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Active Transportation and Demand Management (ATDM) Foundational Research

Analysis, Modeling, and Simulation (AMS) Concept of Operations (CONOPS)

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16. Abstract

As part of the Federal Highway Administration's (FHWA) Active Transportation and Demand Management (ATDM) Foundational Research, this ATDM Analysis, Modeling and Simulation (AMS) Concept of Operations (CONOPS) provides the description of the ATDM Analysis Modeling and Simulation (AMS) system that can be used to evaluate the benefits of dynamic management of a transportation system. In particular, the CONOPS Report identifies limitations of current AMS systems, changes required to enhance the system, and a justification of these changes. The report also identifies the AMS needs for a dynamic approach to traffic and demand management and the detailed description of the AMS system. Finally, the report also includes the description of four ATDM analysis packages for the purposes of developing detailed Analysis Plans.

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Preface/Acknowledgments

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Executive Summary

During the past several decades, traffic management and operations activities have been reactive in nature. In the recent past, however, the need for effective and more proactive transportation solutions to address mobility and environmental and safety issues as well as to meet the expectations of the transportation system user relative to trip reliability and choices has been recognized. Addressing these needs requires transportation organizations to conduct business in a new way, by proactively managing transportation systems and services to respond to real-time conditions while—at the same time—providing realistic choices for managing travel demand. *Active Transportation and Demand Management* (ATDM) is based on this concept.

ATDM is the dynamic management, control, and influence of travel demand, traffic demand, and traffic flow of transportation facilities. Under an ATDM approach, the transportation system is continuously monitored and, through the use of available tools and assets, traffic flow is managed and traveler behavior influenced in real time to achieve operational objectives. These objectives include preventing or delaying breakdown conditions, improving safety, reducing emissions, and maximizing system efficiency. Using historical data and predictive methods, actions are performed in real time to achieve or preserve system performance.

To test the benefits of ATDM approaches and encourage traffic operators and other public agencies to embrace the ATDM concept, it is necessary to create a suite of modeling tools and methods that enable the user to evaluate the potential benefits of implementing ATDM strategies in a dynamic and proactive fashion. As the ATDM implementation requires new investement in physical infrastructure such as data collection, processing and dissemenation systems, control algorithms, and signal systems, it is necessary for the agency to quantify potential benefits of ATDM implementation to justify future investments. In addition, upon implementing ATDM, AMS is needed to support managers/operators at the Transportation Management Centers (TMC) and to support transit agencies' real-time operations. In summary, an Analysis Modeling and Simulation (AMS) system is needed to support agencies in evaluating ATDM at the planning, design, and operational stages.

To support the planning and design phases, a simulated real-time analysis capability is required to quantify the potential impact of dynamic management using ATDM strategies; to support real-time operations, a real-time analysis capability is needed. Even though the analysis for planning/design stages can be done using historical database, in order to capture the dynamic nature of ATDM concept, it is desirable to use real-time data from the field as the input to the ATDM AMS system. The ATDM AMS system includes a prediction system embedded in it and will reside in a TMC or laboratory that is connected to the real-time data feed to support analysis. The AMS system described will use either (1) real-time data that can be either directly fed as the input for ATDM evaluation, or (2) data collected in real time but archived and used later as a historical database. In either approach, the dynamic nature of ATDM concept is captured by using real-time data.

The ATDM Foundational Research project's objectives are to support the development of ATDM program efforts and support the development of an ATDM analysis and modeling framework. The research undertaken as part of the ATDM Foundation Research project is organized into three reports: AMS Concept of Operations, AMS Capabilities Assessment, and Analysis Plan. This report—the AMS ConOps—is the first report in this series. It identifies the state of AMS practice; limitations of current AMS systems; changes required to enhance the system and a justification of these changes; AMS needs for a dynamic approach to traffic and demand management; description of the AMS system to support simulated real-time analysis; and description of four ATDM analysis packages for the purposes of developing detailed Analysis Plans. The AMS needs identified in this report are used to identify AMS gaps. These gaps are detailed in the AMS Capabilities Assessment report.

Chapter 1: Scope

1.1 Identification

For the past several decades, traffic management and operations activities have been reactive in nature. Currently, however, recognition is growing regarding the need for effective and more proactive transportation solutions to address mobility and environmental and safety issues and to meet the expectations of the transportation system user relative to trip reliability and choices. Addressing these needs requires transportation organizations to conduct business in a new way, by proactively managing transportation systems and services to respond to real-time conditions while—at the same time—providing realistic choices for managing travel demand. The Active Transportation and Demand Management (ATDM) is based on this concept.

ATDM is the dynamic management, control, and influence of travel demand, traffic demand, and traffic flow of transportation facilities. Under an ATDM approach, the transportation system is continuously monitored, and through the use of available tools and assets, traffic flow is managed and traveler behavior is influenced in real time to achieve operational objectives. These objectives include preventing or delaying breakdown conditions, improving safety, reducing emissions, and maximizing system efficiency. Using historical data and predictive methods, actions are performed in real time to achieve or preserve system performance.

To test the benefits of ATDM approaches and encourage traffic operators and other public agencies to embrace the ATDM concept, it is necessary to create a suite of modeling tools and methods that enable the user to evaluate the potential benefits of implementing ATDM strategies in a dynamic and proactive fashion. The ATDM Foundational Research project's objectives are to support the development of ATDM Program efforts and development of an ATDM analysis and modeling framework. In particular, this Concept of Operations (CONOPS) document provides the description of the ATDM Analysis Modeling and Simulation (AMS) system that can be used to evaluate the benefits of dynamic management of a transportation system. *It must be noted that the purpose of this document is to lay out a foundation for further work in capturing the dynamic aspect of ATDM and subsequent benefits of the dynamic action. This document* ***does not*** *provide an actual plan for the development of an ATDM test bed.* This CONOPS Report includes the following elements:

- Identification of limitations of current AMS systems, changes required to enhance the system, and a justification of these changes
- AMS needs for a dynamic approach to traffic and demand management
- Description of the AMS system
- Description of four ATDM analysis packages for the purposes of developing detailed Analysis Plans.

The ATDM AMS system is described in Chapter 4:. To illustrate the use of the ATDM AMS system, four specific analysis packages are included in Chapter 5: of this document. The ATDM Analysis Plan Report provides a specific analysis plan for each of the four analysis packages. This ATDM AMS CONOPS also closely relates to the ATDM AMS Capability Assessment Report that describes the capabilities of existing tools that could be used to support ATDM evaluation and the tools' limitations that need to be addressed.

AMS is needed to support agencies in evaluating ATDM at the planning, design, and operational stages. To support the planning and design stages, a simulated real-time analysis capability is required to quantify the potential impact of dynamic management using ATDM strategies; to support real-time operations, a real-time analysis capability is needed. Henceforth in this document, ***offline analysis*** refers to simulated real-time analysis conducted at the planning and design stage, and ***online analysis*** refers to analysis in real time to support real-time operations**.** The scope of the AMS system described in Chapter 4: is restricted to **offline analysis** for planning and design purposes using simulated real-time analysis. In addition, the scope of the AMS system described in Chapter 4: is restricted to ATDM evaluation in the near-term to mid-term time range (less than 10 years), where existing Intelligent Transportation System (ITS) technologies and data-collection mechanisms are used to dynamically manage the transportation system. AMS needs to support the dynamic management of the transportation system using connected vehicle technology (long term), which is not considered part of this document, because there are other ongoing U.S. Department of Transportation (USDOT) efforts to identify and assess the analytical needs for high-priority dynamic mobility applications to support real-time management and operations of the transportation system. Table 1-1 shows the confinement of the scope of this AMS CONOPS.

Table 1-1: AMS CONOPS Scope

Analysis Type	Analysis Purpose	ATDM AMS CONOPS Scope	
		Near to Mid-Term (0–10 Years)	Long Term (More than 10 Years)
Online	Operations		
Offline	Design	X	
	Planning	X	

As the ATDM implementation requires new investement in physical infrastructure such as data collection, processing and dissemenation systems, control algorithms, and signal systems, it is necessary for the agency to quantify potential benefits of ATDM implementation to justify future investments. In addition, upon implementing ATDM, AMS is needed to support managers/operators at the TMCs and transit agencies support real-time operations. This generic ATDM AMS CONOPS being developed as a part of ATDM Foundational Research work will assist in the development of the ATDM simulation test bed in the future. In particular, the ATDM AMS system described in this CONOPS can be used to support ATDM evaluation during the regional transportation planning and investment process and to support planning for operations.

1.2 Document Overview

This document includes six main chapters and is organized as follows:

- Chapter 1: provides the scope and overview of this document.
- Chapter 2: describes the AMS system that exists today, evolving technologies and tools as well as recent developments, and the work done to date in system conceptualization.
- Chapter 3: describes the motivation behind conceptualizing the ATDM AMS system and AMS system needs for a dynamic approach to traffic and demand management.
- Chapter 4: describes the AMS system needed to evaluate the impact of dynamic management.
- Chapter 5: provides four examples of ATDM analysis packages. These analysis packages will be used to develop detailed analysis plans.
- Chapter 6: lists references.

1.3 ATDM Overview

ATDM Background/Concept

ATDM is a dynamic approach to manage a system that is both active and predictive. The goal is to identify problems ahead of time and use an approach to manage demand and supply to meet the desired network performance. The primary hypothesis of ATDM is that proactive management yields better results than reactive management and will improve a system's reliability, safety, and environment. An agency can implement a single ATDM strategy to achieve the desired benefit, or it can implement multiple strategies to gain benefits across the entire transportation system. ATDM is not confined to a specific set of strategies and represents a shift in the traffic management and operations paradigm from static/pre-set operations (e.g., timing plans set by time of day, standard HOV time restrictions) to more dynamic management (e.g., timing plans change by traffic conditions, HOV restrictions change due to incidents) using a variety of traffic, parking, and demand strategies. Figure 1-1 provides an illustrative example of how strategies can evolve from a static/pre-set state to a dynamic state.

Figure 1-1: Moving Toward Active Transportation and Demand Management (ATDM) (Examples)

Variable Speed Limits		Manual operation based on identification of conditions	Automated operation based on pre-defined thresholds	Automated operations based on predicted travel conditions
Parking Management		Static parking information with fixed pricing	Real-time availability information, reservation systems	+ Dynamic pricing like SF Park , wayfinding
En-Route Traveler Information	Scheduled Work and Closures (press releases)	+ Incident information & Current TT	+ Comparative travel times and cost information (transit, rideshare, etc.)	+ Predictive information + Custom traveler based information and guidance

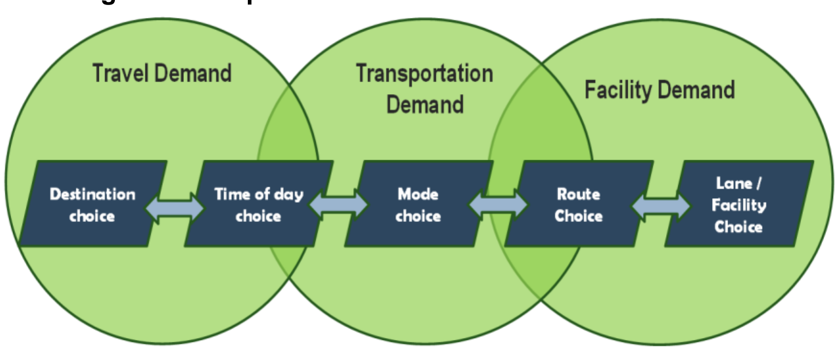
A core principle of the ATDM approach is actively influencing the entire trip chain. The trip chain represents a series of decisions that affect transportation demand and utilization of the network. It also represents the points at which ATDM actions may influence travel activities. To understand the trip chain, an understanding of demand is required. There are three forms of demand, including:

- **Travel Demand.** This is the amount of person-demand for making a trip at a given time, independent of travel mode.
- **Transportation Demand.** This is the amount of person-demand for making a trip using a specific mode.
- **Facility Demand.** This is the amount of demand for facility. For example, vehicles represent roadway facility demand regardless of the number of people in each vehicle.

As shown in Figure 1-2, there are five stages within the trip chain that interface with the aforementioned three types of demand. These five stages are—

- **Destination Choice.** This is the decision to make the trip and where to go.
- **Time-of-Day Choice.** This is the decision to choose when the trip is to be made. It defines travel demand as a function of time. It also helps define transportation demand, as decisions on what mode to use may depend on the availability of particular services at a particular time.
- **Mode Choice.** This is the decision to choose how the trip is to be made: drive alone, carpool, use a form of public transport, or some other form of ride-share (e.g., slug lines). The transportation demand definition involves the demand for specific transportation modes, so this is a critical decision point.
- **Route Choice.** This is the decision to choose which road or transit route to take based on factors, including time, distance, and cost. As the mode of travel is already defined, the route decision helps determine facility demand, typically represented by vehicles for roadways and by passengers for transit services.
- **Lane/Facility Choice.** This is the decision to choose a facility that provides a higher level of service (LOS) but costs more instead of a facility that costs less but provides a lower level of service. For example, it costs more to travel on toll lanes, but these lanes provide a much higher level of service during the peak periods. Other options may involve part-time use of shoulder lanes for traffic flow.

Figure 1-2: Trip Chain and Relation to Demand Activities



One key aspect of the ATDM trip chain is that the chain is neither unidirectional nor sequential; each element of the trip chain can influence the other elements.For instance, lane/facility choice might influence the mode choice, or the route choice in some situations can affect the time-of-day choice. For example, the choice of using the automobile instead of the bus (mode choice) may be guided by the availability of an HOT lane on the highway for which the user is willing to pay. Thus, in this example, mode choice and lane/facility choice are not independent choices. Unlike a single corridor, which may entail the use of one major route, ATDM may involve the use of multiple corridors in a region. With multiple routes, lane choice decisions may be supplanted by route choice decisions and even mode choice decisions, if there is a need to use a park-and-ride facility and an alternate mode on the last leg of a trip.

Transportation agencies currently use several strategies to support management and operation of the transportation system. Many of the strategies, however, are currently reactive in nature and are not used to actively manage the system. Various strategies could help achieve the ATDM vision and define ATDM's responsibilities and features. ATDM actions can be classified into—

- **Active Demand Management (ADM)*.*** Strategies focused on managing the trip demand on the network.
- **Active Traffic Management (ATM).** Strategies focused on managing the flow of vehicle traffic on the network.
- **Active Parking Management (APM).** Strategies focused on managing the parking requirements of vehicles.

When comprehensively applied, active management of transportation and demand include multiple approaches. An agency can deploy a single ATDM approach for a specific benefit, or it can deploy multiple active strategies for desired benefits across the entire transportation system. It is important to note that each ATDM strategy can influence one or more elements of the trip chain and, thus, influence the supply side, the demand side, or both. Table 1-2 provides a list of ATDM strategies that can be used to dynamically manage the transportation system.

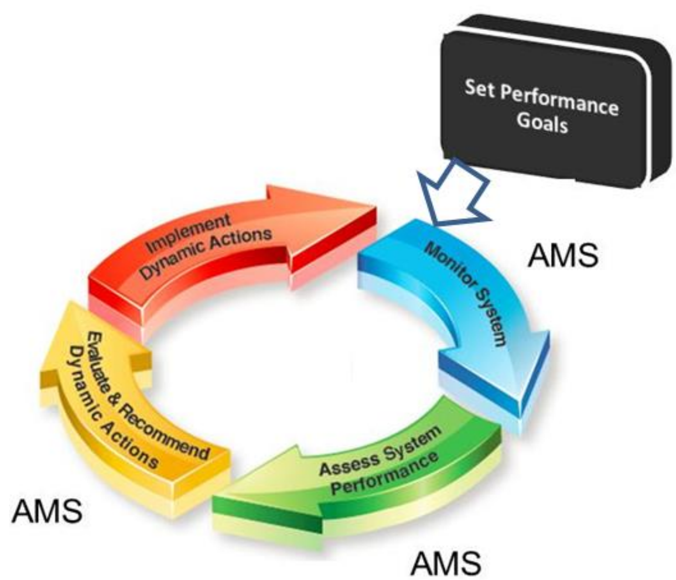
Table 1-2: ATDM Strategies Classified by Categories

Active Demand Management Strategies	Active Traffic Management Strategies	Active Parking Management Strategies
1. Dynamic Ridesharing	10. Dynamic Shoulder Lanes	19. Dynamically Priced Parking
2. Dynamic Transit Capacity Assignment	11. Dynamic Lane Use Control	20. Dynamic Parking Reservation
3. On-Demand Transit	12. Dynamic Speed Limits	21. Dynamic Wayfinding
4. Predictive Traveler Information	13. Queue Warning	22. Dynamic Parking Capacity
5. Dynamic Pricing	14. Adaptive Ramp Metering	
6. Dynamic Fare Reduction	15. Dynamic Junction Control	
7. Transfer Connection Protection	16. Adaptive Traffic Signal Control	
8. Dynamic HOV Conversion	17. Transit Signal Priority	
9. Dynamic Routing	18. Dynamic Lane Reversal or Contraflow Lane Reversal	

1.4 Motivation for AMS

Dynamic management requires a performance- or objectives-driven approach. As described earlier, under an ATDM approach, the transportation system is continuously monitored. Using both archived and real-time data and predictive methods, actions are performed in real time to achieve or maintain a system performance level. Figure 1-3 shows the ATDM implementation cycle, which includes four major components.

Figure 1-3: ATDM Implementation Cycle



The following is a brief description of different elements of the ATDM implementation cycle and the need for AMS to support the implementation:

- **Monitor System.** The system is monitored continuously using real-time and historical data and analysis tools. AMS tools and methods are necessary to process the collected data and analyze the information to monitor the system in real time.
- **Assess System Performance:** Analysis using a continuously moving time-window is performed to ***predict*** future conditions, and predicted conditions and established system-level performance targets are compared at the current time step. AMS tools and methods are necessary to predict future performance based on existing and anticipated changes to network demand and supply. The duration of the prediction window depends on the agency preference and control strategies of interest. Predictions can be made by analytical methods or by using detailed simulation and modeling tools.

- **Evaluate and Recommend Dynamic Actions.** If system performance does not meet the established targets, AMS tools are needed to evaluate and recommend dynamic actions. AMS tools are also needed to identify and recommend ATDM strategies to implement based on predicted improvement in performance.
- **Implement Dynamic Actions.** Dynamic actions are then implemented based on the recommendations that the ATDM decision support tools recommend.

As described earlier, to implement ATDM, AMS tools are needed to support decisionmakers during three of the four key stages, including monitoring the system, assessing system performance, and evaluating and recommending dynamic actions. In addition, AMS can—

- Test the benefit and value of the ATDM concept, especially the proactive versus reactive approach
- Support the evaluation of different ATDM deployment packages
- Test tactical and strategic decisionmaking in an integrated way:
    - Tactical decisions consider operational changes.
    - Strategic decisions attempt to look at the entire system and implement demand-management strategies.

1.5 ATDM Strategies

Transportation agencies currently use several strategies to support management and operation of the transportation system. Many of the strategies, however, are currently static and are not used to dynamically manage the system. Various strategies could help achieve the ATDM vision and define ATDM's responsibilities and features into which ATDM actions can be classified: These strategies include—

- **Active Demand Management (ADM).** Strategies focused on managing the multimodal trip demand geospatially and temporally across the network.
- **Active Traffic Management (ATM).** Strategies focused on managing the flow of vehicle traffic on the network.
- **Active Parking Management (APM).** Strategies focused on managing the parking requirements of vehicles.

When comprehensively applied, active management of transportation and demand include multiple approaches. An agency can deploy a single ATDM approach for a specific benefit, or it can deploy multiple active strategies for additional benefits across the entire transportation system. It is important to note that each ATDM strategy can influence one or more elements of the trip chain and, thus, influence the supply side, the demand side, or both. Table 1-3 provides a list of ATDM strategies that can be used to dynamically manage the transportation system.

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5. Dynamic Pricing	14. Adaptive Ramp Metering	
6. Dynamic Fare Reduction	15. Dynamic Junction Control	
7. Transfer Connection Protection	16. Adaptive Traffic Signal Control	
8. Dynamic HOV Conversion	17. Transit Signal Priority	
9. Dynamic Routing	18. Dynamic Lane Reversal or Contraflow Lane Reversal	

The following is a brief description of various ATDM strategies

Active Demand Management Strategies

- **Dynamic Ridesharing.** This strategy involves travelers using advanced technologies, such as smartphones and social networks, to arrange a short-notice, one-time shared ride. This facilitates real-time and dynamic carpooling to reduce the number of auto trips/vehicles trying to use already congested roadway facilities.
- **Dynamic Transit Capacity Assignment.** This strategy involves reorganizing schedules and adjusting assignments of assets (e.g., buses) based on real-time demand and patterns to cover the most overcrowded sections of network. In an ATDM approach, real-time and predicted travel conditions can be used to determine the changes needed to the planned transit operations, thereby potentially reducing traffic demand and subsequent delays on roadway facilities.
- **On-Demand Transit.** This strategy involves travelers making real-time trip requests for services with flexible routes and schedules. This allows users to request a specific transit trip based on their individual trip Origin-Destination and desired departure or arrival time.
- **Predictive Traveler Information.** This strategy involves using a combination of real-time and historical transportation data to predict upcoming travel conditions and convey that information to travelers pre-trip and en route (e.g., in advance of strategic route choice locations) in an effort to influence travel behavior. In an ATDM approach, predictive traveler information is incorporated into a variety of traveler information mechanisms (e.g., multimodal trip planning systems, 511 systems, dynamic message signs) to allow travelers to make better informed choices.
- **Dynamic Pricing.** This strategy utilizes tolls that dynamically change in response to changing congestion levels, as opposed to variable pricing that follows a fixed schedule. In an ATDM approach, real-time and predicted traffic conditions can be used to adjust the toll rates to achieve agency goals and objectives.

- **Dynamic Fare Reduction.** This strategy involves reducing the fare for use of the transit system in a particular corridor as congestion or delay on that corridor increases. This encourages selection of transit mode to reduce traffic volumes entering the corridor. Fare changes are communicated in real time to the traveling public, through general dissemination channels such as the transit website, as well as personalized messages to subscribers. In an ATDM approach, real-time and predicted highway congestion levels and/or utilization levels of the transit system can be used to adjust transit fare in real time to encourage mode shift necessary to meet agencies' goals and objectives.
- **Transfer Connection Protection.** This strategy involves improving the reliability of transfers from a high-frequency transit service (e.g., a train) to a low-frequency transit service (e.g., a bus); for example, the train is running late, so the bus is held back so train passengers can make their connection with the bus; or providing additional bus services at a later time to match the late arrival time of the train. This ensures that the connections are not missed.
- **Dynamic HOV Conversion.** This strategy involves dynamically changing the qualifications for driving in a high-occupancy vehicle (HOV) lane(s). HOV lanes (also known as carpool lanes or diamond lanes) are restricted traffic lanes reserved at peak travel times or longer for exclusive use of vehicles with a driver and one or more passengers, including carpools, vanpools, and transit buses. The normal minimum occupancy level is 2 or 3 occupants. Many agencies exempt other vehicles, including motorcycles, charter buses, emergency and law enforcement vehicles, low-emission vehicles, and/or single-occupancy vehicles from paying a toll. In an ATDM approach, the HOV lane qualifications change dynamically based on real-time or anticipated conditions on both the HOV and general-purpose lanes. Qualifications that can potentially be dynamically adjusted include the number of occupants (e.g., from 2 to 3 occupants), the hours of operation, and the exemptions (e.g., change from typical HOV operation to buses only).
- **Dynamic Routing.** This strategy uses variable destination messaging to disseminate information to make better use of roadway capacity by directing motorists to less congested facilities. These messages could be posted on dynamic message signs in advance of major routing decisions. In an ATDM approach, real-time and anticipated conditions can be used to provide route guidance and distribute the traffic spatially to improve overall system performance.

<u>Active Traffic Management Strategies</u>

- **Dynamic Shoulder Lanes.** This strategy enables using the shoulder as a travel lane(s), known as Hard Shoulder Running (HSR) or temporary shoulder use, based on congestion levels during peak periods and in response to incidents or other conditions as warranted during non-peak periods. In an ATDM approach, real-time and anticipated congestion levels are used to determine the need for using a shoulder lane as a regular or special-purpose travel lane (e.g., transit only), and the operation of the dynamic shoulder lane is managed continuously,
- **Dynamic Lane Use Control.** This strategy involves dynamically closing individual traffic lanes due to incidents, road work, or other warranted condition, as well as providing advance warning of the closure(s) to safely merge traffic into adjoining lanes. In an ATDM approach, as the network is continuously monitored, real-time incident and congestion

data is used to control the lane use ahead of the lane closure(s) and dynamically manage the location to reduce rear-end and other secondary crashes.

- **Dynamic Speed Limits.** This strategy adjusts speed limits based on real-time traffic, roadway, and/or weather conditions. Dynamic speed limits can either be enforceable (regulatory) speed limits or recommended speed advisories, and they can be applied to an entire roadway segment or individual lanes. In an ATDM approach, real-time and anticipated traffic conditions are used to adjust the speed limits dynamically to meet agencies' safety, mobility, and environmental goals and objectives.
- **Queue Warning.** This strategy involves real-time displays of warning messages (typically on dynamic message signs and possibly coupled with flashing lights) along a roadway to alert motorists to queues or significant slowdowns ahead. This improves safety and reduces rear-end crashes. In an ATDM approach, as the traffic conditions are monitored continuously, the warning messages are dynamic, based on the location and severity of the queues and slowdowns.
- **Adaptive Ramp Metering.** This strategy consists of deploying traffic signal(s) on ramps to dynamically control the rate at which vehicles enter a freeway facility. This encourages a smooth flow of traffic onto the mainline, allowing efficient use of existing freeway capacity. Adaptive ramp metering utilizes traffic responsive or adaptive algorithms (as opposed to pre-timed or fixed-time rates) that can optimize either local or systemwide conditions. Adaptive ramp metering can also utilize advanced metering technologies such as dynamic bottleneck identification, automated incident detection, and integration with adjacent arterial traffic signal operations. Under the ATDM approach, real-time and anticipated traffic volumes on the freeway facility will be used to control the rate of vehicles entering the freeway facility. Based on the conditions, the ramp meter rates will be adjusted dynamically.
- **Dynamic Junction Control.** This strategy consists of dynamically allocating lane access on mainline and ramp lanes in interchange areas where high-traffic volumes are present and the relative demand on the mainline and ramps change throughout the day. For off-ramp locations, this may consist of assigning lanes dynamically for through movements, shared through-exit movements, or exit-only movements. For on-ramp locations, this may involve a dynamic lane reduction on the mainline upstream of a high-volume entrance ramp or might involve extended use of a shoulder lane as an acceleration lane for a two-lane entrance ramp that culminates in a lane drop. In an ATDM approach, the volumes on the mainline lanes and ramps are continuously monitored; lane access will be changed dynamically based on real-time and anticipated conditions.
- **Adaptive Traffic Signal Control.** This strategy continuously monitors arterial traffic conditions and the queuing at intersections and adjusts the signal timing dynamically to optimize one or more operational objectives (e.g., minimizing overall delays). Adaptive Traffic Signal Control approaches typically monitor traffic flows upstream of signalized locations or segments with traffic signals, anticipating volumes and flow rates in advance of reaching the first signal, then continuously adjusting phase length, offset, and cycle length during each cycle to optimize operational objectives.
- **Transit Signal Priority.** This strategy manages traffic signals by using sensors to track when a bus nears a signal controlled intersection, turning the traffic signals green sooner or keeping them green longer, thereby allowing the bus to pass through more quickly. In

an ATDM approach, Transit Signal Priority can be used to improve transit operations and encourage mode shift along congested corridors.

- **Dynamic Lane Reversal or Contraflow Lane Reversal.** This strategy consists of the reversal of lanes to dynamically allocate the capacity of congested roads, thereby allowing capacity to better match traffic demand throughout the day. In an ATDM approach, based on the real-time traffic conditions, the lane directionality is updated quickly and automatically in response to or in advance of anticipated traffic conditions.

Active Parking Management Strategies

- **Dynamically Priced Parking.** This strategy involves parking fees that are varied dynamically based on demand and availability to influence trip timing choices and parking facility choice in an effort to maximize utilization and reduce the negative impacts of travelers searching for parking. In an ATDM approach, the parking availability is continuously monitored and parking pricing is used as a means to influence model choice and manage the traffic demand dynamically.
- **Dynamic Parking Reservation.** This strategy involves the ability for travelers to use technology to reserve a parking space at a destination facility on demand to ensure availability. In an ATDM approach, the parking availability is continuously monitored, and system users can reserve the parking space ahead of arriving at the parking location.
- **Dynamic Wayfinding.** This is the practice of providing real-time parking-related information to travelers associated with space availability and location so as to optimize the use of parking facilities and minimize the time spent searching for available parking. In an ATDM approach, the parking availability is continuously monitored and the user is routed to the parking space.
- **Dynamic Parking Capacity.** This strategy involves the practice of dynamically increasing the capacity of parking facilities through technology based on demand. In an ATDM approach, the parking availability is continuously monitored and additional parking capacity is needed.

Each of the preceding ATDM strategies can be used independently or collectively to influence transportation demand and supply and meet the desired performance goals. Table 1-4 presents a library of ATDM strategies and indicates the elements of the trip chain that each strategy influences.

Table 1-4: Influence of ATDM Strategy on Elements of the Trip Chain

		Trip Chain Affected				
No.	**ATDM Strategy**	**Destination Choice**	**Time-of-Day Choice**	**Mode Choice**	**Route Choice**	**Lane/Facility Choice**
Active Demand Management (ADM) Strategies						
1	Dynamic Ridesharing	◔	◔	●	◑	●
2	Dynamic Transit Capacity Assignment		◑	●		
3	On-Demand Transit	◔	◔	●		
4	Predictive Traveler Information	◑	◑	●	●	●
5	Dynamic Pricing	◑	●	●	●	●
6	Dynamic Fare Reduction		◑	●		
7	Transfer Connection Protection		◑	●		
8	Dynamic HOV Conversion		◑	●	◔	●
9	Dynamic Routing			◔	●	
Active Traffic Management (ATM) Strategies						
10	Dynamic Shoulder Lanes		◑	◔	◑	●
11	Dynamic Lane Use Control	◔	◔		◔	●
12	Dynamic Speed Limits		◔	◔	◑	●
13	Queue Warning		◔	◔	◑	●
14	Adaptive Ramp Metering	◔	◑	◔	◑	◔
15	Dynamic Junction Control		◔		◑	◑
16	Adaptive Traffic Signal Control		◔	◔	●	
17	Transit Signal Priority	◔	◔	◑	◑	
18	Dynamic Lane Reversal or Contraflow Lane Reversal			◑	●	●

		Trip Chain Affected				
No.	**ATDM Strategy**	**Destination Choice**	**Time-of-Day Choice**	**Mode Choice**	**Route Choice**	**Lane/Facility Choice**
Active Parking Management (APM) Strategies						
19	Dynamically Priced Parking	◑	●	◑	◑	
20	Dynamic Parking Reservation		◑	◔	◑	
21	Dynamic Wayfinding		◑	◔	◑	
22	Dynamic Parking Capacity		◑	◔	◑	

Legend:

● – Strategy has a definite influence on the particular trip chain element.

◑ – Strategy has a probable influence on the particular trip chain element.

◔ – Strategy has only a possible influence on the particular trip chain element.

Chapter 2: State of AMS Practice

This chapter documents the current state of AMS practice, identifying existing capabilities that can support evaluation of the ATDM concept. Although this chapter refers to existing applications or/and products, the synthesis has been made using publicly available literature and resources. The report neither endorses a particular commercial tool or product nor intends to present a comparative assessment. It should also be noted that this section references several ongoing research activities that are not fully developed or established.

2.1 AMS Background

The overall AMS capabilities in the transportation industry have been constantly evolving. Existing AMS tools offer the functionalities to test, evaluate, and demonstrate the benefits of alternative transportation management policies, operational strategies, and ITS technologies before committing significant resources to deploy innovative solutions. As a consequence, AMS tools have become an integral part of the toolkit of transportation planners, engineers, and operators because these tools improve and substantiate the decisionmaking process. Comprehensive evaluations of dynamic transportation demand management and operations strategies are likely to require adapting multiple AMS tools because strategic alternatives may interact in such a complex manner that one tool cannot completely capture and reflect effects such as changes in traveler behavior. Each tool is designed and implemented for a specific purpose and has unique analytical methods and data requirements. Most transportation demand management and some ITS operational strategies have the potential to change travel behavior such as trip chaining, number of trips, trip duration, time of day of travel, route choice, and mode choice (e.g., transit, SOV, carpool, telecommuting).

Over the past few decades, traditional four-step travel demand models have been used as a regional planning tool to evaluate the impact of transportation management and operational strategies. The four-step model is particularly effective in evaluating projects that affect capacity but is less effective in estimating the impact of operational strategies. The four steps of this travel demand modeling framework are trip generation, trip distribution, mode choice, and traffic assignment. The trip generation step uses the number of people and the number of jobs in each traffic analysis zone based on land-use data to estimate the number of trips produced or attracted by each traffic analysis zone. In the trip distribution step, the trip productions and attractions determined during the trip generation step are linked to create origin–destination (O-D) trip patterns. Travel times are taken into account when pairing the origins and destinations. In the mode choice step, travel costs are taken into account to determine the possible mode of transportation (e.g., auto, two-person carpool, three-person carpool 3, transit, walk, bicycle) for each trip in the O-D trip table. In the fourth step, the highway trip tables are assigned to the network to compute each roadway segment's volume and speed. The traffic assignment procedures used in traditional travel demand modeling tools use volume-to-capacity ratios and the Bureau of Public Roads (BPR) volume delay functions to compute congested travel speeds.

This simplistic four-step approach to modeling travel behavior is not fully capable of predicting traveler choices in response to dynamic actions and fine-level policy changes. In particular, four-step models are not fully capable of quantifying the changes in traveler behavior associated with implementation of strategies such as operational improvements, demand and access management strategies, and other policy changes that do not directly affect changes to capacity.

One major shortcoming of traditional four-step trip-based models is that they do not consider the link between individual trips that a traveler makes. Each person trip is considered separately, and no trip chaining is considered—that is, a person's trip from home to work and back is split into two one-way trips: one from home to work and the other from work to home. Tour-based models are used to address this issue. Tour-based models consider travel tours at all stages of demand estimation (generation, distribution, and mode choice) but use a simplified structure for tour generation and scheduling that does not explicitly account for intrahousehold interactions, joint travel, and individual schedule consistency. Activity-based models take the tour-based models another step further and consider interactions between members of the household, vehicle ownership, and joint travel to ensure schedule consistency among individual trips made by the members of the household during the entire course of the day. Activity-based models have been gaining popularity in recent years and are well positioned to overcome the shortcomings in four-step models and predict changes in traveler behavior (e.g., mode choice, route choice, time-of-day choice, induced demand) in response to dynamic actions since these models are theoretically sound and model travel behavior as a series of linked activities or tours. Note that these models have not been rigorously tested to model behavior changes in response to dynamic ITS strategies, and the full benefits of using activity-based models have not yet been demonstrated. Although activity-based models address travel demand in great detail, the network or the supply side of the model requires enhancements to ensure that network performance is captured accurately. The current state of practice is to split the highway tours derived from activity-based models into trips aggregated into three or four time periods (AM, midday, PM, night) and to perform a static traffic assignment for each period. The actual trip departure and arrival times within the period are not considered. In addition, trips are assumed to be homogeneous within each time period, while in reality a majority of the trips occur (peak) within a certain part of the period while some of the trips overlap multiple periods.

A few metropolitan planning organizations (MPO) and planning agencies are designing and implementing activity-based models that can potentially support evaluation of operational improvements and dynamic management strategies, but very few agencies have addressed the challenging issue of implementing time-dependent networks to capture time-of-day congestion effects for the entire region. The current state of the practice is to use macroscopic models for regional planning and supplement them with simulation studies for intersection-level analyses or for small sub-areas because the resources required to simulate entire regions is too large; the computationally intensive procedures require a large amount of time to perform a simulation of the entire region. Therefore, it is difficult to capture the regional impacts of ATDM implementations using this approach.

Traffic simulation models—macroscopic, mesoscopic, and microscopic—are well suited to capture the network performance changes associated with implementation of ATDM strategies. Mesoscopic simulation tools track traffic flows in the network to maintain a higher level of detail when compared to macroscopic simulation tools, and they take into account delays at traffic signals. Microscopic simulation tools account for movements of individual vehicles dynamically on a second-by-second basis using cellular automata[1] or car-following models. Microscopic models require detailed geometric, control, and demand data and a large number of calibrated parameters to accurately model driver behavior in the network. Microscopic and mesoscopic models provide detailed outputs that describe network performance during small time increments (e.g., 15 minutes or less). Examples

[1] Cellular Automata (CA) are dynamical systems in which space and time are discretely represented. A cellular automaton consists of a regular grid of cells, each in one of the finitie number of states.

of output data that these models generate include link-level travel time, miles traveled, stop times, queue lengths, and delays with a very high temporal fidelity. Table 2-1provides example AMS tools used in industry today. Note that this list is not meant to be exhaustive or complete but rather to provide some examples for each tool category.

Table 2-1: Illustrative Examples of Analysis Modeling and Simulation Tools

Model/Model Category	Description of Models, With Examples
Land-Use Models	
Simulation-based land-use models	A simulation-based land-use model predicts land-use changes in response to changes in travel cost and accessibility. This model predicts how changes in land-use policy and transportation supply affect the movement of household and employment activities. Examples include UrbanSim.
Travel Demand and Behavior Models	
Four-step travel demand models (traditional models)	These models have been used by planning agencies throughout the United States for several decades to support their planning practices, develop long-range plans, and perform air-quality and National Environmental Policy Act (NEPA) analyses. They use a simplistic representation of travel demand and do not consider interactions among members of a household. Examples include TransCAD, CUBE, TP+, VISUM, and EMME2.
Tour-based models	These models consider travel tours at all stages of demand estimation (i.e., generation, distribution, and mode choice) but use a simplified structure for tour generation and scheduling that does not explicitly account for intrahousehold interactions, joint travel, and individual schedule consistency. Models of this type exist for the following regions: San Francisco County, New York, Sacramento, and Denver. The models for these cities use custom software written solely for use for the region.
Activity-based models	These models consider interactions between members of a household, vehicle ownership, and joint travel and ensure schedule consistency among individual trips made by every member of the household during the entire course of the day. Regions, such as Columbus, San Francisco, Atlanta, and Phoenix, are using or are in the process of developing full-fledged activity-based models. The models for these cities use custom software written solely for use for the region.
Traffic Operations Models and Tools	
Macroscopic models	Macroscopic simulation models are typically used to model large regions, corridors, freeways, and arterials. Examples include Aimsun, PASSER, VISTA, and TRANSYT-7F.
Mesoscopic models	Mesoscopic models are typically used to simulate regional networks. The level of granularity varies from fluid dynamic models to individual vehicle (simplified) modeling, but all these models are capable of producing time-dependent travel times. Most mesoscopic analysis tools include iterative dynamic traffic assignment (DTA) procedures, often based on the Dynamic User Equilibrium principle, that replace the static assignment step in the traditional four-step travel demand models to achieve higher accuracy in understanding path utilization as a function of time. Academic examples include Direct, DynaMiT, DYNASMART and Dynus-T. Commercial examples include Aimsun, CUBE Avenue and Dynameq.
Microscopic models	Microscopic simulation models deploy a time-step approach and thus track individual vehicular movements in every time step and generate detailed estimates of network performance. Examples include Aimsun, CORSIM, Paramics, Transmodeler, and VISSIM. All commercial microscopic analysis tools include one-shot DTA procedures while some others offer an iterative DTA approach. However, the use of microscopic tools with DTA based strictly on the Dynamic User Equilibrium principle is available in few packages and not in wide use at this time.

As previously described, AMS tools have been predominantly used by planners and operators to evaluate the benefits of a variety of traffic management and operations strategies at the planning and design stages. In particular, AMS tools are used to conduct alternative analyses and evaluate the potential impacts of implementing the strategies either for long-range planning or for project justification. To capture the impacts of management and operations strategies, the behavior models (traditional four-step models or, recently, activity-based models) are interfaced with traffic assignment models (traditional four-step model traffic assignment or traffic simulation models) to quantify the net impacts.

In addition to the models described in The overall AMS capabilities in the transportation industry have been constantly evolving. Existing AMS tools offer the functionalities to test, evaluate, and demonstrate the benefits of alternative transportation management policies, operational strategies, and ITS technologies before committing significant resources to deploy innovative solutions. As a consequence, AMS tools have become an integral part of the toolkit of transportation planners, engineers, and operators because these tools improve and substantiate the decisionmaking process. Comprehensive evaluations of dynamic transportation demand management and operations strategies are likely to require adapting multiple AMS tools because strategic alternatives may interact in such a complex manner that one tool cannot completely capture and reflect effects such as changes in traveler behavior. Each tool is designed and implemented for a specific purpose and has unique analytical methods and data requirements. Most transportation demand management and some ITS operational strategies have the potential to change travel behavior such as trip chaining, number of trips, trip duration, time of day of travel, route choice, and mode choice (e.g., transit, SOV, carpool, telecommuting).

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Table 2-1, there are several integrated versions of modeling platforms that couple two or more models. Integration of different models is desirable when modeling scenarios that span a broader time period and geographic region. Besides these traffic modeling tools, analytical techniques such as time-series modeling and multivariate analysis procedures offer a variety of modeling capabilities.

2.2 Current State of Practice

One of the key aspects of ATDM is the use of dynamic strategies to influence all parts of the trip chain, including destination choice, time-of-day choice, mode choice, route choice, and lane and facility choice. To evaluate the impact of ATDM strategies, the AMS needs to support the following activities:

- **Monitor system.** In this step, the transportation system is being monitored continuously using real-time and historical data. AMS is needed to process the collected data and aggregate the information for the regions of interest.
- **Assess system performance.** In this step, a continuously moving time is used to predict future conditions. AMS is needed to predict future performance based on existing and anticipated changes to both network demand and supply. The duration of the prediction window depends on the agency preference and control strategies of interest. Predictions can be made either by analytical methods or by using detailed simulation and modeling tools.
- **Evaluate and recommend dynamic actions.** In this step, an action is performed if the predicted performance from the assessment phase does not meet the target. AMS is needed to Identify and recommend ATDM strategies to implement based on predicted improvements in performance.
- **Implement dynamic actions.** In this step, a dynamic action (e.g., speed limit change) is performed if the predicted performance does not meet the target. For planning analysis (when actions are not actually implemented in the real world), AMS tools are needed to capture the impact of actions.

The following sections describe the current state of practice to support these AMS activities for both real-time operations (**online analysis**) and for evaluating ATDM at the planning and design stage (**offline analysis**). A more detailed discussion on the following sections can be found in Chapter 3 of the Capabilities Assessment report.

Monitor System

Real-time monitoring of transportation systems is essential for dynamic management of a transportation system. Real-time data from the network provides the most recent information on the state and dynamics of the transportation system. A real-time monitoring process gathers, adjusts, and integrates real-time data from different sources to support analysis.

A real-time monitoring process consists of two subprocesses: data collection/processing and archiving. The data collection process collects data from a variety of data sources generally categorized into embedded sensors, surveillance cameras, and mobile devices. Embedded sensors include fixed infrastructure units such as inductive loop and microwave- or radar-based detectors that collect vehicle volume, speed, occupancy, and classification data. The California Performance Monitoring System (PeMS) is an example of a real-time data-collection system that gathers data in real time from 28,000 lane detectors in California. Surveillance cameras are typically deployed for traffic safety and monitor incidents on freeways or urban streets. For example, London uses surveillance cameras for traffic safety management. Surveillance cameras are also used to track road surface conditions. Many state departments of transportation (DOT) publish live web-based feeds from freeway surveillance cameras. The proliferation of cell phones and global positioning system (GPS) devices over the past 20 years has helped realize the concept of mobile traffic sensors. Today, cell phones carried by car drivers or public transit riders and the GPS devices on public transit vehicles offer a rich pool of trajectory and activity data. For example, Google Maps uses data from cell phones to estimate traffic congestion levels on roadways.

Upon collecting the data from different sources, the data needs to be processed for use to monitor the transportation system at a regional level. The data-processing and archiving process varies widely across different transportation agencies. An FHWA 2005 case study across six state agencies, "Archived Data Management Systems, a Cross-Cutting Study," revealed that a wide variety in data formats, system architecture, data quality, and data-collection methods are being used. The following presents the methods and architectures used by the state agencies:

- Relational databases are used predominantly while some agencies use proprietary tools.
- While a few of the agencies automatically impute the missing values in the data, most agencies let the user decide how to deal with bad and missing data. Some agencies that do not impute data have mechanisms to automatically detect and flag erroneous data (physically impossible or implausible values).
- Data is typically archived in flat files on CD-ROMs or other data storage devices. In addition, real-time weather-related data, incident data, and work zone data are published on many different websites by the respective authorities.

In addition to these data sources, advanced traffic management programs use weather conditions data and road surface conditions data for real-time monitoring. Vehicle volume and average speed data is collected by most agencies in the United States. Most of these agencies store the archived data in-house; a few maintain only the most recent data and outsource for long-term data-archiving, storage, and management. With a few exceptions, data is stored in relational databases and is web-accessible through a user interface to query the database query. Data collected in real time is preprocessed minimally. For example, the PeMS temporally aggregates and translates the data into simple measures such as vehicle speed and traffic volume.

Data analysis, during which insights are drawn from the collected and preprocessed data, is the most important step of a real-time monitoring system. Processed real-time data and historical data is analyzed to calculate performance measures. Integrated Corridor Management (ICM) San Diego and ICM Dallas demonstration sites have been testing real-time monitoring systems for active management purposes. University of Maryland and IBM have also each built their own systems to monitor a transportation system in real time, as described in the following sections.

ICM San Diego

ICM San Diego leveraged the local support offered by PeMS to build its real-time monitoring system framework. PeMS, a real-time archive data management system (rt-ADMS), collects freeway lane information from sensors across several districts in California at a temporal fidelity of 20–30 seconds. PeMS incorporates data received from several transportation domains, such as ITS devices, toll tag data, Bluetooth-based data, and incident data. The incoming data is treated for detector diagnostics, an automated process performed nightly to determine the reliability of the sensors. Missing or erroneous values are imputed, and the 30-second data is aggregated to 5-minute data. PeMS uses this processed and aggregated data to calculate speed, other aggregated metrics, and performance measures. Performance measures and other parameters are published in reports that are accessible to Internet-based subscribers. Currently, the PeMS network encompasses 28,000 sensors in six districts in California. Applications supported by the real-time analysis and web-based user interface provided by PeMS for ICM San Diego include the following:

- Historical trend plots of total delay on freeways
- Identification of bottlenecks based on persistent temporal and spatial changes in speed (these bottlenecks are represented on a dynamic freeway corridor thematic map)
- Sensor-based congestion metrics (measured as the percentage of time spent in a congested environment during certain of time periods of the day) displayed as a color-coded dynamic thematic map of the freeway corridor.

The ICM San Diego demonstration site uses an advanced variation of the current PeMS named *3-PeMS.* 3-PeMS includes Arterial-PeMS as well as Transit-PeMS to support integration of data collected from different transportation modes.

ICM Dallas

The ICM Dallas demonstration site leveraged the Dallas Area Rapid Transit (DART) data portal and the Inter-Agency Information Exchange Network to support its real-time monitoring system. The DART data portal uses multiple data sources from various components of the transportation system, such as transit and paratransit operations, emergency management systems, smart card transactions, and HOV systems. These data are consolidated in a central DART database.

SmartFusion is the real-time monitoring component of the system supported by a web-based information-sharing tool, SmartNET. The SmartFusion module is responsible for data collection, aggregation, archiving, storage, and dissemination. Key features of SmartFusion along with SmartNET include—

- A web-based interface to the ICM system
- A data fusion engine
- Entry and management of incidents and planned events
- Receiving data from and publishing data to regional center-to-center (C2C) and other external systems
- Feeding data to the 511 system and the decision support component of the ICM system.

Regional Integrated Transportation Information System (RITIS)–University of Maryland

RITIS is an automated data sharing, dissemination, and archiving system developed by the University of Maryland. RITIS consists of a rigorous IT framework with capabilities to support the real-time system monitoring component of the ATDM AMS framework. The collection and integration of transportation data from various sources, the distribution of this data to participating agencies and users, and its visualization are some of the key capabilities offered by RITIS. These extremely useful capabilities would assist in meeting several ATDM AMS needs.

IBM Smarter Cities–Singapore

IBM's Smarter Cities initiative is developing innovative solutions for smarter transportation in cities around the world. IBM, in association with the Land Transportation Authority (LTA) in Singapore, has demonstrated its capabilities in a pilot implementation in Singapore. The solutions developed rely on data gathered from sources across different modes of transportation. The data available from LTA, however, comes from a small percentage of roadway segments in the network. The implementation uses a data expansion algorithm to impute real-time traffic when sensor data is unavailable.

Commercial Vendors

Several commercial vendors have been developing and offering real-time data-collection and analysis services for a fee. Over the past 10 years, the quality and reliability of real-time analysis from private sources has improved significantly and can currently provide real-time analysis meeting requirements from government agencies. Some of these vendors have already established a support system to several transportation agencies.

To summarize, traffic-related data can be collected in real time from various sources ranging from loop detectors to mobile phones. Data is collected, stored, organized, and made accessible differently; each agency chooses what suits it best. Incoming data can be analyzed to generate preliminary performance measures such as vehicle speed and traffic volume. Recent applications in ICM demonstration sites, RITIS, and the Smarter Cities initiative include the real-time monitoring capabilities required for ATM efforts such as ATDM. Some commercial vendors also provide the required capabilities and have supported transportation agencies in the past.

Assessing System Performance

Assessing system performance for immediate future conditions is the second step in the ATDM AMS cycle. It can be viewed as an extension of the monitoring system performance step to the future time window.

Anticipating future traffic conditions in the transportation system requires an extrapolation of traffic conditions based on historical trends and application of transportation modeling techniques such as O-D matrix estimation techniques and an assessment of system performance for the future time window using forecasted travel demand and network conditions. Demand models, analysis methods, and predictive simulation techniques are necessary to support this functionality. Dynamic management under the ATDM concept requires not only predicting the performance of the system for potential strategies but also continuously predicting system performance to enable proactive mitigation of any stress on the transportation system before it occurs.

The predictive capabilities required to anticipate system performance in the future are supported by simulation techniques. The simulation models can vary in scope of geographical extent and granularity of the simulation level, and thus the data requirements vary. Key features required for the predictive part of the simulation include the following:

- Simulating interactions among agents in the system as well as between agents and the transportation infrastructure. *Agents* in this sense could be individual travelers or vehicles.
- Behavior models to capture reactions of the travelers to the surrounding conditions and advisories or warnings from the ITS infrastructure. This includes—
    - Decisionmaking aspects at trip generation, mode selection, and route selection levels.

  - Consistent anticipatory information—user reactions to ITS advisories will be incorporated into the simulation before selection and issuance of advisories.
- Replicating the data-collection system for the future conditions. Processes such as measurement errors, other noise in the data, limitations of the imputation, and sensor diagnostic procedures need to be simulated for the future conditions.
- Generation of performance measures based on simulated sensor data.

In the ATDM approach, the system is continuously monitored for the agencies' specific goals and objectives. Although certain performance metrics such as traffic volume, average speed, and travel time delays are easy to monitor and predict, safety-related performance metrics are difficult to assess.

Current Capabilities

Performance prediction has been researched in transportation academia and industry alike. Mesoscopic models, such as DynaSmart and DynaMIT have been used in offline mode to simulate the predictive performance of the system for a moving time-window. Both simulators provide short-term traffic prediction in real-time situations and are the only two simulators evaluated for real-time predictions in an operational context. Some of the real-time applications may involve a closed-loop framework in which a mesoscopic model is integrated with a microscopic model, with the microscopic model running predictive simulation of smaller focus areas. Some recent advancements in the area of predictive modeling are provided here:

- **Edmonton Yellowhead Trail Case Study.** The Edmonton Yellowhead Trail Case Study has been used to test predictive traffic modeling pertaining to ATDM goals. The case study framework uses an integration of planning (offline) and real-time analysis. VISUM is used in offline modeling to analyze static and time-dynamic traffic volumes. VISSIM uses these base demand and supply models as well as traffic assignment to simulate traffic volumes. The real-time traffic simulation model, OPTIMA, is supported by DTA models from VISUM. In the online (simulated real time) mode, a macroscopic dynamic network loading model is calibrated with real-time counts and trajectory data. It is used to estimate actual traffic flow and travel-time evolutions within the immediate short-term future. This framework has been tested for assessing future system performance for lane closures by incidents on a network spread over 11 miles and deployed with 127 signals, including 31 adaptively controlled signals.
- **Tools for Operational Planning (TOPL).** The University of California, Berkeley, has developed macrosimulation-based freeway and arterial models that can be easily manipulated, self-calibrated, and self-diagnosed from traffic data. Because of the macroscopic nature of the models in Aurora Road Network Modeler (RNM), a real-time traffic simulation platform, computational burden is relatively low, and the models can be continuously calibrated based on real-time data. A 26-mile stretch on I-210W in Pasadena, California, with 32 on-ramps, 26 off-ramps, and one uncontrolled freeway connector, has been used as the test site for Aurora models. The current models can, however, only be used for training purposes, and research efforts to develop a real-time, predictive, simulation-based Decision Support System (DSS) are underway.
- **ICM San Diego.** The ICM San Diego system performance assessment framework is supported by Aimsun and Aimsun ONLINE. The simulation framework uses an integrated hierarchy of macro-, meso-, and microscopic simulation models. The regional model built by the San Diego Association of Governments (SANDAG) is used to create the macro-level model for the I-15 corridor. The macro model generates traversal O-D matrices that

are input to the meso- and microscopic models. Individual path assignments are generated for the mesoscopic model using DTA with dynamic user equilibrium. These path assignments are used by microscopic models for detailed simulation. Network Prediction System (NPS) is a subsystem of the DSS developed under ICM San Diego and is the predictive component of the simulation framework. NPS receives data in real time from ATMS, Regional Arterial Management System (RAMS), and Sensys. Along with real-time data, NPS uses network capacities and historical detector data as inputs. Offline calibration of NPS is conducted using historical data to reflect the historical trends on the network. Real-time detector data is used in the calibrated NPS to generate detector measure predictions. NPS, supported by Aimsun ONLINE, generates predictive scenarios based on archived data from PeMS and current network conditions. The goal of the NPS is to generate analytical forecasts within a 2- to 5-minute window for flows, occupancy, speeds, and demand optimization. NPS also uses microscopic simulation to generate 15-minute operational forecasts for full network MOEs, LOS, queue, and delay. NPS supports detection of congestion or incidents across the network. ICM demonstration in San Diego is now capable of predicting conditions for the next hour in 5-minute increments (a forecast for the next hour is created every five minutes). Upon predicting the conditions, approximately five response plans are evaluated with respect to the "do nothing" or the baseline scenario and the best response plan is chosen.

- **ICM Dallas.** he ICM demonstration site in Dallas, Texas, is pursuing a collaborative effort with Telvent, Southern Methodist University, and the Texas Transportation Institute (TTI) to test real-time DSS based on predictive modeling. The continuous assessment of system performance for a moving time-window is not part of the ICM AMS. Predictive capabilities, however, are being developed and tested as part of the DSS framework. The experimental setup consists of 27 test procedures and includes DSS and a prediction module. The pilot is being tested as identification of diversion response plans for incidents on US 75. Currently, 120 possible diversion response plans have been identified for the ICM playbook. Diversion response plans are modeled as incidents and the affected control devices. In the DSS framework, DalTrans keeps track of real-time system status and continuously evaluates the system based on rules within the Expert Rules Manager module. These rules are used to recommend diversion response plans. In the proposed framework, response plans proposed by the ICM coordinators can be deployed only after they are approved by stakeholders.
- **Smarter Traffic Initiative.** The Smarter Cities initiative by IBM and the LTA team in Singapore has led a successful pilot test of predictive assessment of system performance for a moving time-window. IBM's Traffic Prediction Tool (TPT) is a patent-pending technology for predicting traffic flows and speeds on road segments. TPT uses historical traffic data and real-time traffic input from the system to predict traffic flows and speeds for 10- to 60-minute time slices in the immediate future. TPT is based on a spatial-temporal model supported by data collected from a variety sources—from cars to transit networks. The spatial-temporal model is recalibrated weekly to adjust to the most recent trends in traffic. Field validation results of TPT's prediction accuracy in Singapore have shown promising results, with more than 85–93 percent accuracy for traffic volume forecasts and 87–95 percent accuracy for vehicle speed forecasts.

To summarize, recent implementations have shown significant promise in supporting capabilities to assess system performance in the anticipated future . The modeling and analysis techniques that are required are currently being researched and tested in offline settings. In recent years, the assessment of predictive system performance capabilities has been implemented and tested in field settings. Specifically, ICM demonstration sites in San Diego and Dallas use predictive tools to assess system performance under anticipated future conditions.

Evaluate Impact of ATDM Strategies

It is important to assess the benefits and other impacts including undesirable externalities of ATDM strategies from an operational point of view. The candidate ATDM strategies intended to mitigate the impending stresses on the transportation system affect the balance between supply and demand in numerous ways. These actionable strategies are at the core of ATDM, where the operator must use the best strategy or an optimum combination of multiple strategies that affect the demand-supply interactions favorably. The evaluation of each of these strategies is conducted in terms of the effectiveness of the strategy in bringing about the desired change in the set performance measures.

A DSS is a useful tool for the operators in situations where selection of the best strategy for the immediate future is paramount for the effectiveness of strategic actions. The FHWA Report "Multimodal Decision Support Systems (DSS) in Transportation Operations CONOPS" (May, 2011) identifies transportation-specific DSS technologies and methodologies and categorizes them as follows:

- **Table-based DSS.** These DSS use predefined response plans and require minimal processing, modeling, or analysis. They can include basic logic-based analysis of tabular data or can be as simple as lookup tables. Examples include Toronto COMPASS, KC Scout, and Georgia DOT NaviGAtor.
- **Knowledge-driven DSS.** These DSS require an expert system engine or custom rules to generate recommendations for response plans. Examples include California DOT (Caltrans) ATMS, Oregon DOT (ODOT) Transport, and PACE Transit Operations Decision Support System (TODSS).
- **Model-driven DSS.** These DSS incorporate real-time simulation and integrate tolling components. Examples include Singapore GLIDE, Madrid, Beijing, and Milan.

Few DSS for transportation management offer real-time operational capabilities as described below.

- **ICM San Diego.** The DSS subsystem of the ICM San Diego AMS framework is composed of response actions and management system constraints. A set of candidate action items across different control categories such as traveler information, traffic signal timing, and ramp metering are defined to be used as strategies to be tested on the DSS. For every event, a response posture matrix is built based on demand characteristics of the network and the corresponding impact of the action item. A *response posture matrix* is a matrix of combinations of multiple strategies combined at varying levels of implementation. Individual action plans from each control category—together—form a unique response plan. These response plans are the candidate strategies that are evaluated for their impact on performance measures to select the optimum strategy. The set of candidate strategies is evaluated by a business rules process management system based on business rules of decisionmaking. The decisionmaking process is supported by the predicted performance measures or MOEs generated by the system assessment modules, NPS, and the real-time simulation subsystem. These subsystems are supported by a suite of online and offline simulation tools by Aimsun.

- **ICM Dallas.** The ICM deployment site in Dallas, Texas, is pursuing a collaborative effort to test a real-time DSS based on predictive modeling. The experimental setup consists of 27 test procedures and includes the DSS and a prediction module. The pilot is being tested to identify Diversion Response Plans for incidents on US 75.
- **Smarter Cities.** The IBM Smarter Cities initiative has developed a Decision Support System Optimizer (DSSO) to help operators use massive amounts of transportation data and make informed decisions. The DSSO includes IBM's TPT, which provides traffic condition forecasts under normal or seminormal conditions. An incident detection module along with an Incident Impact Factor Evaluation component can assess link-by-link list of affected links and the degree of impact. The business rules for designing intervening strategies are provided by the DSSO Optimal Control Plan Generation module. The traffic prediction capability is used to calculate expected benefits under each DSSO-generated plan. The DSSO also offers flexibility to accept an operator-customized plan and evaluate its expected benefits. Though the field validation results of this capability are still awaited, a pilot deployment is soon to roll out in Lyon, France.

Current Capabilities

The evaluation of individual ATDM strategies involves capturing the impact of the strategies on the traveler behavior. Traveler behavior has been well researched and could be applied to various modeling approaches, such as traditional four-step models, tours/activity based models, and traffic simulation models.

Recent FHWA Report on 'Analysis of Network and Non-Networ Impacts upon Traveler Choice" (2012) has revealed that traveler behavior could be portrayed as a chain or a set of decisions made either in the short-, medium- , or the long-term. While long-term decisions depend on changes in land use, environment, place or residence, and place or work, short-term decisions depend on travelers' immediate perception of traffic conditions, available modes, time-of-day options available, or facility choice options. Long-term decisions also influence the lifestyles and mobility patterns of individuals. From a traffic management perspective, these decisions affect policy decisions that drive some of these factors. Short-term decisions are reflected in short-term changes in the traffic flow and speeds. From a traffic management perspective, these decisions are affected by the dynamic traffic management strategies, and hence are very relevant to study the impacts of ATDM strategies. This study has also revealed that socioeconomic factors influence travelers' decisions. Travelers also learn and adapt based on past experiences. This process, however, has a certain amount of choice inertia; that is, the travelers do not modify their choices immediately. Their affinity to modify their choice in the short term is low. These travelers, however, do modify their choice over a period of time. Travelers modify their choices when a substantially better choice is available such as a newly constructed freeway.

Integrated Modeling

Integration of different AMS tools to evaluate strategies has been a focus in recent years. The following presents recent studies that involve an integrated modeling framework:

- Under the recently completed Effective Integration of Analysis Modeling and Simulation Tools Project, FHWA has developed an open-source data hub that enables efficient information exchange and data transfer between models of different domain and scale. The research and discussion on integration of AMS tools in the ConOps report of this project has focused on increasing integration requirements for advanced ITS-related initiatives such as ATDM, ICM, and Connected Vehicles.

- Modeling studies conducted to support ICM Pioneer Site evaluations attempt to link macro-, meso-, and microscopic simulation models to capture the regional impacts of traffic operational improvements.
- The SHRP 2 C10A project partners are developing an integrated, advanced travel demand model with a fine-grained, time-sensitive network simulation for the Jacksonville, Florida, region. This project attempts to integrate the outputs from a detailed activity-based model (DaySim) with a TRANSIMS simulation model to assess regional transportation network performance. The SHRP 2 C10B project partners are developing a framework that integrates the Sacramento Activity-Based Travel Demand with DynusT Simulation Model. Theoretically, these models (that integrate activity based models with simulation models) developed as a part of SHRP 2 C10 program are more capable of quantifying the change in travel behavior in response to implementation of ITS strategies.
- Simulator of Transport, Routes, Activities, Vehicles, Emissions, and Land (SIMTRAVEL) is another universally applicable framework of methods, tools, and data structures that is designed to integrate land-use modeling, activity-travel behavior modeling, dynamic traffic assignment, and simulation. It is built on an open-source platform. Unlike other models that use sequential coupling between demand and DTA models, SIMTRAVEL uses tight coupling (as frequent as every minute) of demand and DTA models. SimTRAVEL is being currently applied and tested for the Maricopa County, Greater Phoenix region simulating a total of 14–15 million trips in the base year. Recently, SimTRAVEL was also used to simulate the impact of a temporary network disruption on activity-travel demand, thus demonstrating the efficacy of the modeling framework.
- The SHRP 2 L02 project has developed a performance measure to capture the reliability of travel time based on the deviation of actual travel time from the desired travel time. The Travel Time Reliability Monitoring System (TTRMS) focuses on using the incoming sensor data, along with supplemental information about the influencing factors, and creates a credible picture of travel time reliability.
- Integration of modeling platforms has also been used in Weather Responsive Traffic Management (WRTM) work. The integrated framework was tested on a network consisting of the I-95 corridor between Washington, DC, and Baltimore, Maryland, and bounded by two beltways. Three scenarios reflecting clear weather, moderate rain, and heavy rain were compared to illustrate the networkwide effect on road-weather conditions.

Predicting traveler behavior and travelers' response to dynamic actions is crucial in evaluating the impact of various ATDM strategies. Activity-based models are theoretically best suited to predict travelers' behavior changes; however, development of activity-based models requires a significant amount of time and resources.. Most agencies have attempted to migrate to an activity-based model by replacing certain portions of the four-step model; however, they have not been implemented as a comprehensive replacement. The impact of environmental factors such as weather is one of the behavior factors to be modeled in ATDM.

To summarize, capabilities to evaluate the impact of strategies are being developed to support decisionmaking across agencies. Some of these efforts also focus on developing a DSS module, as detailed in the aforementioned examples, which relies on a set of business rules that design or help the operators design the response plan. These response plans are evaluated for their expected benefits using the traffic prediction capabilities used in assessing system performance. The ICM demonstration sites in San Diego and Dallas along with the IBM Smarter Cities initiative have built frameworks for a DSS in the respective demonstrations. However, field implementation and subsequent validation of these DSS are yet to be performed.

2.3 Conclusions Regarding the Current AMS Tools and Methods

A review of relevant capabilities revealed the ability of current AMS practices to partially cater to ATDM AMS needs. The ICM demonstration sites in San Diego and Dallas are developing and testing the capabilities relevant to ATDM, and these projects can be seen as a representation of current AMS capabilities that align with ATDM AMS needs. It is observed that the capabilities for monitoring the system in real time and assessing system performance in the anticipated future are on a par with ATDM AMS needs, and they can be further advanced for future ATDM work. The interactions between supply and demand, however, are not extensively captured, and traveler behavior changes in response to dynamic actions are not exhaustively addressed. Although individual building blocks necessary to support ATDM exist with some level of maturity, no agency has an in-house capability to meet all the ATDM needs; additional tools and methods need to be developed and tested to evaluate the impact of ATDM actions.

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Chapter 3: Nature of Changes

3.1 Justification of ATDM AMS System

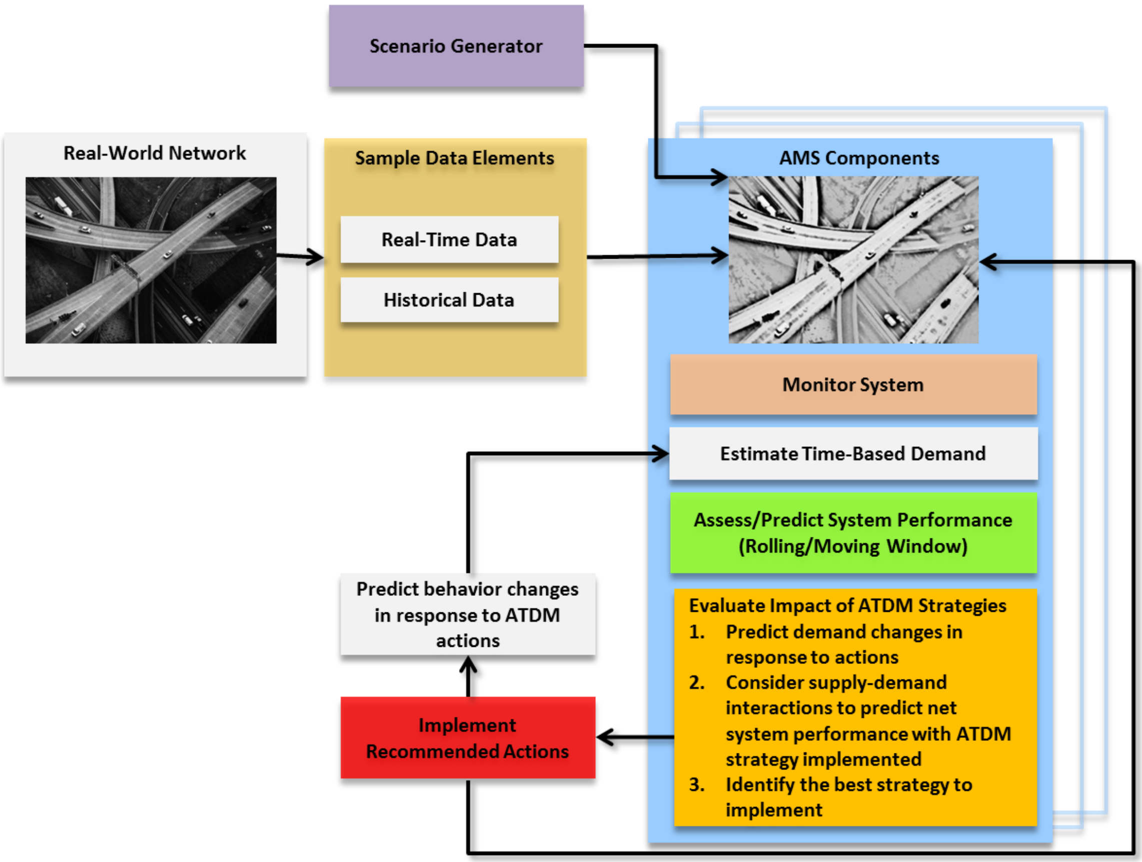
Chapter 3: provided an overview of the existing AMS system. Although existing AMS tools and capabilities have been evolving, an integrated AMS system that includes the full range of predictive capabilities to support ATDM evaluation does not exist. This section describes the justification for the new ATDM AMS system and identifies the AMS needs to monitor, assess, and evaluate ATDM strategies.

To commit resources, embrace the ATDM concept described in Section 1.3, and migrate from traditional transportation management practices to a more dynamic management practice, transportation agencies should be able to assess the benefits of an ATDM approach and its strategies. To support ATDM analysis capabilities, for each identified operational strategy and set of strategies, as well as scaled active management, a robust AMS system is needed. The AMS system will enable the testing of new, innovative traffic management strategies and assess their effectiveness in a laboratory environment. When fully in place, the AMS system will provide opportunities to test the impacts of new technologies and operational approaches prior to more expensive field testing and implementation. The core of the system consists of traffic analysis tools and methods that will be able to model supply/control aspects, demand/travel behavior aspects, safety-related aspects, and environmental-related aspects. This chapter describes the AMS system to support ATDM evaluation.

3.2 Description of Desired AMS System

To support ATDM evaluation, the AMS tools need to support high spatial and temporal fidelity. The tools need to accept a wide variety of data and provide accountability and real-time responsiveness if used for real-time operations. To support the planning/design phase, the tools should be able to conduct analysis in “simulated real time” by replicating real-time operations. These tools also need to capture user response at an individual traveler level and likely need to simulate individual travelers in addition to traffic. Although AMS is needed to support real-time operations and also to support the planning and design phase (using simulated real-time analysis), these are likely to be the same except that to support real-time operations the processing speed of AMS tools is critical and the tools should be able to support analysis several times faster than real time. In the case of evaluating ATDM for planning and design purposes using simulated real-time analysis, while the processing time of AMS tools is not as critical, it is necessary to have additional capabilities within the AMS system to estimate the potential impact of ATDM actions. The scope of the AMS system described in Chapter 4 is restricted to conducting simulated real-time analysis for planning and design purposes and ATDM evaluation in the near-term to mid-term time range (0–10 years), where existing ITS technologies and data collection mechanisms are used to dynamically manage the transportation system. Figure 3-1 shows the AMS system needed to support ATDM evaluation for planning/design purposes by conducting a simulated real time analysis. Even though the analysis for planning/design stages can be done using historical database, to capture the dynamic nature of ATDM concept it is desirable to use real-time data from the field as the input to the ATDM AMS system. The ATDM AMS system depicted below includes an embedded prediction system and will reside in a TMC or laboratory that is connected to the real-time data feed to support analysis.

Figure 3-1: ATDM AMS System Description for Simulated Real-Time Analysis to Support Planning and Design



Individual components are described here.

- **Scenario Generator.** The Scenario Generator creates the scenarios of interest (e.g., incidents, weather, work zone, event) for the analyst to consider for evaluation.
- **Monitoring the System.** The first step in AMS is to monitor the system in real time. Real-time traffic management requires present and future traffic state information. This information needs to be as complete and as accurate as possible. Today, traffic information is obtained from a variety of sources, such as inductive loops, video observation, and floating car data. All of these data acquisition techniques suffer from certain problems. For example, data \ collected from loop detectors can be intermittent and needs significant preprocessing and imputation. Thus, inductive loops and other local detection techniques do not provide information on the actual traffic state in terms of LOS or of queue lengths and delays. It was also shown that data from these sources is unreliable to a high degree . It is necessary to use traffic models and analysis tools to compute the traffic state in a consistent way because the measurements do not provide sufficient information or are to a certain extent unreliable,. To monitor the system, data is collected continuously from the real world using a variety of sources. Examples of data collected include vehicle counts, speeds, turn delays, transit ridership and occupancy, parking lot occupancy, weather, incidents, and work zones. In addition to real-time data, the historical data and transportation network data (e.g., highway lanes, signal systems,

turn restrictions, transit schedules) is also assembled to use as input to AMS to support dynamic management.

- **Time-Based Demand and Supply.** To predict traffic conditions, it is necessary to estimate current traffic demand and O-D relations from data on volumes and occupancies experienced in the network. The fluctuations on the supply side, such as incidents and time variant work zones, need to be considered in the analysis.
- **Assess and predict system performance.** Upon estimating time-based demand and supply, AMS is used to assess the current performance conditions and predict system performance in the future. This involves computing established system-level performance MOEs and comparing to targets. If targets are exceeded, then need to move to next step for evaluating actions to take. The length of the prediction window will depend on the agency preference and the applicable control strategies.
- **Evaluate and recommend dynamic actions*.*** Upon predicting the future performance, AMS is used to compare the predicted performance with the agency's goals or target performance measures. When the goals are not met, AMS will evaluate the impact of different ATDM strategies and recommend the best strategy to implement.
- **Implement the actions.** In real-world implementation, Traffic Management Centers (TMC) or the operator implements the recommended action and continues to monitor the system in the next moving window. For planning and design purposes, AMS is used to predict the dynamic behavior changes (e.g., route choice, mode choice, time-of-day choice) associated with the implementation of the particular strategy or set of strategies, and the anticipated changes are then used to update or adjust the anticipated or forecasted demand.

3.3 Description of ATDM AMS System Needs

For ATDM modeling, the modeling framework needs to consider both the demand and the supply side. On the network supply side, it is important to model the change in network supply or capacity, and on the demand side, it is necessary to capture the change in traveler behavior in response to implementation of dynamic actions. Also essential is capturing the dynamic interaction between supply and demand and how the changes in supply affect different steps of the trip chain. Reproducing the characteristics of the transportation system is essential for realistic forecasting of future demand and performance. Models need to accurately reproduce the underlying phenomenon or at least their impact. One primary challenge is to model traveler behavior and understand user response to dynamic management strategies. In particular, many ATDM strategies are designed to influence short-term behavior, such as in response to an incident or weather event. It is important to understand how ATDM strategies will influence the intended outcome in the short term but also how those short-term dynamic actions can influence long-term, habitual traveler behavior.

Prediction is essential for any real-time traffic management system, and new sources of available data and emerging technologies provide excellent opportunities to predict future network conditions. Prediction capability should be embedded in the modeling approach.

Section 2.1 describes the generic AMS capabilities as they are used in practice today. Although the available behavior models and traffic simulation tools can be used to support ATDM evaluation in various degrees of applicability, special considerations are needed to evaluate impact of dynamic action using ATDM strategies. These considerations include the following:

- **Performance measures.** Performance measures need to be derived from the ATDM goals and objectives to determine the nature of data needed for the analysis. Such measures might include speeds, volumes, travel times, travel time variability and reliability, accident rates, emissions, stopped delay, mode choice (e.g., percent carpooling or using buses or trains), and percentage of commercial vehicles.
- **Data considerations.** A variety of data inputs need to be accommodated to support ATDM evaluation. For example, in addition to real-time fixed data points, the modeling and simulation tools need to be able to incorporate real-time information from transportation system.
- **Model ATDM concept and the strategies.** The modeling and simulation packages need to be able to directly model specific ATDM concepts with predictive capabilities, ranging from peak-hour shoulder usage to dynamic speed limits to HOV. In addition, to model the ATDM concept and the impact of individual strategies, it is necessary to model how ATDM strategies impact different elements on the trip chain (e.g., destination choice, time-of-day choice, mode choice, route choice, and lane/facility choice).
- **Consider Human Factors.** Tools need to be able to incorporate human factors or user acceptance. For example, the model(s) should be able to address the particular percentage of drivers responding directly to real-time messaging (e.g., variable speed limits, rerouting, lane closures).
- **Run-Time Performance.** The ability to run faster than real-time and model changes in conditions is needed to support dynamic management. Although this is a critical need for real-time operations support, it is not a critical need for offline analysis or planning purposes.

To build the AMS system described in Section 3.2, the following AMS needs should be met. The needs have been categorized under the following subcategories:

- Monitoring the system in real time
- Assessing or predicting system performance in a moving window
- Evaluating multiple ATDM strategies under each possible scenario.

Note that the needs described in the following section represent the typical AMS needs that are likely to be applicable for most situations for evaluating ATDM, but the specific needs for ATDM might change depending on the specific evaluation scenario.

AMS Needs for Monitoring the System

To support dynamic management through ATDM, the fundamental need is to monitor the transportation system continuously and generate performance measures (e.g., speeds, delays, travel time reliability, vehicle and person throughput, emissions, crash rates) that align with the agencies' goals and objectives. To generate these performance measures, the AMS tools need process data from various real-time and historical sources. Sample data from the real world to monitor the system includes:

- Transportation network data (e.g., signal timing plans, turn restrictions, toll rates, transit schedules)
- Data to determine available roadway capacity (e.g., lane restrictions, parking lanes, shoulder lanes)

- Traffic counts (by SOV, HOV with two people or more [HOV-2], HOV with three people [HOV-3])
- Transit data (e.g., transit ridership, transit schedules)
- Link speeds
- Turn delays
- Emissions.

Table 3-1 describes the AMS needs for monitoring the system.

Table 3-1: AMS Needs for Monitoring the System

ID	AMS Need for Monitoring the System	Description	Criticality to Meet the Need
M.1	Collect and process real-time data from a variety of sources	*ATDM evaluation will require access to real-time or near-real-time data from multiple data sources, agencies, and transportation modes. Upon completion of analysis, data further needs to be archived to support future analysis.* Transportation and nontransportation-related real-time data can be collected from a variety of sources, including loop detectors, video cameras, weather stations, TMCs, transit operators, private transportation data providers, and fare collection systems. To support simulated real-time analysis, while archived and preprocessed data can be used for analysis, using real-time data will mimic the real-world implementation more closely. To support real-time operations, the AMS system needs to process the data collected from these different sources in real time.	High
M.2	Collect and process historical data from a variety of sources	*ATDM evaluation will require access to historical data from multiple data sources, agencies, and transportation modes.* Historical data needs to be analyzed to build baseline models, support analysis, and provide necessary inputs to predictive analysis tools. AMS system needs to support analysis of data that is archived using different procedures across different agencies in terms of method of storage, structure of database, accessibility, and granularity of the database. Historical data can be preprocessed and be made available for ATDM evaluation in a ready-to-use format.	High
M.3	Need to access transportation network supply (e.g., both highway and transit) data from a variety of sources	*ATDM evaluation will require data on the supply side of the transportation network from transportation agencies. This data is required as input to models in the AMS framework.* Transportation network supply data includes data collected from GIS resources, data on turn prohibitions, turn lanes, signal timing data, phasing plans, lane restrictions, transit routes, schedules, lane closures, parking, and other types of data. Typically the regional planning agencies and operators have access to this data. The AMS system needs to be able to assess the transportation network supply from these different sources.	High

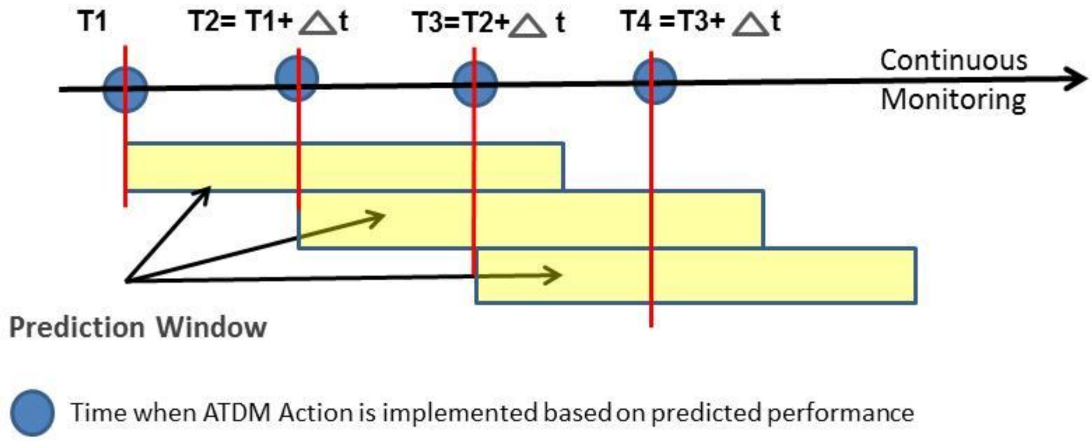
ID	AMS Need for Monitoring the System	Description	Criticality to Meet the Need
M.4	Need to generate the desired performance metrics to monitor the current traffic conditions of the system	*Postprocessing and analytical procedures are required to translate real-time and historical data into performance measures that can be used to monitor performance of the entire region of interest in real time or simulated real time.* To support ATDM, the AMS system needs to process data collected continuously from a variety of sources (by modes; agencies; and different systems, such as freeways, arterials, and parking) from the real world and process data in real time using analytical tools to generate desired performance measures that align to agencies' objectives, such as travel speeds, delays, queue lengths, crash rates, and emissions for the entire region of interest.	High
M.5	Need to integrate data collected from different sources	*Seamless integration and consolidation of data coming from a variety of sources is required to build a structured, accessible data structure that can serve as the single go-to data pool for all AMS tools.* Inconsistencies in format, structure, and temporal and geospatial granularity in data collected from different sources need to be addressed. Relational links need to be established between different databases to create a complete database that can support an integrated analysis.	High
M.6	Need visualization capabilities to support analysis	*Visualization tools will be required to depict the insights from analysis and simulation in graphical medium. Visualization tools will condense large amount of insights in a most efficient manner to present a clear representation of the system performance (e.g., throughput, speeds).* Tools are required to visualize simulated real-time conditions on the transportation network, such as speeds and delays, for identification of critical locations that require detailed analysis.	Medium
M.7	Need to understand demand patterns	*Time-dependent demand patterns need to be generated based on real-time data as well as historical knowledge to support modeling efforts in ATDM to monitor the system in real time.* To monitor the transportation system in real time and to forecast future conditions based on anticipated supply and demand changes, time-dependent O-D trip matrices by mode need to be generated by the AMS system.	High

ID	AMS Need for Monitoring the System	Description	Criticality to Meet the Need
M.8	Need to validate the data before analysis	*Rigorous validation techniques are required within the AMS system to ensure the quality of real-time data before analysis. This involves imputation of missing values and correcting erroneous/improbable observations.* Data validation and cleansing methods are needed to clean up and use the data for monitoring the system. Valid data should be used for monitoring the system so that the current monitoring and future performance can be estimated with some level of confidence.	High
M.9	Support the required analysis scale, both temporal and spatial	*The AMS framework needs to support required temporal and geospatial granularities for ATDM evaluation.* Data from different agencies and systems received in different geographic and time scales needs to be integrated in the AMS system to support the desired analysis scale (e.g., 5-minute or 15-minute time scale for monitoring). To achieve this goal, the AMS system needs to complement contributing data sources.	High
M.10	Auto-correct or self-validate based on the latest data.	*Some level of automation would be required to ensure self-validation and auto-correction of data collected in real time.* The modeling framework in the AMS system needs to reflect the most recent changes in the network by self-adjusting to the network conditions. This will require the AMS system to include recurring self-validation techniques and procedures.	Medium
M.11	Capture uncertainty in data used to monitor the system	*The AMS system needs to capture uncertainties in data collection, availability, and accuracy (on both the demand and supply sides).* The modeling framework in the AMS system needs to reflect the fact that *inherent uncertainties exist with all methods of data collection and processing techniques* and this uncertainty should be explicitly considered during the monitoring stage.	High

AMS Needs to Assess System Performance

One of the core elements of ATDM is to monitor the system on a continuous basis and take dynamic actions, based on anticipated future conditions, before the system performance deteriorates. To achieve this goal, AMS tools should assess the current performance conditions and predict system performance in the future in a moving time-window. Figure 3-2 illustrates this concept where the system is monitored using a moving prediction window. The length of the prediction window can vary depending on the performance goals against which the system is monitored, type of strategies being considered, or the agency preference. For example, if dynamic congestion pricing is considered as an ATDM strategy to implement, it is necessary to capture a longer time window to capture the peak spreading effect. In Figure 3-2, *t* represents the time difference between consecutive analysis time steps (e.g., between T1 and T2).

Figure 3-2: Illustrative Example of Future System Performance Using a Moving Window



AMS needs to assess and predict system performance in a moving window using the current, forecasted, and historical information, are described in Table 3-2.

Table 3-2: AMS Needs for Assessing System Performance

ID	AMS Needs to Assess System Performance	Description	Criticality to Meet the Need
A.1	Use both real-time and historical data to support analysis at the desired geographic and temporal scales.	*The AMS system needs to leverage most recent knowledge from real-time data as well as trends from historical data to support analysis at the desired geographic and temporal scales.* AMS system needs to support ability to use both real-time and archived data in an integrated manner either at the regional or corridor level for desired analysis scale (peak hour, peak period, daily)	High
A.2	Continuously predict network conditions in a moving window	*The AMS framework must include a predictive model that updates itself based on recent data and continuously predicts network conditions, such as link volumes, speeds, delays, in a moving time-horizon window.* The AMS system should include predictive tools and methods that continuously forecast network conditions and predict future network conditions, such as link volumes, in a moving window (say, for example, forecast for the next 20 minutes in a 5-minute moving window).	High
A.3	Generate performance measures and check if they meet agencies' goals and objectives.	*ATDM evaluation will need to predict anticipated conditions in the immediate future and assess those conditions in terms of performance measures that align with the objectives of the operating agency.* The AMS system must be able to use the anticipated network conditions, such as flows and speeds, to generate a variety of anticipated performance measures, such as speeds, delays, crash rates, emissions, and travel time reliability in real time at a local, corridor, or regional level as desired.	High

ID	AMS Needs to Assess System Performance	Description	Criticality to Meet the Need
A.4	Need to consider possible demand and supply changes in the forecast period and their net impact on the system performance	*To forecast future network performance measures accurately, the AMS system needs to consider the impact of possible changes in both demand side and supply side on overall system performance in the forecast period.* The AMS system needs to include forecasting methodologies that can use real-time data in conjunction with the historical data to estimate possible changes in demand and supply within the immediate forecast period to forecast conditions accurately.	High
A.5	Need to explicitly capture human factors and their impact on the network demand	*The AMS system needs to explicitly incorporate human factor elements, such as user preference, trust, understanding and compliance in decisionmaking within in the modeling framework.* Use understanding of human factors, such as behavior and decisionmaking to variable message signs, incidents, weather, and work zones, to predict the near-term performance. Incorporating human factors in modeling the demand-supply interaction will lead to more accurate reflection of real-world interactions.	High
A.6	Need to capture uncertainties in the demand and supply	*The AMS system needs to capture uncertainties in data collection, availability, accuracy (on both the demand side and supply side) as well as lack of knowledge on human factors in the AMS framework.* Inherent uncertainties exist with all methods of data collection and processing techniques. In addition, there are a lot of unknowns in modeling human factors accurately. The model and tools need to consider uncertainties in daily decisionmaking (e.g., trip start time flexibility, transit delays) and their impact on the predicted demand and supply changes.	High
A.7	Support interactions between demand and supply for multimodal trip chain analysis.	*ATDM evaluation will need modeling and analysis of multimodal trip chains and activities and multimodal ATDM strategies on the demand side.* The AMS system needs to include multimodal integrated analysis capability and consider demand and supply interactions for all modes (SOV, HOV-2, HOV-3+, transit) to accurately capture mode choice impacts and other demand changes across different modes.	High

ID	AMS Needs to Assess System Performance	Description	Criticality to Meet the Need
A.8	Explicitly model transit operations impacts on highway system performance.	*ATDM evaluation will need to consider impacts of transit operations (e.g., bus stopping at a bus stop or increasing the bus frequency) on system performance and overall transportation demand.* The AMS system needs to incorporate transit operations (e.g., buses, light rail, Bus Rapd Transit) in the real-time modeling component of ATDM to model the impact of transit operation strategies on travel demand. The AMS system also needs to capture the impact of bus operations on overall network performance.	Medium
A.9	Include visualization capabilities to display forecasted network conditions	*Assessing system performance in the forecasted future conditions will require a user-friendly graphical user interface (GUI)/API that can help operators draw insights from the analysis with ease in simulated real time and offer easy-to-use channels to alter or implement their strategies.* The AMS system needs to include visualization tools to display predicted network conditions in a variety of easy-to-understand, insight-rich graphics, in conjunction with the network conditions in simulated real time. The tools must facilitate easy visual identification of the performance measure	Low
A.10	Calibrate/validate the tools to estimate the impact of anticipated demand and supply changes	*Some level of automation would be required to calibrate/validate the tools used for estimating future network conditions based on the anticipated changes in demand and supply.* The modeling framework in the AMS system needs to reflect the behavior changes in response to anticipated changes in the network demand and supply conditions . This need will require that the AMS system include procedures that ensures that the tool used are calibrated and validated to estimate future conditions reasonably well.	High

AMS Needs to Evaluate and Recommend Dynamic Actions

Upon assessing system performance, AMS tools will be used to evaluate and recommend implementation of ATDM strategies. Key AMS needs for achieving this objective are shown Table 3-3.

Table 3-3: AMS Needs for Evaluating and Recommending Dynamic Actions

ID	AMS Needs to Evaluate and Recommend Dynamic Actions	Description	Criticality to Meet the Need
E.1	Identify the ATDM strategy or a group of strategies to implement	*The AMS system needs to include an automated algorithm or a dynamic set of business rules that can identify the best or optimal strategy to implement, when to implement it, and where to implement it. To select the best strategy, multiple alternatives must be tested simultaneously.* The AMS system must identify best-suited ATDM strategies to implement (i.e., replicate a DSS) by using modeling tools that can determine the impact of alternative ATDM strategies. The system needs to compare predicted future performance against the ATDM strategy and the baseline predicted condition to determine the net impact. Tools must be able to capture the impact of a variety of demand management, traffic management, and parking management strategies and consider how the dynamic action implemented affects different parts of the trip chain.	High
E.2	Model the impact of the ATDM strategy on different elements of the trip chain	*ATDM evaluation will require modeling the impact of individual ATDM strategies on the decisionmaking processes involved in different parts of the trip chain.* The AMS system must model traveler behavioral changes, such as destination choice, mode choice, time-of-day choice, and route choice, in response to dynamic ATDM strategies (short term for real-time operations and both short term and long term for planning purposes).	High
E.3	Model microscopic driver behavior changes resulting from dynamic actions, as applicable in the subarea of interest (e.g., for variable speed limit)	*Microscopic components of the ATDM AMS framework will need to model all the components of driving behavior at the individual driver level.* The AMS system must include capabilities to model driver behavior changes (e.g., car following, lane changing, merging) in response to ATDM strategies, as applicable. Depending on the strategies tested, regional-level impacts resulting from microscopic driver behavior changes must be estimated.	Medium

ID	AMS Needs to Evaluate and Recommend Dynamic Actions	Description	Criticality to Meet the Need
E.4	Model the demand-supply interactions resulting from implementation of ATDM strategies	*ATDM evaluation will need the modeling component to capture impacts of dynamic actions and strategies on the demand and supply sides of the transportation system.* The AMS system must capture demand and supply changes in response to the implementation of dynamic actions and capture the interaction between demand and supply and the net impact of implementing multiple strategies together.	High
E.5	Consider anticipated behavior changes to predict future performance	*The AMS system needs to capture the human factor component to develop a predictive capability that can forecast anticipated changes in behavior under future conditions.* The predictive component used to assess system performance in the moving time-window must be supported with human factor modeling that can forecast anticipated changes in traveler behavior in the future. For example, the AMS system must capture user acceptance of traveler information, such as route guidance and multimodal traveler information, when predicting the impact of ATDM strategies.	High
E.6	Support multiple spatial and temporal extents of analysis (e.g., region, corridor, peak period, peak hour)	*ATDM evaluation will need seamless integration of all of the components along the geographic and temporal dimensions. This integration must support consistent and reliable exchange of data, results, and information across different models and levels of analysis.* The AMS system must support different geographic (extent of the region considered) and temporal (time interval considered) extents. Certain strategies, such as congestion pricing, can have regional impacts, whereas strategies, such as arterial signal timing, are likely to have a localized impact. The system must be sensitive to these differences.	High

ID	AMS Needs to Evaluate and Recommend Dynamic Actions	Description	Criticality to Meet the Need
E.7	Validate the network performance conditions	*Some level of automation would be required to ensure that the anticipated network conditions are validated using data from past experience or historical observations.* The modeling framework in the AMS system needs to ensure that the impact of the ATDM strategy is captured reasonably well with desired level of confidence. This need will require that the AMS system include recurring real-time calibration and validation techniques and procedures.	High
E.8	Include visualization capabilities to display forecasted network conditions with the ATDM action	*Evaluating impact of dynamic actions in the forecasted future conditions will require a user-friendly graphical user interface (GUI)/API that can help operators draw insights from the analysis with ease in simulated real time and offer easy-to-use channels to finalize the strategies to be implemented.* The AMS system needs to include visualization tools to display predicted network conditions in a variety of easy-to-understand, insight-rich graphics, in conjunction with the network conditions in simulated real time. The tools must facilitate easy visual identification of the performance measure.	Low

Chapter 4: Concept for the ATDM AMS

This section provides an overview of the ATDM AMS system to evaluate the impact of ATDM strategies for the purpose of planning and design using a simulated real-time analysis.

4.1 Background, Objectives, and Scope

Background

As described in Chapter 1:, ATDM is the dynamic management, control, and influence of travel demand, traffic demand, and travel flow of transportation facilities. In the ATDM approach, transportation system performance is continuously monitored at both microscopic and macroscopic levels, and the gathered data is used in real time to deploy actions or strategies that are best suited for the prevailing or impending conditions. The goal of this dynamic monitoring and influencing of the transportation system is to preemptively negate or delay the onset of impending unfavorable conditions and to optimize the efficiency and safety of the transportation system. Examples of ATDM strategies include dynamic speed limits,, dynamic shoulder lanes, adaptive signals and ramp meters, dynamic merge control, queue warning, dynamic pricing, and APM. Each is potentially transformational to agency operations, emphasizing the importance of implementing the ATDM vision.

Current transportation management practices have historically been reactive, at best, monitoring traffic conditions and reacting with changing operations. Traffic operations and traffic safety can further be enhanced by taking a proactive approach to avoid undesired traffic conditions. This requires a combination of reactive and predictive operation activities where the transportation system has a more direct role in guiding users than merely informing them of traffic conditions. The demand for transportation is envisaged as a chronologically sequential or step-wise process. The transportation demand typically begins with a user deciding to make a trip followed by mode choice, route choice, temporal choice, and at a further microscopic level, by lane choice. The underlying idea of ATDM is to use the AMS capabilities in an integrated manner to model and predict these choices made by the user, capture the supply/demand relationships, and use these predictions to take necessary preemptive counteractions.

Objectives and Scope of the AMS System

Although several AMS tools exist, a systematic framework to evaluate the full impact of a dynamic management approach with predictive capabilities is lacking. The objectives of the ATDM AMS system being presented in this chapter are to overcome limitations and provide a generic concept that can be used to test the benefit and value of the ATDM concept and evaluate the impact of dynamic management and operations strategies during the planning and design stages. In particular, that proposed AMS system can be used to—

- Evaluate the net benefits of a proactive management system
- Quantify the impacts of different ATDM strategies described in Section 1.3 and their impact on different elements of the trip chain
- Conduct sensitivity analysis and identify the best set of strategies that can help the agency achieve systemwide or regionwide goals for single agency or under a multi-agency collaboration

- Support the development of a future simulation test bed to evaluate the impacts of the ATDM concept.

4.2 Constraints

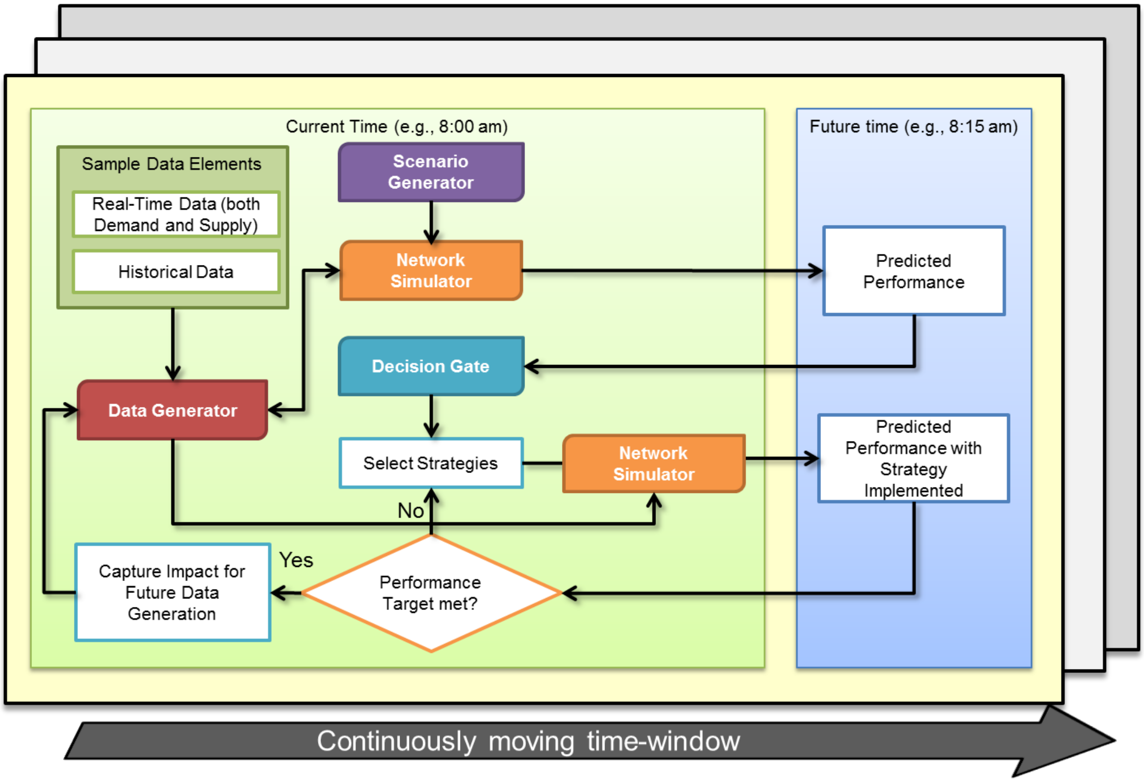
The application of the AMS system to evaluate the impacts of ATDM strategies will initially be limited by the following:

- Limitation in historical data availability and quality to adequately process the data and generate the performance metrics needed (speeds, delays, queue lengths, crashes, emissions) to monitor the system in a simulated real-time analysis
- Inadequate understanding of the impact of dynamic ATDM actions on traveler behavior and how to quantify the impacts that the actions have on different elements of the trip chain
- Ability to seamlessly integrate behavioral models with network supply models
- Ability to model supply/control aspects, demand/travel behavior aspects, safety-related aspects, and environment-related aspects
- Ability to validate the modeling tools to match dynamic conditions of the network
- Ability to generate desired network performance measures
- Lack of practical knowledge and experience of the current agencies to develop, design, and deploy an AMS framework of such complexity with empirical success and high fidelity. The only current work by government agencies that is closer to the ATDM paradigm is the ICM project. The AMS work at ICM demonstration sites Dallas and San Diego is under development and has achieved some of the ATDM needs (such as predictive capabilities to evaluate strategies in real time) with satisfactory success.
- Commercial traffic simulator models are hard-wired and cannot be customized for specific scenarios or strategies. Enough guidance should be made available to allow users to develop an API to override the default settings in the commercial tools (e.g., change the driving behavior and signal system operations specific to the strategy).

4.3 Description of the Proposed AMS System

The proposed ATDM AMS system to support simulated real-time analysis is shown in Figure 4-1. As previously described, even though the analysis for planning/design stages can be done using historical database, to capture the dynamic nature of ATDM concept it is desirable that the real-time data from the field be used as the input to the ATDM AMS system. The ATDM AMS system depicted in Figure 4-1 includes an embedded prediction system and will reside in a TMC or laboratory that is connected to the real-time data feed to support analysis. In the ATDM approach, the system is continuously monitored and the analysis is carried for the entire analysis period using a continuously moving time window, as discussed in Figure 3-2. The AMS system described will use real-time data, which can be either directly fed as the input for ATDM eveluation or data collected in real time, archived, and used at a later stage as a historical database. In either approach, the dynamic nature of ATDM concept is captured by using the real-time data.

Figure 4-1: ATDM AMS System for Simulated Real-Time Analysis



The AMS system consists of the following primary components:

- Scenario Generator
- Data Generator
- Network Simulator
- Decision Gate.

Figure 4-1 shows how the different components of the ATDM AMS system interface with each other to support simulated real-time analysis. A Scenario Generator creates multiple scenarios (e.g., lane closures due to incidents, work-zone conditions) of interest to the analyst. The Data Generator component of the AMS system accepts real-time and historical data from multiple sources and modes. Data Generator creates the necessary inputs for analysis and monitoring of the system and provides the inputs to the Network Simulator, which replicates the real world in a simulation setting. A performance interpreter within Network Simulator generates performance metrics (e.g., travel time reliability, travel times) of interest to monitor the system. Upon successfully monitoring the system in real time, a prediction window for future forecasted conditions is created (e.g., at current time step 8:00 AM, network conditions are evaluated for time step 8:15 AM). The forecasted future conditions are compared with agencies' goals at Decision Gate (at current time step) to determine requirement of ATDM action. If the performance goals are met at the future time step, no action is taken and the Network Simulator is used to continuously monitor the system. If the forecasted performance does not meet the agency goals, a set of dynamic actions to implement is selected, and selected strategies are re-created in the Network Simulator to forecast a new performance metric with strategy implementation. The net impact of strategy on different elements of the trip chain are captured and used to adjust estimated demand in the next time-window by Data Generator. The process is progressively repeated during desired time durations.

Key elements of the AMS system are described in the following sections.

Scenario Generator

The Scenario Generator component of the AMS creates multiple scenarios for the analyst to choose for simulated real-time analysis. These include train delays, lane closures due to incidents, work-zone conditions, special events, such as a game day and inclement weather conditions as they can occur in the real world. A user of the AMS system can use the Scenario Generator to create situations of interest under which impact of ATDM action is to be tested. Scenario Generator provides the necessary demand and supply adjustments to the Network Simulator component, which re-creates the real world in a simulation environment.

Data Generator

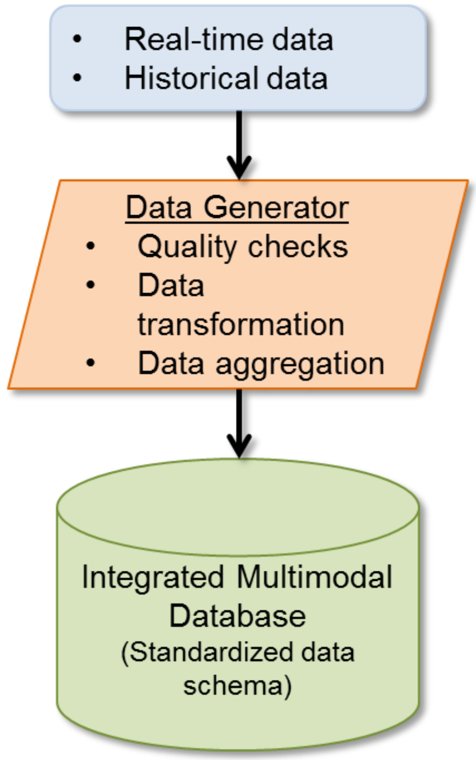
Data Generator is an important component of the AMS system and serves as an interface between the real world and the Network Simulator component. The Data Generator continuously receives the data from the real world in real time. The Data Generator processes the real-time and historical data and generates the data needed to monitor and assess the transportation system using the virtual/simulation world. A variety of data inputs that are collected continuously from the real world are processed using analytical tools to feed into the ATDM AMS system. Example data from the real world and archives include the following:

- Transportation network data (e.g., signal timing plans, phasing plans, cycle offsets, lane restrictions, turn restrictions, toll rates, transit schedules, parking restrictions)
- Traffic counts by facility or lane (by SOV, HOV-2, HOV-3)
- Transit ridership and transit schedules
- Link speeds and occupancies
- Turn delays
- Emissions
- Weather
- Incidents
- Work zones
- Other data, such as social networking data, ferry data, and airport data.

The most important step to effectively monitor transportation systems in real-time is data analysis. Data collected from different sources must be filtered, cleaned, integrated, and preprocessed to make it usable for dynamic management. Real-time system monitoring begins the analysis of incoming real-time traffic data and historical data to infer traffic conditions and performance measures of interest (such as travel time delays, average speeds) across the region.

Data from various types of sensors across different modes of travel is collected and aggregated. Each type of sensor outputs data in different formats. The Data Generator converts this data into a standardized format (expected by demand and traffic assignment models) for use by the Network Simulator. Figure 4-2 shows how the Data Generator processes the data.

Figure 4-2: Data Processing and Integration



To support ATDM evaluation, the Data Generator:

- Receives real-time traffic data and historical traffic data
- Receives real-time weather-related data that affects traffic flow, including:
    - Visibility
    - Icy and slippery conditions
    - Roadway segments treated for snow
    - Debris blocking roadways
    - Traffic sign visibility.
- Generates the data needed by the Network Simulator
- Feeds data to the Network Simulator
- Receives data from the Network Simulator to prepare data for the next time-window
- Assembles data needed to continuously validate the tools used in the Network Simulator.

The Data Generator processes real-time data into a standardized data schema and updates the Integrated Multimodal Database that will contain the historical and real-time data updates in a standardized format and consistent geospatial-temporal granularity. The Data Generator continuously communicates and feeds data to the Network Simulator during the system monitoring stage. Once the modeling is completed in the Network Simulator, the Data Generator receives the data for the window of current movement of vehicles from the Network Simulator. This data is used by the Data Generator to capture the driver behavior and traveler choices as modeled in the Network Simulator and to update the data for the next time-window. The next section describes the Network Simulator and its interactions with the Data Generator.

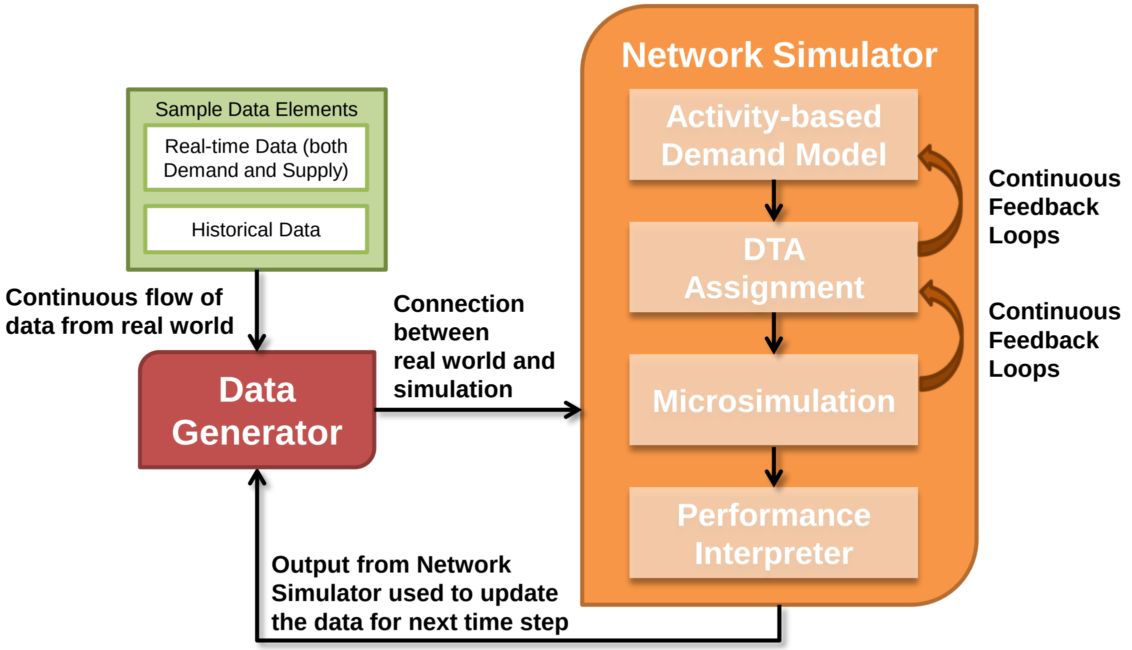
Network Simulator

The Network Simulator component re-creates the real world in a simulation environment and supports simulated real-time analysis. The Network Simulator continuously receives data from the Data Generator in real time. To monitor, assess, and evaluate the system performance in response to implementation of ATDM actions, the Network Simulator:

- Uses data from the Data Generator and supports multimodal integrated analysis capability and considers demand and supply interactions for all modes and supply characteristics (SOV, HOV-2, HOV-3+, transit, parking)
- Computes performance measures and interprets these measures
- If ATDM actions are to be tested, evaluates the impact of implementing the strategies
- Feeds back data to the Data Generator for the Data Generator to generate data for the analysis next time-window.

The data generated by the Data Generator is used as input to the virtual/simulation world in the Network Simulator that is a representation of the real world in a simulation setting. Network Simulator uses the data from the Data Generator to create time-dependent demand data and network supply data and is used to conduct multimodal integrated analysis. The Network Simulator will likely include a multi-resolution analysis framework that includes a macro model for demand estimation and traffic assignment models, with tight integration between the demand estimation and traffic assignment components. To capture the dynamic nature of the ATDM concept, an advanced demand estimation model (that generates time dependent activity patterns) and advanced traffic assignment models need to be linked in a tightly integrated manner so that a constant communication occurs between the demand model and traffic assignment model within the time-window. Tight integration will ensure that trips are routed on the network as they are generated by the activity model and activity patterns of individual travelers are dynamically updated based on real-time traffic conditions. Figure 4-3 shows the high-level process flow for monitoring the system in a simulated real-time setting.

Figure 4-3: Network Simulator



Network Simulator is a critical component of the AMS system and is used to monitor the system in real time, predict future system performance, and evaluate impact of dynamic actions. Provided in the following section is a brief description of how the Network Simulator supports these activities.

Monitoring the System

For the current time step (e.g., 8:00 AM), data from Data Generator is used by the demand model in the Network Simulator to produce activity patterns by mode (drive alone, carpool, and transit) with individual traveler departure and arrival times. The output from the demand model (trips by individual trip start and end times and mode) are then used as an input to traffic assignment model that assigns passenger car/transit trips onto the network to generate flow distributions due to time-varying congestion throughout the entire network. The output from traffic assignment model will result in travel times for all links in the entire region for the current time step. The traffic assignment results are fed back to the demand model to adjust activity patterns, and convergence is achieved between network conditions and activity generation in real time. The outputs from the traffic assignment are validated with the real-time data that is provided by the Data Generator, and demand and traffic assignment tools are calibrated to produce vehicle flows that match the ground conditions. When the traffic assignment results match the real-time data, current movement of vehicles on the network is created. The movement of vehicles is then sent back to the Data Generator, where the data will be used to update the data fed to the Network Simulator for the next time step (e.g., 8:01 AM).

The Performance Interpreter within the Network Simulator will use the output from the traffic assignment tools at every time step (e.g., 8:00 AM) to produce a variety of anticipated performance measures, such as speeds; delays; crash rates; emissions; and travel time reliability at a network, corridor, or regional level as desired. A calibration module compares the output performance metrics with the MOEs from real-world data and ensures that the models/tools used for monitoring system performance are calibrated on a regular basis for each time step.

Predicting Future Performance using Network Simulator

Once the current movement of vehicles is created and the system is monitored successfully in simulated real time, a predictive window (e.g., 20 minutes) will be used by the Network Simulator to identify potential problems or breakdown traffic conditions. The demand model in the Network Simulator generates future predictive activity patterns by mode (drive alone, carpool, and transit) with individual traveler departure and arrival times. The predicted activity patterns from the demand model (trips by individual trip start and end times and mode) are then used as an input to traffic assignment model that assigns passenger car/transit trips onto the network to generate future flow distributions due to time-varying congestion throughout the entire network. The output from traffic assignment model will result in forecast travel times and performance measures for all links in the entire region. The traffic assignment results are fed back to the demand model to adjust forecast activity patterns, and convergence is achieved between network conditions and activity generation.

Assessing Impact of Strategies

Creation of a current and predictive moving window allows the monitoring of the transportation system in virtual real time. If a problem is not identified in the predictive moving window, the information is sent to the Data Generator to update the data at the given time interval. If a potential breakdown is identified in the predictive moving window, a Dynamic Action needs to take place, in advance, to prevent the breakdown. In this case, the dynamic actions are implemented in the Network Simulator and the multi-resolution model is used to evaluate the new performance measures in the predictive moving window. The impact of ATDM actions on different elements of the trip chain are captured to predict the network performance changes with the action implemented. The vehicle movements on the network, with a specific ATDM strategy in place, will then be fed back to the demand until convergence is reached between the demand and the traffic assignment model. The new driver and traveler behavior data that result from the ATDM strategy will be sent to the Data Generator, where the real-time data will now be updated to reflect the behavior changes. The steps are repeated every time interval for the duration of the analysis period to evaluate the ATDM approach with the dynamic actions in place.

The strategies are manually implemented (for analysis purposes) in the multi-resolution model in the Network Simulator, where the vehicle movements on the network will be simulated at the microscopic level to capture the operational impact of dynamic actions (e.g., change in speed limit, use of shoulder lane). Upon selection of the set of strategies to use, the behavior changes associated with the selected strategies are captured using behavior models, and the supply and the demand data generated by the Data Generator for the next time period is adjusted to reflect the behavior changes (e.g., destination choice, time-of-day choice, mode choice, route choice, lane choice). The adjusted demand and supply estimates are used as input for the Network Simulator, and the performance interpreter is used to analyze the results and generate MOEs upon implementing the ATDM actions. The forecast MOEs, with and without implementing the ATDM actions, are used to quantify the net impact of an ATDM action. If the new MOEs do not meet the agencies' performance targets, a new set of strategies is selected and tested using the Network Simulator. Upon deciding the final set of ATDM strategies to use, the captured behavior changes are input to the Data Generator to adjust the demand and supply data for the next moving window. This is essential for simulated real-time analysis because the real-world data does not represent the ATDM actions implemented in the virtual/simulation world.

Decision Gate

Upon forecasting the performance, the MOEs are compared with the agencies' objectives, and a decision is made in real time as to whether dynamic actions are needed to meet the performance goals in the future time period. If the performance goals will not be met without an intervention, the set of ATDM actions to test are selected. Note that for real-time operations, a DSS will evaluate and suggest the best strategies to use; however, for simulated real-time analysis, it is envisioned that the user inputs the strategies to test (a manual DSS).

4.4 User Types and Groups

The primary user groups of the ATDM AMS system described in this document are—

- Transportation modelers
- TMC managers or operators
- Researchers
- Vendors or software developers.

Transportation modelers apply transportation models to evaluate the transportation benefits of different management and operations techniques. They build and develop models to justify investment decisions and to conduct alternative analysis to support long-range planning both for infrastructure improvement and operations. In addition, they are responsible for maintaining and updating the models to meet the latest trends and modeling techniques. Similarly, the AMS development for ATDM would be carried out by a research team of transportation modelers led by subject matter experts (SME).

TMC managers and operators rely on the transportation modelers to help them understand the benefits of applying different management and operations techniques through visualization tools and summary reports. Typically, TMC managers work with transportation modelers to define the scope of analysis, modeling approach and techniques, and the output performance measures to be generated by the tools. TMC managers and operators are the end users of the AMS tools developed by the modelers, and hence their perspective is a critical component of AMS development. The developed and tested AMS tools are finally incorporated in a user-friendly IT system of the agency for use in daily operations.

Researchers work with a variety of modeling tools and develop state-of-the-art modeling tools and procedures to help advance the state of the practice in tools and methods used by transportation modelers.

Vendors or software developers constantly improve or enhance the capabilities of the existing software packages to meet transportation industry needs.

Chapter 5: Analysis Packages

This section describes illustrative examples of scenarios under which the AMS framework described in Chapter 4: can be applied to evaluate the impact of dynamic management of the transportation system using ATDM. Note that the analysis packages described in this section have been developed for the purpose of developing the Analysis Plan and are not meant to be considered as the only scenarios that can be of interest to the potential users of the AMS system nor the only scenarios under which ATDM is applicable.

The four analysis packages have been developed to specifically illustrate how dynamic management or a collection of dynamic strategies can be applied to specific operational scenarios. To quantify the benefit of ATDM concept, for each analysis package, the performance measures generated for the baseline condition without any ATDM implementation is compared to the performance measures with the implementation of ATDM stragies. Each analysis package includes a combination of different:

- Operational scenarios
- Performance goals and objectives
- Applicable ATDM strategies.

Twelve ATDM use-case scenarios were developed in the ATDM Operational Concept and were defined in Appendix B of that document, including:

- Normal Operations:
  1. No Incident.
- Incident:
  1. AM Peak
  2. Large-Scale Crash
  3. Commuter Rail Breakdown During AM Peak
  4. On Arterial During AM Peak
  5. Oil Spill on Roadway During AM Peak
  6. Bomb Threat During AM Peak.
- Planned Event:
  1. Arterial Construction
  2. Travel to Sporting Event During PM Peak
  3. Friday Before Labor Day PM Peak
  4. Major Weather Event (Blizzard)
  5. Minor Weather Event (Light Snow).

Six scenarios depict unplanned events, five depict planned or forecasted events, and one depicts normal operations free of incidents. For the purpose of defining the four analysis packages, the research team considered using the following four operational scenarios:

1. Normal Operations—No Incident
2. Incident—AM Peak
3. Planned Event—Travel to Sporting Event During PM Peak
4. Major Weather Event (Blizzard).

Under the ATDM approach, the system can be dynamically managed and operated to meet or exceed a variety of performance objectives with a mobility, environment, or safety focus. For the purposes of developing the analysis packages, the following are considered to be illustrative examples of performance objectives as they relate to each of the four operational scenarios described previously:

- Person throughput
- Reduction in travel delays
- Travel time reliability
- Crash rates
- Emissions.

Table 5-1 maps the operational scenarios to illustrative performance objectives that will be considered as a part of the analysis package.

Table 5-1: Performance Objectives for the Sample Analysis Packages

Analysis Package #	Performance Goals					
	Example Measurable Objectives	Person Throughput	Mobility Delays	Travel Time Reliability	Safety Crash Rates	Emissions Quantity
1	Normal Operations—No Incident	X		X		
2	Incident—AM Peak		X	X		X
3	Planned Event—Travel to Sporting Event During PM Peak	X	X			
4	Major Weather Event (Blizzard)		X	X	X	

Table 5-2 shows specific ATDM strategies applied for each analysis bundle.

Table 5-2: Sample ATDM Strategies Applicable to Different Analysis Scenarios

ATDM Strategies	1: Normal Operations—No Incident	2: Incident— AM Peak	3: Planned Event—Travel to Sporting Event During PM Peak	4: Major Weather Event (Blizzard)
Dynamic Ridesharing			X	
On-Demand Transit			X	
Predictive Traveler Information	X	X		X
Dynamic Pricing	X			
Dynamic Shoulder Lanes	X			X
Dynamic Speed Limits		X		X
Queue Warning		X		
Adaptive Traffic Signal Control	X		X	X
Adaptive Ramp Metering		X		
Dynamically Priced Parking			X	
Dynamic Wayfinding			X	

Table 5-3 shows the activity scope and the potential impact of the ATDM strategies considered on different elements of the trip chain.

Table 5-3: Scenario, Management Strategy, and Impact on Trip Chain Overview

Scenario	Activity Scope	Primary Impact on Trip Chain
Normal Operations—No Incident	Regionwide, all modes, routes and parallels, 24 hours	All
Incident—AM Peak	Regionwide, all modes, affected route and parallels, AM peak	All
Planned Event—Travel to Sporting Event During PM Peak	Regionwide, all modes, affected route and parallels, corridor, PM peak	All
Major Weather Event (Blizzard)	Regionwide, all modes, affected route and parallels, weather event period	All

The system assessment phase provides the baseline for the analysis package while the system evaluation phase provides the alternative scenario that is compared to the baseline to evaluate whether the chosen strategies were effective.

5.1 Scenario Description

To describe the AMS needs to evaluate the impact of implementing ATDM strategies, it is necessary to describe the geographic region and the demand/supply characteristics that are applicable to each of the four analysis packages described in Table 5-3. Each analysis package includes the following:

- Network (highway and transit) description
- Demand characteristics
- Supply characteristics
- Operating goals and objectives applicable to a particular scenario
- ATDM strategies applicable to each analysis package.

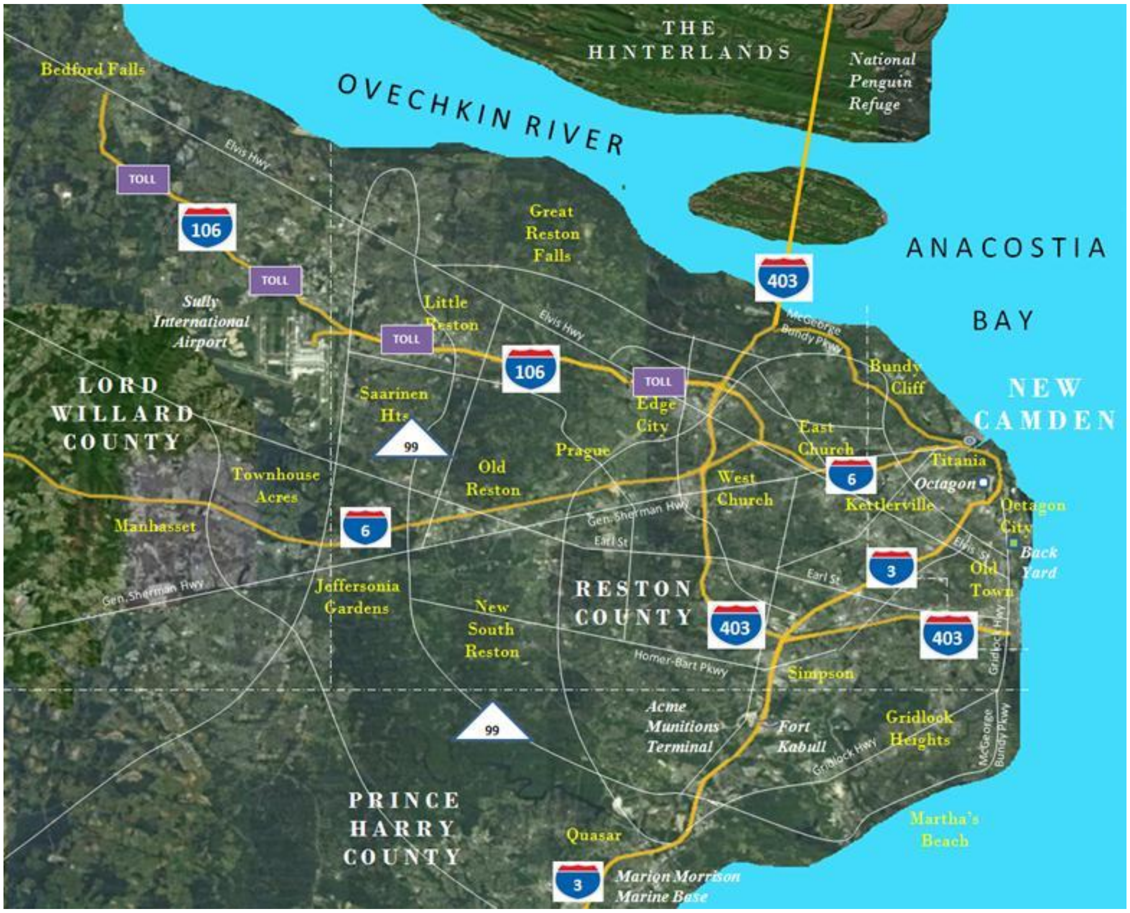
The purpose of this section is to introduce a typical regional environment under which each analysis package described previously is applicable. This environment provides a representation of typical issues that impact traffic congestion and travel demand, which would in turn drive development of specific ATDM strategies. The following elements will be defined in this section:

- Regional description
- Operational characteristics and needs
- Current traffic management activities
- Example deficiencies relative to needs
- Types of strategies being considered.

5.2 Region Characteristics and Current Activities

The fictional region, New Camden and Northern Jeffersonia (NCNJ), presented in Figure 5-1, is a metropolitan area of approximately 3 million people, which includes various state and municipal entities and transportation characteristics.

Figure 5-1: New Camden/Northern Jeffersonia Region Local Entities



The following major metropolitan area in the northeast corner of the State of Jeffersonia includes a major city and several counties:

City of New Camden

New Camden, a city with a population of 600,000, contains a central business district and clustered commercial/retail zones along with a mix of distressed and prosperous residential districts. Several older areas, including Old Town and Titania, are extensively gentrified and attract residential traffic and off-peak travel from other areas in the region. High-density areas for housing, office, and retail space are prominent around metro rail stations and major intersections in the vicinity of the metro stations, including Octagon City, Kettlerville, and sections of Old Town and Titania. The Back Yard is the sports and entertainment district, in the vicinity of Octagon City, which includes baseball and football stadiums and a hockey arena. New Camden policies emphasize public transit, pedestrian and bicycle access, and discourage the use of SOVs in urbanized areas and along congested corridors. Parking is limited in older areas and in the central business district; it is available, but parking in the employment centers is expensive throughout the city. Several high-capacity arterial routes and freeway facilities serve New Camden, and traffic signal operations are coordinated through a central system that operates traffic-control devices along several routes based on traffic-responsive control schemes or based on the time of day/day of the week. About 25 percent of the intersections are pretimed, while the remainder use a combination of semi-actuated and fully actuated controllers, generally compliant with NEMA TS 2 standards. Several arterial routes with heavy bus traffic are equipped for transit signal priority operations. The city maintains a central traffic control center that is staffed during peak periods and during special events.

Reston County

Reston, a county with a population 1.2 million, lies to the west and southwest of New Camden. This county includes low-to-medium density suburban communities along with several high-density apartment/townhouse communities near metro rail stations and in areas bordering New Camden. Edge City, a large shopping mall and office park, attracts the largest amount of private sector employment in the region and is equidistant to New Camden and Sully International Airport (SIA). Commuter rail service exists for several communities in the corridor, but most of the county is served by buses that connect to commuter and metro rail services. The primary beltway facility, the Sansa Beltway, passes through the county.

Lord Willard County

Lord Willard, a county with a population of 600,000, lies to the west of Reston County and includes suburban, exurban, and rural communities. Commuter buses connect regions in this county to metro rail and commuter rail services. Most Lord Willard residents commute to jobs in New Camden and Reston County. The County Council voted against commercial and business development as well as the development of a major historic theme park in the county. Subsequently, residential development increased, causing more congestion than might have occurred from the nonresidential developments.

Major Transportation Facilities

Major transportation facilities in the NCNJ region include the following:

Freeway Network

Interstate 6, an east-west freeway, narrows from eight lanes (four lanes in each direction) in the western parts of the region to four lanes (two lanes in each direction) inside the beltway. This freeway is restricted to two-persons or more carpools (HOV-2) and buses in the peak direction during peak periods. I-6 is in need of refurbishment but includes a directional HOV lane outside the beltway (eastbound left lane in the morning, westbound left lane in the evening), and permits hard-shoulder running along a 5-mile section outside the beltway in peak directions (east in morning, west in evening). I-6 terminates near the New Camden central business district and connects to I-3 and a freeway (SR 10) to Octagon. It typically operates at levels ranging from an LOS D to F during peak periods and during many weekend periods, with traffic equally heavy in both directions during evening peak periods because of extensive employment in Reston County and the resultant reverse commuting. Ramps inside the beltway are metered., The freeway contains an ITS infrastructure, east of the Prague interchange, including detection every half mile and closed-circuit television (CCTV) cameras every mile along with full fiber-optic infrastructure. The freeway contains CCTV with some dynamic message signs (DMS) used for HOV operations and to warn of downstream delays west of the Prague interchange. However, there is currently no detection west of the Prague interchange.

Interstate 3, a north-south freeway, is a six- to eight-lane road with two reversible lanes used for HOV-3 operations (north in morning, south in evening) and ramp metering at interchanges inside the beltway. It typically operates at an LOS E to F inbound in the morning and outbound in the evening, with extensive reverse peak congestion in the northbound direction on baseball or hockey game days and football games on Sundays or weeknights. This freeway contains an ITS infrastructure, including detection every half mile and CCTV cameras every mile along with full fiber-optic infrastructure.

Interstate 403, also known as Sansa Beltways, is an eight-lane road that connects Prince Harry County and the southern region of New Camden, including the dense commercial and residential areas near Gridlock Heights, with Edge City to the north, and experiences delays due to heavy traffic throughout the week. It serves as the primary truck route in the metropolitan area. Traffic operates typically at LOS D. Off-peak traffic operates close to capacity and at a higher LOS mainly as a result of excessive speeds. High accident rates result in a lower LOS and substantial delays across the entire road network. The freeway contains limited CCTV infrastructure. New detector infrastructure is being implemented as part of a high-occupancy toll (HOT) lanes project (discussed in the following section), along with an expansion of DMS and a full fiber infrastructure.

Interstate 106, or the Sully-Edge Toll Road, is a toll facility that contains toll-free median lanes connecting to Sully International Airport. It has a junction with the beltway near Edge City and a connecting link to I-6 just west of the New Camden line. It is heavily congested inbound (LOS E to F) during the morning peak period but moves relatively well in the outbound direction (LOS D as worst case). CCTV cameras are located at 1- to 2-mile intervals east of the airport, but there is no detector infrastructure. Fiber-optic infrastructure is present along the corridor. The section of I-106 west of the airport is a newer, privately built toll road extension primarily used during peak hours in the peak travel directions (east in the morning, west in the evening) and contains no ITS infrastructure.

The McGeorge Bundy Parkway travels along the regional waterfront from the beltway through the center of New Camden and into the Old Town section. This highway carries a mix of traffic that includes both commuters and tourists. This causes congestion and high accident potential because of the short ramps, tourist-oriented access or viewing points, and high commuter speeds. ITS infrastructure does not currently exist along this route.

Major Arterials

General Sherman Highway is the main east-west arterial heading west from the central business district into Reston County. Its capacity ranges from four to six lanes, it supports bus services and includes capabilities for transit signal priority within Central City.

A northwest-southeast arterial, Elvis Street stretches from the outer regions along the Ovechkin River through northern Reston County and Edge City and leads to the Old Town section of New Camden. Its capacity ranges from four to eight lanes but narrows to two lanes as it approaches the congested Old Town section. A companion street, Earl Street, travels west from Old Town and connects the central areas of Reston County.

The primary north-south arterial is Gridlock Highway, which passes through Octagon City and the southern industrial/commercial area into Prince Harry County. It connects the military installations indicated previously with the rest of the region. Its capacity ranges from six to eight lanes and carries numerous bus services. Outlying segments provide transit signal priority.

Other arterials provide a discontinuous grid network or curve around into east-west routes, especially closer to Central City. This makes north-south travel difficult without multiple turns. Hence I-3, the beltway, and Harry Reston Parkway carry a disproportionate share of north-south traffic.

State Route 99, also called the Harry Reston Parkway, is a limited-access arterial with a few at-grade signalized intersections, following a circumference of around 8 miles outside the beltway, and provides the primary alternate route around New Camden relative to the beltway.

Public Transit

New Camden is served by several public transit modes that include metro and commuter rail, bus rapid transit through the use of bus lanes, and local and express buses. New Camden Transit Authority (NCTA) operates local and express buses in the metropolitan area along with a 55-mile metro rail system that serves the western and southern regions, and the suburban regions, as shown in Figure 5-2 The Northern Area State Commuter Rail system, also shown in Figure 5-2, serves the south and southwest suburbs along the existing freight rail right-of-way, with a combination of express buses, local buses, and bus circulator routes that connect suburban areas with the rail network. Edge City and the Sully-Edge Corridor along I-106 have recently received a new metro rail line, which serves a corridor that was largely developed without any transit services.

Figure 5-2: Major Camden/Northern Jeffersonia Rail Transit Services

Metro rail provides north (Sully-Edge) and south (Prague) branches in Reston County, which merge at East Church station into a single line into Kettlerville and the central business districts. The line travels past Octagon and Octagon City into Old Town, splitting into two branches and serving the south suburbs.

Commuter rail travels from Octagon City south through Old Town, then splits into two branches, one serving southern Lord Willard County, and one serving Prince Harry County, traveling near the military installations.

Bus services in each of the counties are operated by independent contract operators, although Reston County has coordinated its route system and transfers with NCTA. The other counties operate mainly commuter bus services that connect with metro rail or with large-scale destinations in New Camden and Reston County, typically employment centers.

Intercity bus services are provided by national carriers, such as Greyhound, and use an aged facility remote from other multimodal and commercial centers in the northern section of Old Town near the rail yards, although they do connect with some outlying rail stations.

Intelligent Transportation Systems

Several routes in the region are well-instrumented with detection, monitoring, and information systems. Figure 5-3 provides an overview of the ITS infrastructure in the region. I-3 and I-6 are fully equipped with detectors (1/2-mile spacing) and include cameras at 1-mile intervals. I-106 and the beltway (I-403) have traditionally been monitored with CCTV, although I-403 is being equipped with ITS as part of the HOT lanes project. DMS, about 1-1/2 miles ahead of decision points, provide advisory information and travel times on instrumented routes. Fiber communications along all freeways are provided with ring networks maintained through a connection along SR-99 (Harry Reston Parkway) between I-6 and I-3.

The Super-Regional Transportation Management Center (STMC) in Reston County incorporates Jeffersonia DOT (JDOT), State Police, and Reston County Police in a single, multipurpose facility that provides freeway management, arterial management on state highways, and county highways with state traffic signals, including both traffic and incident management. Reston County 911 services also are handled through the STMC.

Camden City maintains its own Traffic Control Center (TCC), as described previously. The individual cities and counties handle their own police and emergency 911 dispatches.

No interconnections currently exist between the various operations facilities for real-time operations, although a regional traffic data and incident management database operated by the transportation research laboratory at the University of Jeffersonia in central Reston County collects information from all major agencies in the region.

Transit services are monitored from the NCTA headquarters' Transit Operations Facility (TOF). It features a large-scale electronic vehicle location map (thanks to systemwide bus GPS and rail track circuit information). The commuter rail GPS locations are handled on a series of small PCs and laptops located in a corner of the TOF (the track circuits are monitored through the Freight Railway supervisory control and data acquisition (SCADA) systems, so there is no active control of the passenger rail track operation from the TOF).

Figure 5-3: New Camden/Northern Jeffersonia Freeway ITS Infrastructure

5.3 Current Traffic Conditions

The significant congestion described previously on major highways (freeways and major arterials) occurs despite the relatively heavy transit use in the region (approximately 20 percent of commuters). Metro rail operates at capacity in peak directions, and at 60 percent to 70 percent in off-peak periods. Commuter rail and bus service operate at less than 70 percent load factors for the most part and less than 40 percent during the day. Reverse-commute traffic, particularly toward the Edge City-Sully Airport corridor, is significant in the morning and even more significant in the evening peak, as traffic bottlenecks at the merge of the I-106 connector with I-6.

From a bus transit perspective, a major exception to the preceding rule of relatively low bus usage is the Gridlock Highway corridor in Northern Prince Harry County, which connects with the metro rail station at Gridlock Heights. Fort Kabull, Morrison Marine Base, and numerous apartments and commercial/strip mall developments are within the corridor. The bus load factor is generally more than 100 percent during peak periods and 80 percent in off-peak periods, with even all-night services boasting 40 percent to 50 percent load factors. However, little transfer connectivity exists between bus and rail services on either end of the corridor.

Event traffic generated by the Back Yard sporting venues, especially for weekday night games, mixes with peak-hour traffic to create even more congestion, as well as parking conflicts in the Central Business District and parts of Old Town.

Although several park-and-ride facilities exist as a result of the parallel operations of metro rail with I-6 and I-3 in suburban areas, there is neither any real-time information on parking availability nor a single source for traffic and transit information. Travel time information and colored maps are provided on the

JDOT website, but transit information is received through accessing the individual NCTA, RestBus, Northern Area State Commuter Rail, or HarrTrans sites. All sites offer bus location information, and the metropolitan planning organization (NJMPO) has attempted to develop a consolidated trip-planning website. However, only RestBus and NCTA have cooperated on the development of a common trip-planning website.

In addition, frequently antagonistic relationships exist between NCCDOT and JDOT, particularly because of JDOT's suburban orientation, which has impacted JDOT's ability to develop freeways within New Camden. A famous environmental decision limited I-6 to two lanes in each direction inside the beltway, and the aforementioned lawsuit has limited the I-3 HOT facility to outside the beltway, though New Camden is contemplating its own cordon-based congestion pricing scheme for access points into the city, including I-3. The region in general provides a number of alternative travel modes but not all areas of the region provide similar modal options or place the same emphasis on alternative travel modes.

Climactic conditions include subtropical summer heat and hurricanes that often lash the waterfront with floods and the region with torrential rains. Inland areas are often the site of tornados, and the region in general has been afflicted by high winds, downed trees, and exposed power lines. These occur during major storms that result in at least one catastrophic power outage a year in the region. At the other extreme, the region receives 20 inches to 30 inches of snow per year (with 20-year storms dumping up to 36 inches at a time) as well as occasional temperatures of 0^{0} F and below. Due to heightened liability fears as a result of ice and snow on sidewalks in school zones and concerns about the safety of bus travel, most schools close when 2 or more inches of snow accumulates. Snow and ice storms during peak-hour periods can result in 30-minute commutes becoming 3- to 4-hour commutes. Excessive snow and ice have also shut down several aboveground metro rail segments, making public transit travel less reliable in winter.

5.4 ATDM Analysis Package 1—Normal Operations: No Incident Scenario Description

Starting Point: 7 AM

ATDM Framework for Operations:

The transportation system in the New Camden/Northern Jeffersonia Region uses a combination of multimodal demand and supply-side strategies to improve travel in the region.

Scenario Objective:

The objective of this scenario is to illustrate use of ATDM applications to manage travel in the project corridor during the AM peak. New Camden/Northern Jeffersonia Region is the chosen project corridor.

Scenario Relevance:

This scenario shows the benefits of employing ATDM strategies on a large-scale basis during normal operations, which is effectively the most common scenario. This scenario shows how ATDM can optimize the daily typical challenges of changing demand during peak periods. In this recurring and predictable situation ATDM optimizes the use of the transportation network, affecting all components of the trip chain.

Scenario Description:

It is 7 AM on Monday morning, and the traffic builds up as expected. Commuters are driving to their workplaces in the Octagon, Edge City, Old Town, and elsewhere.

SYSTEM PERSPECTIVE

The overarching goal is to influence travel demand and supply for all portions of the trip chain. Given that the scenario is predictable and recurring (every day), the transportation system has been prepared to implement predictive measures to proactively deal with the situation. The key objectives from a system perspective are—

- Influence drivers and travelers to make informed decisions at every step of the trip chain, starting with destination and time-of-day choice
- Manage the road network according to the changes in traffic volume
- Improve travel time reliability: reduce travel time variance to less than 20 percent of the average travel time
- Maximize system throughput.

MOEs of interest include:

- Person throughput
- Delays
- Travel time reliability.

Each of the ATDM strategies applicable to the scenario is described in the following sections:

- Predictive Traveler Information
- Dynamic Pricing
- Dynamic Shoulder Lanes
- Adaptive Traffic Signal Control.

Predictive Traveler Information

The transportation network is managed based on the modeling of historical data and on the continuous collection and processing of data, which supports updates to operational models as well as overall system performance measurement. As the system detects and verifies initial, early indications of traffic congestion or conditions that are linked to incident occurrence, alerts are automatically generated and disseminated to appropriate incident responders. In addition, safety service patrols are alerted and dispatched if conditions are strongly associated with specific locations.

System input is gathered from parallel arterials and other sensors on the freeway to rapidly detect unusual conditions indicating a crash or other incident with detrimental impact on travel.

Normal transit operations focus on encouraging the use of public transit and making it as easy and attractive to regular and potential riders as possible. Near-real-time information is provided via the transit's website and via applications that travelers in the region program to alert them in the event certain events occur or thresholds are reached.

Information from the TMC is also used to enable on-the-fly increases in the number of suburban express commuter buses arriving at park-and-ride lots to accommodate changes in demand.

Dynamic Pricing

Regional transit providers are able to use variable pricing—the model is the reverse of the system used to support HOT Lanes. As congestion/delay on selected highways increases, the fare for use of the transit system in the incident corridor is decreased to encourage transit mode selection to reduce traffic volumes entering the incident area. That change in fares is communicated in real time to the traveling public, through general dissemination channels such as the transit website, as well as through personalized messages to subscribers.

The toll road uses a variable pricing scheme to change the price. During the off-peak periods, the toll rates are reduced to incentivize travelers who would otherwise use major parallel arterials to use the toll road.

Dynamic Shoulder Lanes (Hard Shoulder Running)

A series of lane monitoring and control systems continuously collect and compare data against historical data. Lane control signals, including variable speed limit displays, are automatically adjusted to maintain desired traffic flow. The system enables HSR based on congestion during peak periods and in response to incidents or other conditions as warranted during nonpeak periods. The system uses real-time data to adjust Adaptive Ramp Metering as well as Variable Speed Limit (VSL) displays to maintain optimal flow for each lane, especially to improve merging operations of vehicles entering the facility.

Adaptive Traffic Signal Control

Predicted traffic conditions are used to time the signals to maximize the throughput through the system. The signal timing plans are changed in anticipation of additional demand and coordinated to ensure progression.

EFFECT ON USERS' TRIP CHAIN

In a normal AM Peak situation, system management has a marginal impact on destination or time-of-day choice; in most cases, travel occurs at the time that people choose to travel. However, the travelers who choose the time of day to travel know that their travel is more reliable. The efficiency with which travelers reach their destination is affected.

Travelers make educated decisions at that point in time based on their knowledge of the network—they know which parts of the freeway network they can use without delay. A certain number of travelers decides to use public transit.

Destination Choice

Destination choice is a function of needs and options. Due to the ATDM, the traveling public can pick destinations of their choosing with a higher likelihood of getting there on time reliably. However, travelers will rarely pick another destination.

Time-of-Day Choice

Time-of-day choice is affected. As travel becomes more reliable, travelers can leave later. They can optimize travel times to suit their individual needs.

Mode Choice

Having a responsive transit system increases mode choice pre-trip and during the trip in case of incidents. Transit needs to be conveniently available, and travelers need to be informed about their options.

Route Choice

During the morning peak hours, travelers who follow the real-time information news change their routes accordingly.

Lane/Facility Choice

Lane and facility choices are affected by the dynamic use of HOT and dynamic toll road pricing schemes.

5.5 ATDM Analysis Package 2—AM Peak Incident

NORMAL OPERATIONS

Starting Point: 5 AM

ATDM Framework for Operations:

The transportation system in New Camden/Northern Jeffersonia Region uses a combination of multimodal demand and supply-side strategies to improve travel in the region.

Scenario Objective:

The objective of this scenario is to illustrate use of ATDM applications to manage travel in the project corridor during the AM Peak with additional challenges resulting from an incident on the freeway that affects the transportation network. The project corridor is the New Camden/Northern Jeffersonia Region.

Scenario Relevance:

This scenario shows the benefits of employing ATDM strategies on a large-scale basis in response to a geographically constrained situation. It covers a nonpredictable, infrequent but recurring large-scale event that disrupts the transportation network on a regional basis, calling for predictive and proactive strategies to prevent and alleviate negative impacts.

Scenario Description:

Near the start of the AM Peak, a rear-end collision occurs on the eastbound left lane of I-106 when the lead vehicle unexpectedly slows to let another vehicle merge onto the left-most lane, just past the Highway 99 interchange. The incident blocks the two left-most lanes on I-106. The duration of the incident is approximately 90 minutes.

SYSTEM PERSPECTIVE

The overarching goal is to influence travel demand and supply for all portions of the trip chain. Although the exact time and location of the occurrence of this scenario is unpredictable, the occurrence itself is a reoccurring situation that the transportation system is prepared for: The system can use measures to proactively deal with the situation and its consequences. The key objectives from a system perspective are—

- Resolve the current situation—provide incident management
- Alert the traveling public of the hazardous situation
- Prevent follow-on incidents from occurring
- Manage the road network accordingly
- Reduce delays
- Improve travel time reliability
- Reduce negative environmental impacts (emissions quantity) due to increase in congestion.

Each of the ATDM strategies applicable to the scenario is described in the following sections:

- Predictive Traveler Information
- Dynamic Speed Limts

- Queue Warning
- Adaptive Ramp Metering

Predictive Traveler Information

The transportation network is managed based on modeling of historical data and on the continuous collection and processing of data, which supports updates to operational models as well as overall system performance measurement. As the system detects and verifies initial, early indications of traffic congestion or conditions that are linked to incident occurrence, alerts are automatically generated and disseminated to appropriate incident responders. In addition, safety service patrols are alerted and dispatched if conditions are strongly associated with specific locations.

System input is gathered from parallel arterials and other sensors on the freeway to rapidly detect unusual conditions indicating a crash or other incident with detrimental impact on travel. As the incident occurs during the AM peak, Adaptive Ramp Metering is operational. Vehicle detectors send data to the Superregional TMC at the interchange between I-6 and HWY 99.

Dynamic Speed Limits

Reduce the posted speed on the variable advisory speed signs (VASS) in the mile upstream of the end of queue, past the HWY 99 interchange. The VASS progressively reduces the advisory speed to 35 mph as vehicles approach the congestion. At the location of the congestion, the VASS will be blank.

Queue Warning

Automatically detect queues and then warn motorists in advance of the queue via variable message signs to improve safety and reduce rear-end crashes.

Adaptive Ramp Metering

Regulate the flow of traffic entering freeways according to current traffic conditions by adjusting the timing plans of traffic signals at freeway on-ramps.

EFFECT ON USERS' TRIP CHAIN

Under normal circumstances, only people who have to travel do travel that early in the morning. System management has no impact on destination or time-of-day choice; in most cases, travel occurs at the time that people choose to travel. The efficiency with which travelers reach their destination is affected. Travelers make educated decisions at that point in time based on their knowledge of the network—they know they can use the freeway network without delay. A certain number of travelers decides to use public transit.

Destination Choice

Alerting the public early in the morning about the incident conditions marginally affects destination choice—people will still need to go to their destination at that time of day.

Time-of-Day Choice

Time-of-day choice is marginally affected. As the incident is unpredictable, only those travelers who can afford to do so and who check on the current traffic conditions ahead of time will change their time of travel. In most cases, those travelers will decide to travel later, not earlier.

Mode Choice

Some morning commuters change their mode in the morning; instead of getting stuck on I-106, they choose to use the rail to downtown, or they drive to the nearest bus station, especially because they know that the public transportation system is offering free transportation services for affected travelers.

Route Choice

During the morning peak hours, travelers who follow the real-time information news change their routes accordingly. Route choice will be the most heavily affected component of the trip chain.

Lane/Facility Choice

Lane and facility choice are affected in the vicinity of the incident. The lane flow management strategies affect and guide the traffic approaching and passing the incident

5.6 ATDM Analysis Package 3—PM Peak Baseball Game

NORMAL OPERATIONS

Starting Point: 5 PM

ATDM Framework for Operations:

The transportation system in New Camden/Northern Jeffersonia Region uses a combination of multimodal demand and supply-side strategies to improve travel in the region.

Scenario Objective:

The objective of this scenario is to illustrate use of ATDM applications to manage travel in the project corridor during the PM Peak with additional challenges resulting from a major league baseball game in the Back Yard Entertainment Center. The project corridor is the New Camden/Northern Jeffersonia Region.

Scenario Relevance:

This scenario shows the benefits of employing ATDM strategies on a large-scale basis in response to a geographically constrained situation. It covers a predictable, planned, and recurring large-scale event that adds demands to the transportation network on a regional basis, calling for predictive and proactive strategies to prevent and alleviate negative impacts.

Scenario Description:

It is Wednesday evening. The New Camden Pitbulls are playing the current champions, the Portland Green Sox, at the Back Yard.

SYSTEM PERSPECTIVE

The overarching goal is to influence travel demand and supply for all portions of the trip chain. In this case, the exact time and location of the event affecting the traffic situation are known. The occurrence itself is a reoccurring situation for which the transportation system is prepared: The system can use measures to proactively deal with the situation and its consequences. The key objectives from a system perspective are—

- Manage the road network accordingly, balancing traffic toward Back Yard Entertainment Complex with traffic departing Old Town and the Octagon and passing through on the way home or to other places
- Improve person throughput
- Reduce delays
- Improve travel time reliability.

Each of the ATDM strategies applicable to the scenario is described in the following sections:

- Dynamic Ridesharing
- On-Demand Transit
- Adaptive Traffic Signal Control
- Dynamically Priced Parking
- Dynamic Wayfinding

Dynamic RideSharing

Facilitates real-time and dynamic carpooling to reduce the number of auto trips/vehicles trying to use the major facilities.

On-Demand Transit

Provide public transit service that has flexible routes and schedules and picks up and drops off passengers based on individual needs to encourage more travelers to use the transit mode.

Adaptive Traffic Signal Control

Predicted traffic conditions are used to time the signals to maximize the throughput through the system. The signal timing plans are changed in anticipation of additional demand and coordinated to ensure progression.

Dynamically Priced Parking

Change parking fees dynamically based on demand and availability. Encourage peak spreading by providing early-bird parking fees that are lower than the peak travel period parking fees.

Dynamic Wayfinding

Provide parking availability information to reduce the time taken by motorist to search for parking.

EFFECT ON USERS' TRIP CHAIN

Destination Choice

Destination choice is not affected—people either go to the game or they do not. Commuters will leave their work to go home.

Time-of-Day Choice

Time-of-day choice is marginally affected. One effect of improved traffic conditions may be that some travelers depart later, because they know that the traffic situation is better managed. Some travelers may also depart earlier to make sure they "get on the bus."

Mode Choice

Some morning commuters change their mode; the added temporary feeder and event buses definitely will entice drivers to switch from their vehicles to public transportation. Mode choice will be heavily affected.

Route Choice

Route choice will be heavily affected but not necessarily more than the mode choice.

Lane/Facility Choice

Lane and facility choice are not or at most are marginally affected—if travelers know of a recurring bottleneck, they will choose another route and/or facility to get to their destination.

5.7 ATDM Analysis Package 4—AM Peak Blizzard

NORMAL OPERATIONS

Starting Point: 5 AM

ATDM Framework for Operations:

The transportation system in the New Camden/Northern Jeffersonia Region uses a combination of multimodal demand and supply-side strategies to improve travel in the region.

Scenario Objective:

The objective of this scenario is to illustrate use of ATDM applications to manage travel in the project corridor in anticipation of and in response to a blizzard during the AM Peak on a workday. The project corridor is the New Camden/Northern Jeffersonia Region.

Scenario Relevance:

This scenario shows the benefits of employing ATDM strategies on a large-scale basis. It also uniquely covers the rare but realistic scenario of a predictable large-scale event that disrupts the transportation network, calling for predictive and proactive strategies to prevent and alleviate negative impacts.

Scenario Description:

At 5 AM, all roads are open. The weather forecast is calling for a significant drop in temperatures and increasing snow and high winds starting at approximately 8 AM. The snow is expected to continue falling until the early afternoon and 5 feet of snow are expected. Due to the dropping temperatures, the conditions will deteriorate because freezing snow will be covered by new accumulation.

SYSTEM PERSPECTIVE

The overarching goal is to influence travel demand and supply for all portions of the trip chain. Given that the scenario is predicable, the transportation system has been prepared to implement predictive measures to impact trip generation, as well as to proactively deal with the situation and its consequences. The key objectives from a system perspective are—

- Alert the traveling public of the impending blizzard
- Motivate the public to not travel unless absolutely necessary
- Help traveling public to get to its destination as safely as possible, possibly rerouting traffic depending on the accessibility of the road network
- Manage the road network accordingly, including closing affected roads
- Provide support to stranded travelers in conjunction with emergency responders
- Reduce crash rates
- Reduce delays
- Improve travel time reliability.

Each of the ATDM strategies applicable to the scenario is described in the following sections:

- Predictive Traveler Information
- Dynamic Shoulder Lanes
- Dynamic Speed Limits

- Adaptive TrafficSignal Control

Predictive Traveler Information

The transportation network is managed based on modeling of historical data and on the continuous collection and processing of data, which supports updates to operational models as well as overall system performance measurement. As the system detects and verifies initial, early indications of traffic congestion or conditions linked to incident occurrence, alerts are automatically generated and disseminated to appropriate incident responders. In addition, safety service patrols are alerted and dispatched if conditions are strongly associated with specific locations.

Dynamic Shoulder Lanes

Manage dynamically opening a shoulder lane to traffic on a temporary basis to address congestion issues on freeway. Close lanes in response to incidents.

Dynamic Speed limits

Adjust speed limits based on condition of the roadway, weather conditions, and existing traffic levels.

Adaptive Traffic Signal Control

Predicted traffic conditions are used to time the signals to maximize the throughput through the system. The signal timing plans are changed in anticipation of additional demand and coordinated to ensure progression.

EFFECT ON USERS' TRIP CHAIN

Under normal circumstances, only people who have to travel do travel that early in the morning. System management has no impact on destination or time-of-day choice; in most cases, travel occurs at the time that people choose to travel. The efficiency with which travelers reach their destination is affected. Travelers make educated decisions at that point in time based on their knowledge of the network; they know they can use the freeway network without delay. A certain number of travelers decides to use public transit.

However, this is not a normal situation. The weather scenario and the implementation of supply and demand-side strategies affect all components of the trip cycle, albeit to varying degrees.

Destination Choice

Alerting the public early in the morning about the weather conditions marginally affects destination choice. The majority of the travelers at that time of day are traveling to or as part of their work (e.g., milk, newspaper delivery); the inclement weather does not affect their destination choice. A few travelers are waiting in the morning because they have the opportunity to come to work later. They decide to work from home once they see the weather deteriorating, affecting their destination choice. Some travelers who had chosen to get up early for leisure travel may decide to cancel their trip altogether; however, as the media had been alerting the public for days about the coming storm, only a very few brave souls were planning to spend their free time traveling to a leisure destination that morning.

Time-of-Day Choice

Time-of-day choice is affected. Actually, due to the warnings the previous days about the storm, a lot of travelers are planning in extra time to reach their destination by leaving earlier, effectively spreading the travel demand across the morning. Another group of travelers decides to travel at a later time in the morning or even to wait and check on the weather and eventually decides not to travel at all.

Mode Choice

Some morning commuters change their mode in the morning; instead of facing the increasing snow in their cars, they choose to use the rail to downtown.

Route Choice

During the morning peak hours, travelers who follow the real-time information news change their routes accordingly.

Lane/Facility Choice

Generally, lane and facility choices are only marginally affected. Due to the increasing accumulation of snow, the interstate shoulders become blocked, limiting the options for HSR. Travelers use the lanes and facilities that remain open during the snow storm.

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Appendix A: List of Acronyms

Acronym	Definition
ADM	Active Demand Management
AMS	Analysis, Modeling, and Simulation
APM	Active Parking Management
ATDM	Active Transportation and Demand Management
ATM	Active Traffic Management
ATMS	Advanced Transportation Management System
C2C	Center-to-Center
Caltrans	California Department of Transportation
CONOPS	Concept of Operations
DART	Dallas Area Rapid Transit
DOT	Department of Transportation
DSS	Decision Support System
DSSO	Decision Support System Optimizer
DTA	Dynamic Traffic Assignment
GPS	Global Positioning System
HOT	High-Occupancy Toll
HOV	High-Occupancy Vehicle
HSR	Hard Shoulder Running
ICM	Integrated Corridor Management
ITS	Intelligent Transportation System
LOS	Level of service
LTA	Land Transportation Authority
MOE	Measure of Effectiveness
MPO	Metropolitan Planning Organization
NEPA	National Environmental Policy Act
NPS	Network Prediction System
PeMS	Performance Monitoring System
O-D	Origin–Destination
ODOT	Oregon Department of Transportation
RAMS	Regional Arterial Management System
RNM	Road Network Modeler
rt-ADMS	Real-Time Archive Data Management System
SANDAG	San Diego Association of Governments
SHRP 2	Strategic Highway Research Program
SOV	Single-Occupancy Vehicle
TMC	Traffic Management Center

Acronym	Definition
TODSS	Transit Operations Decision Support System
TPT	Traffic Prediction Tool
TSP	Transit Signal Priority
TTI	Texas Transportation Institute
USDOT	U.S. Department of Transportation

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