Authorities</td>
<td></td>
</tr>
<tr>
<td>Regional Operating Organization</td>
<td></td>
</tr>
<tr>
<td>Private Partners</td>
<td>Towing and recovery operators</td>
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<tr>
<td></td>
<td>HazMat contractors</td>
</tr>
<tr>
<td></td>
<td>Insurance industry</td>
</tr>
<tr>
<td></td>
<td>Information Service Providers (ISPs)</td>
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<tr>
<td></td>
<td>Traffic media</td>
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<tr>
<td>Associations</td>
<td>Professional Wrecker Associations</td>
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<tr>
<td></td>
<td>Technical societies (ITS Chapters, State Districts/Sections, ITE)</td>
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<tr>
<td></td>
<td>American Automobile Association (AAA)</td>
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<tr>
<td></td>
<td>Community Traffic Safety Teams (CTSTs) if they exist</td>
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<tr>
<td></td>
<td>Chambers of Commerce</td>
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<tr>
<td></td>
<td>Associations of Cities, Counties, Sheriffs, Police, EMS, etc.</td>
</tr>
<tr>
<td>Other</td>
<td>&quot;Better Transportation&quot; Organizations</td>
</tr>
<tr>
<td></td>
<td>National TIM Coalition and National TIM Network</td>
</tr>
<tr>
<td></td>
<td>Citizens’ groups</td>
</tr>
</tbody>
</table>

While ideally most of these stakeholders would be somehow represented at least at some stages of team formation, there should be a core group that participates regularly in the continuing activities of the team. Usually this includes the state DOT and district personnel responsible for managing the TIM program, maintenance, and traffic operations; local transportation counterparts; state and local law enforcement; fire/rescue; emergency medical services (EMS); safety service patrol provider; and towing service representatives. Other members would participate as needed by circumstances.

Some states have statewide or regional TIM programs, such as the Traffic Incident Management Enhancement (TIME) program in Wisconsin, to provide broad-based and standardized training, and information sharing. Effective TIM program strategies include promoting the adoption of an open roads philosophy in which the key players agree to adopt an open roads policy (ORP) that sets a goal to clear the roadway and open the lanes to traffic as quickly as possible. Several states, notably Florida, Georgia, and Washington, have statewide ORPs that fix a time on that goal—within 90 minutes of the arrival of the first responder (i.e., the first official, such as a police officer or safety service patrol operator, to respond to the scene to render assistance). These ORPs are signed as official policy by the state DOT and the state police/patrol. Some district or other regional DOTs and public safety agencies have expanded the execution of ORPs to the local level and have them signed by local police and fire rescue departments, and even the medical examiner’s office. The medical examiner’s office is important because its ORP gives responders the authority to remove fatal victims’ bodies from the roadway after certain conditions (including taking of digital photographs) are met, rather than waiting for the coroner to arrive and direct the removal. This makes roadway clearance much faster in these serious cases.
Safety Service Operations and Towing Services

Safety service patrols (SSPs) are an important element of operations programs across the country. Although these service patrols are not ITS per se, transportation agencies are using ITS-type systems to help them improve the efficiency of these operations. SSPs have evolved over the years. In the early days of their deployment, they usually were purely service patrols, providing limited roadside assistance to vehicles having difficulty, such as changing flat tires, providing a small amount of gasoline, jumping batteries, and the like. The concept was to help stalled vehicles get on their way and cease being a hazard to traffic. TIM managers began to realize this resource was not being used to the fullest. They began to expand the scope of their operations, and thus services.

Vehicles were better equipped and operators better trained to provide more proactive services for traffic management. In addition to the earlier services, they now can push or pull vehicles from the roadway (if permitted by state law), secure and clean up minor vehicle fluid spills, set up maintenance of traffic (MOT) controls (e.g., cones and flares), perform minor repairs to stalled vehicles, provide information to travelers via truck-mounted PCMSs, provide protection of the back of the queue, and even assist injured passengers.

Minute Man program in Chicago, IL, operates recovery and towing services for heavy vehicles on the city’s many freeways. These units also were instrumental in helping the Utah DOT during the 2002 Winter Olympic Games in Salt Lake City.

Whatever their mission and capabilities, SSP operators’ top priorities are ensuring the safety of themselves and impacted motorists, and then clearing the roadway. SSP operators are first responders and are increasingly appreciated by an initially skeptical law enforcement community.

Towing is not a component of ITS per se, but it is a vital service for incident clearance. There are several major issues associated with towing and recovery related to traffic operations. Effective TIM programs should involve the towing industry and work cooperatively to address issues associated with equipment needs, rotational and contract procedures, and billing practices. Several state towing associations have tried to get towing certified in their states, or at least have a required training and qualification program, that would ensure proper training and appropriate equipment. These efforts have not been successful for political reasons. TIM teams can help by expanding the pool of agencies supporting such changes.

The Role of ITS in Traffic Incident Management

ITS devices play an important role in managing traffic and improving scene safety during highway traffic incidents. Incidents can be discussed by phases, which occur in sequence with varying duration and complexity based on the specific incident. Although phases can overlap, the general order of traffic incident management phases is:
• Detection—The point at which an incident has occurred and is detected or reported to the transportation or emergency response agency.
• Verification—Confirmation of the incident and associated information, such as type of incident and location.
• Response—Initiated when an agency dispatches resources to an incident.
• Clearance—Includes the removal of victims, vehicles, debris, and responders.
• Recovery—The point at which traffic operations return to a normal state.

Figure 7 shows the application of ITS devices, TMC, and safety service patrols to the different stages of traffic incident management.

### Figure 7. Roles and Responsibilities in Stages of Incident Management

<table>
<thead>
<tr>
<th>Incident Stage</th>
<th>Roles and Responsibilities</th>
<th>ITS Devices</th>
<th>TMC</th>
<th>SSP</th>
</tr>
</thead>
</table>
| Detection      | • Sensors detect traffic perturbations  
• CCTV captures images  
• In-vehicle emergency services, such as OnStar® | • Some TMC software uses incident detection algorithms  
• Operators observe incident  
• Operators exchange notification with other sources (e.g., PSAP, police, etc.) | • Operators observe incident  
• Operators exchange notification with other dispatchers  
• Operators dispatch SSP and notifies other official dispatchers | • Roving patrol sees incident |
| Verification   | • CCTV captures images | • Operators observe incident  
• Operators exchange notification with other dispatchers  
• Operators dispatch SSP and notifies other official dispatchers | | • Unit(s) dispatched to the scene and report verification to TMC |
| Response       | • DMS display alerts  
• Ramp metering rate adjusted | • Operators and TIM specialists begin to manage the incident  
• Full array of ATIS deployed | | • If first responder, render immediate aid  
• Assist in scene protection  
• Protect the back of the queue(s) |
| Roadway Clearance | • Continue response activities  
• Cameras focused to optimize surveillance | • Continue managing the incident, calling in resources as needed  
• Continue ATIS | | • If first responder, try to clear the roadway  
• Otherwise, assist other responders  
• Protect the back of the queue(s) |
<table>
<thead>
<tr>
<th>Incident Stage</th>
<th>ITS Devices</th>
<th>Roles and Responsibilities</th>
<th>SSP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incident Scene</td>
<td>• Continue clearance activities</td>
<td>• Continue managing the incident, calling in</td>
<td>• Be watchful for secondary incidents</td>
</tr>
<tr>
<td>Clearance</td>
<td></td>
<td>resources as needed</td>
<td>• Protect the back of the queue(s) until</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>dissipated</td>
</tr>
<tr>
<td>Recovery</td>
<td>• Continue clearance activities</td>
<td>• Continue managing the incident, watchful for</td>
<td>• Be watchful for secondary incidents</td>
</tr>
<tr>
<td></td>
<td>• Cameras focused to observe the queue(s)</td>
<td>secondary incidents</td>
<td>• Protect the back of the queue(s) until</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Extend upstream alerts as necessary</td>
<td>dissipated</td>
</tr>
<tr>
<td>After Action</td>
<td>• Data and recorded images used for analysis</td>
<td>• Participate in after-action review</td>
<td>• If a major incident, participate</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Update response plans as needed</td>
<td>personally in after-action review</td>
</tr>
</tbody>
</table>

Technology for automated detection of incidents is being developed, and the European Union is attempting to impose a rule that by 2015 all new road vehicles sold in Europe must have this technology. The OnStar-like device called eCar can be used to notify, either manually or automatically, the nearest PSAP in case of a crash. For more information, see www.lexology.com/library/detail.aspx?g=093680bc-40c3-4190-8698-ba26e61d42b3.

**Emergency Transportation Operations**

Events that are more serious in nature and require more extensive response and resources are considered emergencies. These include significant natural events, such as hurricanes, flooding, or wildfires; events that impact transportation infrastructure, like a bridge collapse; or even events such as terrorist acts. Emergency transportation operations (ETOs) generally require a more extensive response to manage these events. This section addresses the characteristics and responses to emergency events when little or no advance notice is provided, as well as for events, such as a hurricane, that provide more advanced notice but with largely unpredictable impacts.

The scope or severity of incidents can occur as part of a continuum along which the responders and managers change or expand. Figure 8 illustrates this continuum. As shown, the core ground-level responders are generally the same throughout—law enforcement, fire rescue, EMS, towers, DOT maintenance, and SSPs. The command and support agencies, however, change and new players, such as emergency managers, and state and even Federal agencies play a role as the severity increases. Figure 9 shows the continuum of preparedness and response as the incident evolves from a minor event with a predominately local response to a more complex event that requires response and coordination among local, state, and Federal agencies.
Figure 8. Complexity of Emergency Transportation Operations
Although the term incident correctly applies to all these levels as stated earlier, the involved agencies and extent of response vary, or expand, from the left side of these graphics to the right. This section deals with the national, state, and regional portions of Figure 9.

At the national level, FHWA has brought emergency management to the forefront through its ETO program (see www.ops.fhwa.dot.gov/eto_tim_pse/index.htm) and the primary handbook for ETO is an NCHRP document. A key tenant is that transportation officials need to be more proactive in participating with emergency managers in the development of emergency operations plans (EOPs), which are the primary tools used for managing emergencies. This ePrimer does not delve further into the institutional bases for emergency management; instead refer to A Guide to Emergency Response Planning at State Transportation Agencies. This reference explains the escalation of minor incidents into major ones. A comprehensive overview of emergency operations
can also be found in the National Incident Management System (NIMS) (see www.fema.gov/national-incident-management-system). All incidents, even minor traffic crashes, are subject to NIMS, which is adapted to reflect the complexity of an incident.

**Emergency Response**

Most emergencies are characterized as short or no-warning emergencies, such as a sudden major storm or other severe weather event, airplane or train crash in occupied areas, earthquake, flash flood, or terrorist threat. The less frequent, but usually more devastating events are with-warning emergencies, such as a hurricane, tsunami, major river flood, or major spreading fire. The response to these levels of emergencies can be very different.

The two aspects of all of these emergencies that are of concern here are the effect of the emergency on the transportation system and the role of the transportation system in the response. The latter is more easily dealt with and is covered first.

When the transportation system itself is not materially impacted, by a pandemic for example, the transportation system becomes a set of tools for responding agencies. Highways, buses, trains, and even ships and airplanes become a means of avoiding or evading the emergency. As far as traffic operations, and ITS in particular, are concerned, the following are actions that transportation managers can take to assist emergency managers:

- Use DMS, PCMS, HAR, and motorist information systems to inform the public of routing, emergency shelter locations, evacuation routes (more on this later), etc. In actual emergencies, media (including social media) feeds will come from the incident command post, but TMCs should continue to provide traffic information to the media to support the emergency managers.
- Feed video images from CCTV to the EOC and intelligence fusion center (FC), if available.
- Use SSPs to help control traffic and assist public safety agencies as needed.

When the transportation system is directly impacted, it is less effective in serving the emergency and its managers. This is when preplanning and preparation within the transportation agency are so important. For example, the Florida DOT and several seaside urban areas of the state stockpile traffic signals and generators in order to be able to replace downed signals and to control restored ones in the absence of commercial power. PCMS can temporarily replace downed DMS. Portable HAR units can be used for a similar purpose, but these have to be supplemented by fixed signage informing travelers of the HAR station.

It was mentioned earlier that there is a need for interagency communications among TMCs, EOCs, and FCs. Unfortunately, this is not always fully achieved because transportation agencies, emergency managers, and security people have different responsibilities and authorities that may seem at odds without structured coordination.
and open, nonproprietary communication protocols. The open interoperability promised by the NTCIP standards has not been fully achieved for various reasons. The case can certainly be made for better interagency exercising of the 4-Cs, particularly communication.

Equal arguments can be made for including law enforcement dispatch centers (LEDCs) and 9-1-1 Centers (PSAPs) in this mix. These groups could communicate by telephone and the Internet, but direct electronic linkages for data and information sharing would be better. In Florida, a number of TMCs and LEDCs are actually co-located. In Kentucky, a TMC and a regional FC are co-located. In northern Virginia, a major regional TMC and PSAP are co-located.

**Evacuation**

Extreme emergencies, such as those mentioned earlier, might require evacuation of residents and visitors, sometimes from large areas and across multiple jurisdictions. Because of the nature of these, a region can never be fully prepared to meet all of the challenges, both physical and institutional, that arise. From a traffic perspective, any evacuation is going to severely threaten the capacity of the transportation system to handle it. Most of the actions agencies can take to mitigate the negative impact of an evacuation and help keep traffic flowing require changes in the physical infrastructure or the use of mass-passenger modes. Here are some examples:

- In urban areas, entire city streets can be shifted to one-way operations to move larger numbers of vehicle away from harm. ITS plays a role here by minimizing the conflicting guidance that traffic signals might indicate (e.g., not showing green displays in the wrong direction). These require large numbers of police or military officials to control traffic.

- Contraflow lanes, as noted earlier, can be used effectively to shift the inbound capacity for outbound evacuating traffic, as shown in the photo on the right of traffic evacuation before Hurricane Rita in 2005 in Houston, TX. Contraflow requires a great deal of planning, physical preparation (such as the cross-over lanes), large teams of officials to implement the plan, and time to deploy and later restore the area to normal. A number of states on the Gulf of Mexico and Southeast Atlantic Coast, even as far north as Baltimore, MD, have contraflow plans, but most would use these plans only as a last resort. ITS plays a role in using DMS to reinforce contraflow guidance, CCTV to monitor traffic, and ATIS to inform travelers, although, most public information is generated by the incident command center. Most contraflow lanes are in rural areas without ITS; however, the increasing use of probe vehicles can give transportation and emergency managers data on travel times.

Source: Courtesy Houston TranStar.
Also as a result of Hurricane Katrina, Hurricane Rita and other storms, the Texas DOT began implementing a different approach to adding capacity to primarily rural highways. Designated as “evaculanes,” shoulders on selected highways are signed and marked as shown in the photo, and, in some cases, intersections were reconfigured to accommodate these lanes.

One challenge to emergency managers is unnecessary evacuations. Following Hurricane Rita, TranStar spokeswoman Dinah Martinez said at a town hall meeting, “During the disastrous Hurricane Rita exodus, part of the problem was that for every five people who evacuated, four of them probably didn’t need to.” ATIS is another tool for discouraging people from unnecessarily evacuating.

The opposite of evacuations is the confinement of people within an area, for example to contain a potential pandemic. In this case, CCTV can show where vehicles are traveling when they should not be, and ATIS can augment public safety notices.

**Security**

Security threats are not that different from natural emergencies, except that they can cover a broader range of impacts, such as cyber/information technology (IT) attacks; chemical, biological, radiological, nuclear, and explosive (CBRNE) threats; terrorist actions; etc. Much of the same information provided above for emergency services apply to security threats, particularly the comments regarding threats to the transportation network itself (like a bomb in a tunnel or on a bridge) or use of the transportation network to respond to the threat (such as the closure of all access to Manhattan Island following the 9/11 attack on the Twin Towers).

This represents the most appropriate argument for linking TMCs, EOCs, FC, etc., as noted earlier. Emergency and security responders must know the status of routes to and from the threatened area, both for responders and rescue assets.

**Planned Special Events**

FHWA defines a planned special event (PSE) as “a public activity with a scheduled time, location, and duration that may impact the normal operation of the surface transportation system due to increased travel demand and/or reduced capacity attributed to event staging.” (Source: see above citation.) Figure 9 refers to them as planned activities. They include sporting events, concerts, festivals, conventions, etc. occurring at permanent multiuse venues (arenas, stadiums, racetracks, fairgrounds, amphitheaters, convention centers, etc.). They also include less frequent public events such as parades, fireworks displays, bicycle races, sporting games, motorcycle rallies, seasonal festivals, and milestone celebrations at temporary venues, such as a Presidential inauguration at the nation’s capitol.

The operational characteristics of PSEs create the following five event categories:
• Unique or recurring event at a permanent venue, such as sporting events.
• Continuous event, such as a major theme park.
• Street-use event, such as a parade.
• Regional/multi-venue event, such as the Olympics.
• Rural event, such as Woodstock.

These are also incidents of a sort and often require massive preparation and response; however, these activities are different from the other incident types discussed previously and warrant different participants and resources. The greatest difference is that there is a whole new set of stakeholders involved that are not involved in most other types of incidents and emergencies, such as:

• Event sponsors
• Event organizers
• Visitors’ bureaus
• Venue managers and operations staffs
• Event planners and consultants
• Caterers
• Commercial transportation (i.e., coach) and limousine companies
• Social (as opposed to public safety) media
• Security companies
• Long- and short-haul transportation companies
• Elected officials

PSEs can significantly impact travel safety, mobility, and travel-time reliability across all surface transportation modes and roadway facilities. Managing travel for PSEs involves operations planning, stakeholder coordination, and partnerships; developing a multiagency transportation management plan; raising awareness of general public and event patrons of potential travel impacts; and coordinating agency services and resource sharing.

The practice of managing travel for PSEs targets the following objectives:

• Establish innovative stakeholder partnerships that provide continuous exercise of the 4-Cs, and personnel and equipment resource sharing, including traffic operations, the TMC, SSP, etc.
• Adopt procedures and protocols to improve advance planning and day-of-event operations, including a comprehensive transportation plan, complete with incident response scenarios.
• Mitigate potential travel impacts, particularly using ATIS, to non-attendee road users and the community at large.
• Apply technologies, such as PCMSs, to minimize field personnel requirements, improve travel conditions monitoring, and reduce congestion.
• Influence the utility of all travel choices through transit and TDM initiatives and traveler information dissemination.
• Facilitate sound traffic-management-team organization and communication on the day of the event.
• Integrate evaluation results into regional planning activities for future PSEs, including updating TMC, TIM, and/or emergency operations plans.

The goals of managing travel for PSEs are as follows (with transportation applications added):

• Achieving predictability—Applying ICMM-type processes.
• Ensuring safety—Active TIM teams and SSP.
• Maximizing efficiency—Using the entire ITS toolkit.
• Meeting public and event patron expectations—Maximizing the efficiency of traffic operations.

An excellent reference for additional information on PSEs can be found in Managing Travel for Planned Special Events.25

Work Zones
By their very nature, work zones have a negative impact on traffic operations. The purpose of using ITS and other techniques is to minimize the negative impacts and keep traffic moving through the zone as efficiently and safely as possible for both the travelers and workers. This is especially important for nighttime work, which is becoming increasingly common on highways.

ITS technologies provide many opportunities for monitoring and managing work zone operations. Early applications of ITS were used to measure spot speeds in work zones, and more recently to support speed enforcement through the work zones. In recent years, however, agencies have been rapidly turning to the capabilities of new technologies to collect data that accurately reflects travel conditions through work zones, and provides real-time monitoring of conditions in the work zones. ITS technology can be applied in work zones for:

• Traffic monitoring and management
• Providing traveler information
• Incident management
• Enhancing safety of both the road user and worker
• Increasing capacity
• Enforcement
• Tracking and evaluation of contract incentives/disincentives (performance-based contracting)
• Work zone planning
Many ITS applications in work zones serve a combination of the above purposes. The reference has case studies, deployment examples, and other resources.

Some of the applications of ITS in or in advance of work zones are summarized as follows:

- Detect when queues form to alert drivers to upcoming slower or stopped traffic so they can stop in time or take an alternate route.
- Warn motorists that trucks are entering or exiting the travel lanes from a work area and may be moving at a slower speed than traffic flow.
- Provide dynamic merging to encourage drivers to use both lanes to the merge point in heavy traffic in order to reduce queue length or to merge early in lighter traffic to reduce conflicts.
- Alert motorists to travel times/delays in work zones so they can either choose an alternate route on their own or have the system recommend/encourage diversion in cases of significant delays.
- Automate enforcement in work zones.

Data and information can be collected through the use of Bluetooth, cameras, third-party data, coordinating with the TMC, etc.

A growing number of state and local agencies are developing smart work zones, which employ a combination of data sources that measure travel times through the work zones, to support a range of applications. Real-time capabilities are being used to support a wide array of innovative applications that include active management of work zones based on observed traffic conditions. Agencies are using these capabilities to extend work hours when acceptable travel times are maintained, curtail work when travel times exceed certain thresholds, and notify managers when travel speeds are dangerously high and police presence may be warranted.

The use of ITS in work zones is not limited to urban areas. In fact, temporary ITS devices, such as PCMS, HAR, and trailer-mounted cameras and sensors, can easily be deployed in a rural work zone where permanent ITS does not exist. Several commercial companies provide a service that includes these devices, which communicate their data and images to a central location where they are monitored. If issues arise, operators at that location can contact law enforcement and/or transportation officials to respond to the issue.

Most work zones are relatively short-term in nature, but some are quite lengthy. Early deployment of ITS can be effective in supporting diversions, managing incidents, and mitigating capacity reductions. Two examples are cited: 1) the reconstruction of I-95 in Palm Beach County, FL, and its interim traffic management system (ITMS), which is an example of using ITS in a long-term work zone (first example below) and 2) the full closure of I-64 in St. Louis, MO (second example below).
Example of ITS in a Long-Term Work Zone – Interim Traffic Management System on I-95 in Palm Beach County, Florida

When the Florida DOT (FDOT) decided to widen I-95 in Palm Beach County over the period beginning in 2001 and (currently planned) ending in 2013, including constructing two major new interchanges, they decided that extraordinary efforts were needed to deal with the expected disruptions to traffic operations on this major north-south highway and abutting corridor—by far the most heavily travelled route in the county, including Florida’s Turnpike to the west. During the roadway construction period, it was expected that congestion and delays would increase substantially from lane closures and other construction-related activities. It is not uncommon to experience increased incidents within major construction projects as well, so an Interim Traffic Management System (ITMS) was envisioned as a way to mitigate the impacts of freeway incidents during the construction period.

To help manage the anticipated continuing impacts of construction, FDOT implemented the ITMS to provide the public with real-time information on current traffic conditions along I-95. The ITMS was connected with the highway safety service patrol program (Road Rangers), the SmartTraveler® ATIS program, the Palm Beach County County-wide Traffic Signal Control System (which has several cameras strategically positioned to view arterial highways and several interchanges with I-95), the I-95 Public Information Office (PIO), the FHP, and the Palm Beach County TIM Team.

The ITMS project implemented and managed portable field devices, including CCTV, DMSs, and radar vehicle detection all mounted on Smart Zone units, all monitored and controlled through a centralized computer system, with connections to local agency partners. For most of the project, the ITMS was controlled from a fully equipped, but interim, Traffic Management Office (TMO). The central software used during this period was the Management Information System for Transportation (MIST®).

For eight years this interim system operated a fully functional ITS deployment, albeit with temporary devices. Its success was not quantified due to budgetary considerations, but it was an uncontested success in accomplishing its goals.

This example was adapted with liberal verbatim language from Wallace, C.E., “Palm Beach County Interim Traffic Management System (ITMS), Lessons Learned in the ITMS Deployment and Operation, Final Evaluation Report,” Prepared for the Florida DOT by Telvent, July 2011.
Example of ITS in a Full Freeway Closure – Missouri DOT Rehabilitation Project

In March 2007, the Missouri DOT (MoDOT) began a two-and-a-half year project to rebuild the I-64 corridor through St. Louis. The project involved repairing or rebuilding 10 miles of roadway and 30 bridges. To plan for this large-scale project, MoDOT performed a work zone impacts analysis to determine the best method of doing the work with minimal disruption and inconvenience to the surrounding community. The results of the analysis led MoDOT to decide to fully close the highway (with the western half of the project closed for one year, followed by a one year closure of the eastern half) and to bid the project as design-build. MoDOT challenged the contractor to use regional modeling to develop the transportation management plan (TMP) and project design, and gave the contractor joint responsibility for handling the public outreach for the project.

The closure was expected to bring the largest traffic disruption that St. Louis had experienced in decades, and many, including the press, were doubtful that everything would go smoothly; however, MoDOT found that commutes during the closure went fairly smoothly, due to drivers adjusting their work hours and avoiding routes that were known to be problem spots, their carefully-developed strategies for signal timing on the primary diversion route (Highway 40), and due to MoDOT's ability to respond quickly to problem spots and incidents. The alternative routes devised by MoDOT and its experts worked spectacularly well. Public works departments in St. Louis County and affected municipalities synchronized traffic signals in an excellent manner. The project, originally anticipated to cost $535 million, finished $11 million under budget and several weeks ahead of schedule, with all lanes of I-64 reopening on December 7, 2009.

The involvement of MoDOT’s Gateway Guide TMC, a comprehensive ATIS and construction public information program (including a project website), deployment of the SSP on the arterial routes, and other ITS applications, along with the traffic signal timing strategies, were collectively the keys to success of this total freeway closure project.

This subsection was adapted with liberal verbatim language from http://ops.fhwa.dot.gov/wz/resources/final_rule/modotcasestudy.htm.
Performance Management

The need for performance measures (PMs) is widely recognized. PMs have been a topic of discussion for many years; however, only recently have ITS devices provided the data that are essential to supporting PMs and their importance in operations.

The current transportation authorization act, Moving Ahead for Progress in the 21st Century (MAP-21), created a new standard for performance- and outcome-based programs. MAP-21 created a national policy in support of performance management, which is stated as follows (see fact sheet at www.fhwa.dot.gov/map21/pm.cfm):

Performance management will transform the Federal-aid highway program and provide a means to the most efficient investment of Federal transportation funds by refocusing on national transportation goals, increasing the accountability and transparency of the Federal-aid highway program, and improving project decision-making. [§1203; 23 USC 150(a)]

All seven of the national goals identified in MAP-21 have some relation to ITS and traffic operations, some more directly than the others (i.e., safety, congestion reduction, and freight movement and economic viability).

At this writing, it is not known exactly what impact this will have directly on ITS. By December 2013, the USDOT is required to issue rules governing the mandated PMs and states have 1 year to implement these by setting targets for urban and rural areas. The Metropolitan Planning Organizations (MPOs) then have 180 days to establish their targets. The possible categories of PMs applicable to traffic operations are as follows, with possible traffic operations implications added by the author:

- Performance of the Interstate Highway System and the remainder of the National Highway System (NHS)—If this is viewed from the operational perspective, and not strictly physical condition (pavement condition is covered in another PM), then ITS will be very much involved.
- Fatalities and serious injuries—ITS and related TIM activities should play major roles here.
- Traffic congestion—ITS will be at the heart of this one.
- On-road mobile source emissions—Environmental sensors, referred to elsewhere in this module, will play a major role in this category as the data collection mechanism.
- Freight movement on the Interstate System—Commercial vehicle operations (CVO) is at the heart of this one.
Thus ITS could, and should, play a major role in the mandated PMs. Note that the USDOT may not expand this list of PMs (including the others not mentioned), but states could possibly expand the list.

The foregoing is not to suggest that performance management is important only because it is now federally mandated. The Federal government, the states, and local governments spend billions of dollars annually investing in the U.S. transportation system with a significant portion of the funds devoted to deploying, operating, and maintaining advanced transportation systems, or ITS. It is essential for all, including the traveling public and our economy, to ensure that these investments are prudent and effective. Performance management from the ITS industry’s perspective is important to:

- Ensure that the agency achieves its goals and objectives.
- Ensure that the systems deployed are cost effective.
- Ensure that managers and operators get feedback to let them know how effective their actions have been and give indications of needed changes to their plans.
- Ensure that the return on investment is positive in terms of road user benefits.
- Ensure that the performance measurements are consistent across the country.
- Ensure that the performance measurements are increasingly based on outcome.

As to the PMs themselves, according to FHWA, after a review of a number of proposed PMs, these four are being strongly considered at this time:27

- Travel-time reliability (buffer index)—The buffer index is the additional time that must be added to a trip to ensure that travelers, 95 percent of the time, will arrive at their destination at or before the intended time.
- Extent of congestion (spatial or also measurable by time)—Miles of roadway, within a predefined area and time period, for which average travel times are 30 percent longer than unconstrained travel times.
- Incident duration—The time elapsed from the notification of an incident until all evidence of the incident has been removed from the incident scene.
- Customer satisfaction—A qualitative measure of customers’ opinions related to the roadway management and operations services provided in a specified region.

The actual number of states that already have official ITS-related PMs is not known, but Florida does have one. In 2005, the Florida Transportation Commission (FTC), which oversees Florida DOT, issued three ITS output-related PMS:

- Annual 5-1-1 calls
- Annual Road Ranger (SSP) stops
- Miles managed by ITS
Florida DOT began reporting these in 2007 (for 2006). The FTC also mandated three outcome-related PMs that would take more time to prepare for and begin data collection. These PMs and the years Florida DOT began reporting them are as follows:

- Incident duration—2006 (for half a year)
- Travel-time reliability—2008
- Customer satisfaction—2007

These serve as a possible model for other states. For more information on Florida DOT’s ITS PMs, see [www.dot.state.fl.us/trafficoperations/ITS/Projects_Deploy/ITS_PM.shtml](http://www.dot.state.fl.us/trafficoperations/ITS/Projects_Deploy/ITS_PM.shtml). These PMs cover all state highways, both urban and rural.

The above notwithstanding, a synthesis of all official PMs can be found at [http://stats.mtkn.org/measures](http://stats.mtkn.org/measures); however, not very many ITS PMs are listed. An AASHTO (American Association of State Highway and Transportation Officials) Standing Committee on Performance Management (SCOPM) task force report does include several operational measures in its findings on national PMs:\(^{28}\)[http://scopm.transportation.org/Documents/SCOPM%20Task%20Force%20Findings%20on%20National%20Level%20Measures%20FINAL%20(11-9-2012).pdf](http://scopm.transportation.org/Documents/SCOPM%20Task%20Force%20Findings%20on%20National%20Level%20Measures%20FINAL%20(11-9-2012).pdf).

### The Role of the Private Sector in Traffic Management

The public sector has generally provided ITS services; however, the private sector is playing an increasing role in operations. This role is even more important for complex systems with advanced functions and demanding data requirements. In addition to the traditional role of the private sector as a consultant on individual projects, private sector companies are now hired as general consultants, in many cases providing staff located in the public agency offices to work on various ITS tasks. In addition, as described earlier, many agencies have outsourced the operations of their TMCs and even ITS device maintenance to private sector companies.

Private sector companies have provided the hardware and software required for ITS and, in many cases, have played the leading role in the innovations in these technologies. In addition, the increased needs for data collection, archiving, analysis, and reporting also provides an opportunity for the private sector to offer products and/or services in these areas. Some of these companies have used what can be referred to as crowdsourcing to collect and fuse data from multiple sources and sell the processed data to public agencies. Others provide data archiving, analytics, and visualization services. Private sector weather data are also important input to operations, as noted previously.

Private sector companies, generally under contracts to the public sector, have provided information to travelers using the traveler information phone system (5-1-1), websites, and other methods. These companies, normally referred to as information service
providers (ISPs), continuously interact with public agencies exchanging data and information about the transportation system. In some cases, the ISP has installed its own infrastructure detection and other devices and exchanged this information with the public agencies. The expectation is that the role of private sector companies will increase with the increased complexity of ITS and the emerging use of connected-vehicle technologies in ITS. Technology advancements are expected to increase the role of private companies in providing more accurate and reliable data at lower cost to the agency. Indeed, in several states, private companies operate the 5-1-1 system at no cost to the public sector, relying on advertising and sponsorship revenues to recover their investments.

On a larger scale, government agencies are increasingly turning to the private sector as a source not only of deployment, but also for financing through public-private partnership (PPP or P3) arrangements. In these cases, the agency might contract or enter into some other agreement with a private company or joint venture to finance, design, build, operate, and maintain (FDBOM) a new or major upgraded facility. The private sector receives its compensation through collection of tolls, or so-called availability payments, from the government over a long period of time. Since P3s tend to be major freeway (more likely toll) facilities, ITS is almost always involved, particularly for ETC. For more information on P3s, see www.fhwa.dot.gov/ipd/p3/index.htm.

Several industries, notably parking management and commercial vehicle operations (CVO), have almost exclusive private sector involvement, although the public has interest in both. Public parking systems employ many of the advanced techniques developed by the private sector, such as parking space availability systems and electronic fare collection (EFC), the latter of which is similar to ETC. The public sector partners with private trucking companies for automated processing of truck weights and inspections. The USDOT even has a major program called CVISN (Commercial Vehicle Information Systems and Networks) to standardize CVO/government integration nationally. These are covered in more detail in Modules 5 and 6, respectively.

Summary
This module is designed to instill a sense of passion for the importance of traffic operations. Highways and other modes are merely conveyances for vehicles, people, and cargo. How effectively the transportation system users maneuver through the system is—or should be—the primary business of transportation agencies and their partners. The priorities in this regard are the following:

- Safety—Of both the traveling public and those who service the system in any way.
- Efficiency—For people and goods to complete their trips in a timely and cost-effective manner.
• Environment—Minimize the use of fuel and other resources, while also minimizing pollutants.
• Security—Ensuring the welfare of transportation users and those affected by traffic.

Key tenets of this effort are interagency/multijurisdictional exercising of the 4-Cs (communication, cooperation, coordination, and consensus); focusing on operations and not simply equipment; and viewing transportation users as customers, placing their satisfaction first.

Probably the most significant technological development since ITS itself is the rapidly developing world of connected vehicles and infrastructure. Vehicles linked wirelessly to each other and to roadside devices will share data and help avoid vehicle-vehicle crashes and red-light running crashes, and provide many other incident-avoidance benefits. Autonomous operation of vehicles where computers control the vehicles, enabling collision-free, close proximity, high-speed operation also has the potential to significantly expand the capacity of highways. They will alert others to unseen dangers, like icy roadways or incidents in progress.

Just as vehicles may communicate with each other, so too may a TMC or roadside devices communicate with them. This will facilitate a traffic management strategy, known as dynamic traffic assignment (DTA). DTA allows the network to dynamically determine the optimal route (or in pre-trip mode) of travel and direct equipped vehicles to follow that route. Emergency services can be given priority in real-time to reach an incident scene quickly and efficiently. Vehicles on conflicting routes can be commanded to give way to the emergency vehicles.

Most of the technologies to accomplish this already exist and millions of dollars have already been spent in research and development in this country and abroad. In 1997, a demonstration of automated highways was conducted in San Diego, CA. Connected vehicles have been successfully demonstrated in numerous venues throughout this country, as illustrated in the TMC of the Future video. In fact, Walt Disney envisioned many of these types of advanced transportation systems—and then some—as early as 1958, as seen in his classic cartoon at www.snotr.com/video/750.

Meanwhile transportation agencies and providers can only continue to make the best with what they have, which was a primary factor in the initiation of ITS in the first place.

"Any sufficiently advanced technology is indistinguishable from magic." - Arthur C. Clarke
References

2 Note that the information in this graphic is from the work cited; however, the graphic itself was adapted from Wallace, C.E., J. O’Laughlin, and T. Smith, “Toolkit for Deploying TIM/QC Best Practices,” prepared for the I-95 Corridor Coalition, Telvent Farradyne, 2007, updated 2009, available at www.i95coalition.net/i95/Training/QuickClearanceWorkshop/tabid/188/Default.aspx
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Source: http://ops.fhwa.dot.gov/wz/its/index.htm

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