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Active Transportation and Demand Management (ATDM) Foundational Research

Analysis Plan

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16. Abstract As part of the Federal Highway Administration's (FHWA's) Active Transportation and Demand Management (ATDM) Foundational Research, this publication presents a high-level analysis approach to evaluate four illustrative described in the AMS CONOPS Report (FHWA-JPO-13-020). The Analysis Plan Report can be used to identify the collective modeling requirements for ATDM (specific to individual strategies) to support future test bed development and AMS research using four illustrative examples. This publication also identifies the collective modeling requirements for ATDM to support future test-bed development and associated research. This publication provides guidance on the development of a robust set of requirements for the ATDM AMS framework and — potentially — future test-bed development. This document is not intended to be a guiding document for agencies or analysts to develop their own analysis plans or modeling requirements.		
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Preface/Acknowledgments

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Executive Summary

During the past several decades, traffic management and operational activities have been reactive in nature. Recently, however, the need has been recognized for a more proactive approach to transportation solutions, which will address mobility and environmental and safety issues, and meet transportation system user expectations about trip reliability and choice. Transportation organizations will have to conduct business in a new way, through proactive management of systems and services to respond to real-time conditions, and to provide realistic choices to manage travel demand. Active Transportation and Demand Management (ATDM) responds to these newly recognized needs.

ATDM takes a dynamic approach to manage, control, and influence travel demand, traffic demand, and traffic flow of transportation facilities. 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 at least forestalling breakdown conditions, improving safety, reducing emissions, and maximizing system efficiency. Through the use of historical data and predictive methods, actions are performed in real time to achieve or preserve system performance.

A suite of modeling tools and methods is needed to test the benefits of ATDM, and to encourage traffic operators and other public agencies to embrace the concept. Such a suite will enable the user to evaluate the potential benefits of ATDM strategies in a dynamic and proactive fashion. An Analysis Modeling and Simulation (AMS) system is needed to help agencies evaluate 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 through ATDM strategies. To support real-time operations, a real-time analysis capability is needed. The ATDM Foundational Research project’s objectives are to support the development of ATDM program efforts and to support the development of an ATDM analysis and modeling framework.

The research undertaken as part of the ATDM Foundation Research project is described in three reports: Concept of Operations, Capabilities Assessment, and Analysis Plan. The report described here is the third in the series, and presents a plan to evaluate the analysis packages with the proposed AMS system, described in the Concept of Operations Report. The analysis packages described in this report have been defined for the purpose of Analysis Plan development. They are not thought to be the only scenarios of interest to potential users of the AMS system, nor are they the only scenarios under which ATDM is applicable. In particular, 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. Each analysis package includes a combination of different—

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

For each analysis package, this report details the analysis scenario, the region and existing conditions, the data needs to conduct the analysis, performance measures of interest, the tools needed to conduct the analysis, the analysis approach, model calibration and validation approach and needs, and modeling requirements to perform the analysis.

This report may be used to identify the collective modeling requirements for ATDM (specific to individual strategies) to support future test-bed development and AMS research, with the use of four, illustrative examples. This report is not a practitioner guidance document, which agencies with an interest in ATDM might use to conduct a detailed analysis on the basis of the plan presented. Rather, the report is a research guidance document to help FHWA develop a robust set of requirements for the ATDM AMS framework and future test-bed development.

Chapter 1: Scope

1.1 Background

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 has been recognized as an effective way 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. To address these growing transportation needs requires transportation agencies 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. ATDM is based on this concept.

ATDM is the dynamic management, control, and influence of travel demand and traffic flow on 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 AMS tools and methods that enable the user to for 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 concepts and support the development of an ATDM analysis and modeling framework. The AMS needed for evaluating ATDM concept is documented in three documents. This report is the third in the series. The two accompanying documents to this report are as follows.

- **ATDM AMS Concept of Operations (CONOPS) Report.** The CONOPS Report describes the ATDM AMS system that can be used to evaluate the benefits of dynamically managing a transportation system. The report presents limitations of current AMS systems, the AMS needs to support ATDM evaluation, and the description of an ATDM AMS system. The CONOPS Report also provides four illustrative examples of analysis packages for the purpose of developing a detailed Analysis Plan that illustrates how ATDM modeling can be conducted.
- **Capabilities Assessment Report.** The Capabilities Assessment Report provides an assessment of ATDM AMS needs and existing capabilities and identifies gaps between existing and desired AMS capabilities. This report identifies current AMS capabilities that can directly or potentially support ATDM evaluation and presented a summary of gaps in AMS capabilities and needs.

This Analysis Plan Report presents a high-level analysis approach for evaluating the analysis packages described in the AMS CONOPS Report. The Analysis Plan Report can be used to identify the collective modeling requirements for ATDM (specific to individual strategies) to support future test-bed development and AMS research using four illustrative examples. This report includes the following for each of the four analysis packages:

- Scenario description with goals, objectives, and hypothesis
- Data needs for analysis
- Performance measures generated to evaluate the impact of ATDM strategies
- Analysis settings
- Analysis approach
- Modeling requirement.

Twelve ATDM operational scenarios were developed in the process of developing the ATDM Operational Concept. The analysis scenarios are the following:

- Normal Operations
  1. No incident
- Incident
  1. Rear-end collision on freeway during the AM peak
  2. Large-scale crash on freeway during the AM peak
  3. Commuter rail train breakdown during the AM peak
  4. Rear-end collision on an arterial during the AM peak
  5. An oil spill on freeway during the AM peak
  6. A terror threat in a downtown skyscraper during the AM peak
- Planned Event
  1. Closure of a lane due to construction on an arterial during the AM peak
  2. A baseball playoff game during the PM peak
  3. Vacation-bound traffic on the Friday before Labor Day during the PM peak
  4. Inclement weather in the form of a blizzard during the AM peak
  5. Inclement weather in the form of light snow during the PM peak.

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

1. Normal Operations—No incident
2. Incident—On freeway during the AM peak
3. Planned Event— A baseball game during the PM peak
4. Planned Event—Inclement weather in the form of a blizzard during the AM peak.

These four scenarios represent planned and unplanned, and recurring and nonrecurring events that cause stresses on the transportation system. In addition, these scenarios help investigate the effects of both location specific incidents such as an incident on the freeway and the systemwide effects of a blizzard. These four scenarios were chosen in order to develop analysis packages that would investigate all facets of the events that would cause stresses on the transportation system.

1.2 Document Overview

This document includes the following chapters:

- Chapter 1 provides the scope and overview of this Analysis Plan document.
- Chapter 2 describes the hypothetical region and provides a description of the four analysis packages.

- Chapter 3 provides the main points of the Analysis Plan, including the overall scope and objectives, data needs, performance measures, analysis approach, and modeling requirements for the four analysis packages.
- Chapters 4–7 describe each of the four analysis packages in detail, including their scope and objectives, data needs, performance measures, analysis approach, and modeling requirements.
- Chapter 8 presents a summary of the modeling requirements.

The analysis plan, and modeling requirements for the four analysis packages presented in this document are illustrative in nature. These provide guidance on the development of a robust set of requirements for the ATDM AMS framework and potentially future test-bed development. This document is not intended to be a guiding document for agencies or analysts to develop their own analysis plans or modeling requirements.

1.3 Report Overview

The analysis scenarios described in this report have been developed for the purpose of developing the Analysis Plan and are not meant to be considered as the only analysis scenarios or situations that may be of interest to the potential users of the AMS system nor the only analysis packages for which ATDM is applicable. These four analysis packages have been developed to specifically illustrate how AMS can be used to assess the impact of dynamic management or a collection of dynamic strategies under specific operational scenarios. Each analysis package includes a combination of different—

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

An Analysis Plan has been developed for each analysis package. Provided below is the high-level description of the contents of the Analysis Plan for each analysis package:

1. **Analysis Plan Scope.** This section describes the scope of analysis plan.
2. **Region and Existing Conditions.** This section describes the geography and demographics of the region, the major transportation facilities, and the supply and demand characteristics of the region.
3. **Analysis Scenario and ATDM Strategies to Be Analyzed.** This section of the Analysis Plan presents a description of the strategies used and the anticipated impact of the strategies on each component of the trip chain.
4. **Data Needs.** This section presents the data needs to support ATDM evaluation.
5. **Performance Measures.** This section describes the performance measures of interest base on the ATDM goals and objectives.
6. **Tools Needed for Analysis.** This section presents a discussion of the possible tools needed for the analysis.
7. **Analysis Settings.** This section develops and defines the analysis and assumptions used to develop the analysis approach.
8. **AMS Approach.** This section details the steps involved in evaluating the impact of the ATDM concept. In addition, it describes the modeling approach for monitoring the system, assessing system performance, and evaluating the impact of ATDM actions.
9. **Model Calibration.** This section describes the calibration approach and considerations.
10. **Modeling Requirements.** This section details the set of modeling requirements for analyzing the analysis package.

Chapter 2: Region and Existing Conditions

To develop the Analysis Plan to evaluate the impact of implementing ATDM strategies, it is beneficial to describe the geographic region and the demand and supply characteristics that are applicable to each of the four analysis packages. The purpose of this section is to introduce a typical hypothetical regional environment under which each of the four analysis packages is applicable.

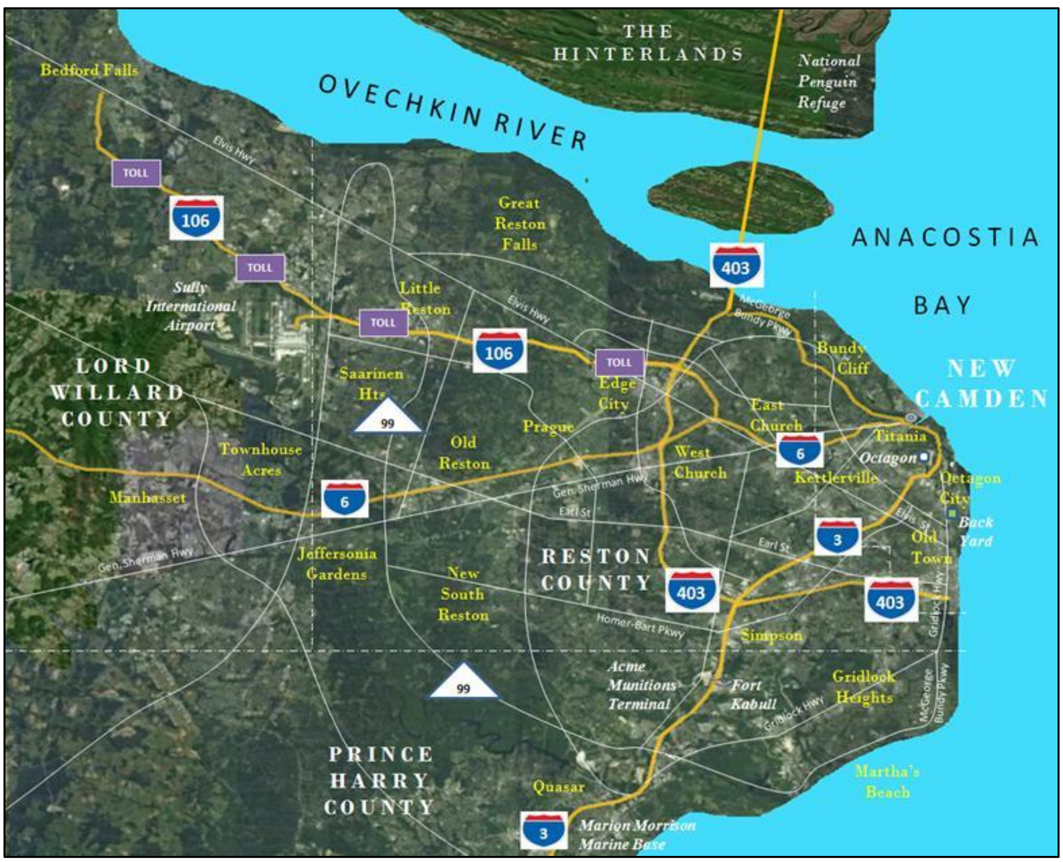
2.1 Region Description

This section details the geography, the demographic characteristics, and the transportation system elements for the fictitious region created for the purpose of developing the Analysis Plan.

Geography and Demographics

The fictional region—New Camden and Northern Jeffersonia (NCNJ)—presented in Figure 2-1 is a metropolitan area of approximately 3 million people that includes various state and municipal entities and transportation characteristics.

Figure 2-1: NCNJ Region Local Entities



This 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 and retail zones along with a mix of distressed and prosperous residential districts. The Back Yard is the sports and entertainment district in the vicinity of Octagon City that includes baseball and football stadiums and a hockey arena. Parking is limited in older areas and in the central business district; it is available throughout the city, but parking in the employment centers is expensive. 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 time of day/day of week. About 25 percent of the intersections are pretimed, while the remainder use a combination of semiactuated and fully actuated controllers, generally compliant with National Electrical Manufacturers Association TS 2 standards. The city maintains a central traffic control center that is staffed during peak periods and 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 and townhouse communities near metro rail stations and in areas bordering New Camden. 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 large-scale commercial and business development. and against development of a major historic theme park in the county. Subsequently, residential development increased, which caused 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-person or more carpools (high-occupancy vehicle with two or more people [HOV-2]) and buses in the peak direction during peak periods. I-6 is in need of rehabilitation 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 runs 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 (State Route [SR] 10) to Octagon. It typically operates at levels that range from a level of service (LOS) D to F during peak periods and during many weekend periods. Traffic is equally heavy in both directions during evening peak periods because of extensive employment in Reston County and resultant “reverse commuting.” Ramps inside the beltway are metered.

Interstate 3, a north–south freeway, is a six- to eight-lane road with two reversible lanes used for HOV with three or more people (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. Extensive reverse peak congestion occurs in the northbound direction on baseball or hockey game days and during football games on Sundays or weeknights.

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. It experiences delays, which result from heavy traffic throughout the week. 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.

Interstate 106, or the Sully-Edge Toll Road, is a toll facility that contains toll-free median lanes that connect to Sully International Airport. The Interstate 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).

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, and it supports bus services .

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 it 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.

SR 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. It provides the primary alternate route around New Camden relative to the beltway.

Public Transit

New Camden is served by several public transit modes, including 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. A 55-mile metro rail system serves the western and southern regions as well as the suburban regions (Figure 2-2). The Northern Area State Commuter Rail System, also shown in Figure 2-2, serves the southern and southwestern suburban regions and uses existing freight rail right-of-way. The commuter rail network is supported by a combination of express buses, local buses, and bus circulator routes that connect suburban areas with the rail network.

Figure 2-2: Major NCNJ Rail Transit Services

Metro rail provides service to the north (Sully-Edge) and the south (Prague) branches in Reston County. These branches merge at East Church station into a single line and continue into Kettlerville and the central business districts. The line travels past Octagon and Octagon City into Old Town, where it splits into two branches and serves the south suburbs.

Intelligent Transportation Systems

Several routes in the region are well instrumented with detection, monitoring, and information systems. I-3 and I-6 are fully equipped with detectors (1/2-mile spacing) and include cameras at 1-mile intervals. I-6 contains CCTV with some variable message signs used for HOV operations and to warn of downstream delays west of the Prague interchange. I-106 and the beltway (I-403) have traditionally been monitored with CCTV, and I-403 is being equipped with ITS as part of the high-occupancy toll (HOT) lanes project (see Figure 2-3). Variable message signs, typically located about 1 1/2 miles ahead of decision points, provide advisory information and travel times on instrumented routes. Fiber-optic 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. Figure 2-3 provides an overview of the ITS infrastructure in the region. CCTV cameras are located along I-106 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 Super-Regional Transportation Management Center (STMC) in Reston County incorporates the Jeffersonia Department of Transportation (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.

Transit services are monitored from the NCTA headquarters' Transit Operations Facility (TOF). It features a large-scale electronic vehicle location map that uses systemwide bus Global Positioning System (GPS) and rail track circuit information. The commuter rail GPS locations are handled on a series of small PCs and laptops located in 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 2-3: NCNJ Freeway ITS Infrastructure

2.2 Existing Conditions

Major highways in the NCNJ region experience significant congestion, especially during peak periods in the peak direction. Table 2-1 presents LOS for major highways (freeways and major arterials) in the region.

Table 2-1: Level of Service for Major Highways

Highway	LOS
Interstate 6	DF
Interstate 3	E–F
Interstate 403	D
Interstate 106	E–F
General Sherman Highway	D–F
Elvis Street	D–E

Highway	LOS
SR 99	D–E

This significant congestion along major highways occurs despite relatively high use of the regional transit system. I-6 and I-3 usually operate at lower LOS during peak period hours. I-6 is burdened by heavy traffic in both directions in the evening peak hours because of the relatively high number of reverse commuters. I-3 also faces additional reverse peak congestion on game days. Travel delays that result from traffic volume that is higher than capacity are a daily problem on I-403. Unsafe average speeds on I-403 have led to higher crash rates, which further compound travel delays.

More than 20 percent of commuters use transit. Metro rail operates at capacity in peak directions and at 60–70 percent in off-peak periods. Commuter rail and bus services operate at less than 70 percent load factors for the most part and less than 40 percent for the entire day. Reverse commuter traffic, particularly toward the Edge City–Sully Airport corridor, is significant in the morning and even more significant in the evening peak, because traffic bottlenecks at the point where the I-106 connector and I-6 merge.

A major exception to relatively low use of bus transit is the Gridlock Highway corridor in northern Prince Harry County, which connects to the metro rail station at Gridlock Heights. Fort Kabul, Morrison Marine Base, and numerous apartments and commercial and strip mall developments are located within the corridor. The busload factor here generally is more than 100 percent during peak periods and 80 percent during off-peak periods. Even all-night bus service has a 40 to 50 percent load factor. Connectivity between bus and rail services on either end of the corridor is limited, however.

Event traffic generated by the Back Yard sporting venues, especially traffic generated by night games during the week, creates further problems: event traffic, mixed with peak-hour traffic, adds to existing congestion, and reduces parking availability 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 real-time information on parking availability nor a single source for traffic and transit information. Travel time information and thematic maps are provided on the JDOT website, but transit information is accessed through the individual NCTA, RestBus, Northern Area State Commuter Rail, or HarrTrans websites. All the websites offer bus location information, and the NCNJ 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.

Chapter 3: Common Analysis Plan Elements

Chapter 2: presents the baseline conditions of the transportation system to be evaluated in the four analysis packages. The regional characteristics and current activities have been described to present a snapshot of trip demand levels across the region. This chapter presents common elements of the Analysis Plan for the four analysis packages and describes the scope, data needs, and tools needed to analyze and evaluate the analysis packages. The next four chapters present the analysis package specific sections of the Analysis Plan.

For the purpose of this Analysis Plan, it is assumed that macroscopic, mesoscopic, and microscopic travel demand and simulation models exist for the region. It is further assumed that the computing resource is a large-scale parallel-computing cluster that is capable of executing models in a very small amount of time. It is assumed that the software used by these models is capable of parallel-processing and can run efficiently on a cluster of computers. Typically, most agencies develop macroscopic, and mesoscopic (DTA) models for the entire region but develop a microscopic model only for a small subarea or a corridor. It is assumed that a similar approach will be established with feedback loops (more tightly connected than the traditional, sequential feedback loop). It is likely that a significant portion of the region will be micro-simulated, especially during investigation of strategies such as adaptive traffic signals for multiple corridors along the region.

Although the system is monitored and analyzed for a certain time period, such as a 3-hour AM peak period, the simulation models used to monitor, assess, and evaluate the system are executed for the entire day. It is essential to simulate the entire day to ensure that traffic and delays on roadways are accumulated and dissipated, and that a traveler’s activities during the day are preserved.

3.1 Analysis Plan Scope

AMS is needed to support agencies during their evaluation of ATDM at the planning, design, and operational stages. To support the planning and design stages, a simulated, real-time analysis with the use of ATDM strategies is required to quantify the potential impact of dynamic management. tTo support real-time operations, a real-time analysis is needed. The scope of the Analysis Plan described in this chapter is restricted to the conduct of analysis for planning and design purposes with the use of simulated, real-time analysis. It is assumed that a continuous feed is available to the analyst of real-time data that applies AMS to evaluate the benefits of ATDM implementation.

While this analysis plan is under development, the availability of the data in the real world is not a concern. To investigate how the analysis can be conducted to test the impact of real-world implementation in an AMS environment, however, the dynamic nature of the real world needs to be replicated. The Analysis Plan for the analysis packages is designed to address the following questions:

- What AMS steps are required to—
  - Monitor the system
  - Assess system performance through the use of a prediction moving window
  - Evaluate the impact of ATDM strategies in real time?
- How can dynamic actions be used to influence every component in the trip chain?

- How are behavioral changes captured in response to implementation of dynamic actions?
- What are the potential benefits that result from proactive management compared with reactive management?
- How are different models integrated to support evaluation?

3.2 Regional and Existing Operational Conditions

Chapter 2: presents an overview of the hypothetical region and details the various transportation demand and supply elements for that region.

3.3 Analysis Scenario and ATDM Strategies to Be Analyzed

This section presents a snapshot of the scenario and the ATDM strategies chosen for the four analysis packages. The next four chapters, which present the Analysis Plans for the four packages, describe these strategies in more detail. Table 3-1 shows specific ATDM strategies selected for each analysis package.

Table 3-1: Operational Scenario and ATDM Strategies Applicable to Each Analysis Package

ATDM Strategies	Analysis Scenarios			
	1: Normal Operations—No Incident	2: Incident— On Freeway During AM Peak	3: Planned Event—Baseball Game During PM Peak	4: Planned Event—Blizzard During AM Peak
Dynamic ridesharing			X	
On-demand transit			X	
Predictive Traveler Information	X	X		X
Dynamic pricing (roadway and transit)	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	

3.4 Data Needs

The data needs for the analysis for all four analysis packages include both historical data and real-time data. The following sections elaborate on the data elements that need to be collected for each of the aforementioned categories of data. Additional analysis package-specific data needs are presented in the next four chapters, which describe the Analysis Plan for the four analysis packages.

Historical Data

To support dynamic management, it is necessary to analyze historical data trends and the system's response to various events. Historical data needed to support ATDM evaluation include—

- Demographics data
- Traveler behavior data
- Transportation network data
- Traffic control device and traffic sensor device information
- Time-of-day trip table data.

Demographics Data

The following list includes and provides a brief description of the demographic data needs for analysis:

- Activity locations[1] are needed to generate trips and to choose destinations. Examples include—
  - Residences
  - Places of employment
  - Schools
  - Grocery stores and shopping centers
  - Centers for social recreation
- Data is needed on—
  - Vehicle ownership by vehicle classification to compute total emissions
    Household vehicle ownership for mode choice
- Household income levels are needed for mode and facility (toll) choices.

Traveler Behavior Data

Traveler behavior data is necessary to develop stochastic models that capture traveler and driver behavior. It has been observed that traveler behavior typically varies by type of urbanized area and its geographic extent. The following list provides the traveler behavior data needs for the analysis:

- Traveler trust in ATDM strategies (e.g., traffic operator advisories)
- Transit propensity
- Rate of traveler compliance with traffic rules and traffic signals
- Driver behavior, including aggressiveness.

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[1] An individual's day consists of various activities, such as working, shopping, eating meals, and meeting friends. An *activity location* may, for example, be a place of residence, a place of employment, a school, a restaurant, or a grocery store. During the course of a typical day, an individual travels from one location to another to perform an activity.

Transportation Network Data

The following list provides a brief description of key transportation network data needs to support analysis:

- Roadway segment and lane information
- Traffic signal locations, timing plans, phasing plans, and cycle offsets
- Transit routes, stops, and time-of-day schedules
- Parking location and capacity data
- Roadway segment shoulder information
- Lane merge, diverge, and turn pocket information.

Traffic Control and Sensor Device Information

Traffic control device and traffic sensor information is necessary to be able to assess and monitor the existing system. The following list shows the traffic control and traffic sensor device data needs for the analysis:

- Sensor detector vehicle count and speed data
- Video surveillance data, including vehicle occupancy data
- Locations and functions of message signs
- Road-side sensors—
    - Locations
    - Type
    - Functional uptime and reliability.

Time-of-Day Trip Patterns Data

Time-of-day trip pattern data is necessary to understand the temporal distribution of trip-making, assess the impact of strategies on time-of-day choice, and to forecast future system performance.

Real-Time Data

To analyze the impact of dynamic actions, it is necessary to analyze not only historical data trends but also real-time data and the system's response to various events. The following list provides real-time data needs and a brief description of how the data will be used. Section 3.8 details how each of these data items will be used for the analysis. Real-time data can include—

- Sensor detector vehicle count and speed data
- Video surveillance data, including vehicle occupancy data
- Signal plans and traffic control device data and real-time operations data (e.g., toll prices, HOV restrictions, turn restrictions, parking restrictions, shoulder lane operations)
- Real-time bus and train locations
- Work zone data
- Incident information.

Although some of the aforementioned data items are necessary inputs for AMS tools, others are necessary to operate the system in real time in a dynamic manner. For example, traffic control device data will be used by the AMS tools, while video surveillance data will be used to monitor the system. Some of these data sets are useful to monitor the system and for AMS tools. For example, sensor detector data will be used to monitor the system and will be used by the AMS tools.

3.5 Performance Measures

The system can be dynamically managed and operated with the ATDM approach to meet or exceed a set of performance objectives that focus on mobility, environment, or safety. To develop the analysis packages, the following are considered illustrative examples of performance objectives, because they relate to each of the four operational analysis packages described above:

- Person throughput
- Travel delays
- Travel time reliability
- Crash rates
- Emissions.

Although any performance measure can be chosen to evaluate the analysis packages, each analysis package has specific performance measures associated with it to help evaluate ATDM strategies. Table 3-2 maps the operational analysis packages to the performance objectives that will be considered as a part of the analysis package.

Table 3-2: Performance Objectives for Sample Analysis Packages

Analysis Package #	Analysis Package Description	Performance Measures of Interest				
		Person Throughput	Delays	Travel Time Reliability	Safety Crash Rates	Emissions Quantity
1	Normal Operations— No incident	X		X		
2	Incident—On freeway during AM peak		X	X		X
3	Planned Event—Baseball game during PM peak	X	X			
4	Planned Event—Blizzard during AM peak		X	X	X	

Each analysis package's performance measures are detailed in the next four chapters.

3.6 Tools Needed for Analysis

The tools used for analysis typically depend on existing models and tools that the agency for the region currently uses. The tools selected depend on the analysis scenario, the modes considered, the type of strategies implemented, and the performance measures to be generated. For the purpose of this Analysis Plan development, it is assumed that all tools are available for the modeler to conduct the analysis.

Advanced activity-based models are well suited to capture traveler behavior, including trip chaining, at a high fidelity. Traffic simulation models (macroscopic, mesoscopic, and microscopic) are well suited to capture the changes in system performance through the implementation of ATDM strategies. Mesoscopic simulation tools track time-dependent traffic flows in the network and thus capture a higher level of detail than macroscopic simulation tools. They also capture the delays caused by traffic signals. Microscopic simulation tools simulate the movements of individual vehicles dynamically on at least a second-by-second basis with the use of cellular automata 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 illustrate network performance in small time increments (15 minutes or less). Examples of output data that these models generate include link-level travel time, miles traveled, stop times, queue lengths, and delays. Table 3-3 lists various AMS tools commonly used in the industry today.

Table 3-3: Illustrative Examples of AMS 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 price and accessibility. This model predicts how changes in land-use policy and transportation supply affect the movement of households 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 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 San Francisco County, New York, Sacramento, and Denver.
Activity-based models	These models consider interaction among 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. Cities such as Columbus, San Francisco, Atlanta, and Phoenix are using, or are in the process of developing, full-fledged, activity-based models.
Traffic Operations Models and Tools	
Macroscopic models	Macroscopic simulation models are typically used to model corridors, freeways, and arterials with small or subarea networks. Examples include 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

Model/ Model Category	Description of Models, with Examples
	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.
Appendix A: Emissions Model	
Microscopic Emissions Model	MOVES is a modal emission model that derives emissions estimates based on second-by-second vehicle performance characteristics for various driving modes and geographic areas ranging from the nation down to link. MOVES received inputs from traffic simulation/traffic assignment models to generate emissions estimates.
Appendix B: Safety Tools	
SSAM	Surrogate Safety Assessment Model (SSAM) is a FHWA tool to analyze vehicle-to-vehicle interactions to identify conflict events and calculate several surrogate safety measures of interest

In addition to the aforementioned analysis tools, scenario-specific tools might be required for each analysis package. If an analysis package requires additional tools, the tools are presented in each of the next four chapters.

3.7 Analysis Settings

Table 3-4 describes the common analysis settings and assumptions for all the analysis packages. Analysis package-specific analysis settings are provided in the next four chapters. The time steps, time periods, and time windows are presented for illustrative purposes only. The local agency would choose these settings as it deemed appropriate for the analysis it was conducting.

Table 3-4: Analysis Settings for All Analysis Packages

Analysis Setting	Description
Simulation Time	All day.
Forecast period	For this analysis, a 30-minute (or an interval chosen by the local agency) forecast of future conditions will be made once every 10 minutes (or an increment chosen by the local agency).
Data	It is assumed that traffic count data is continuously fed from the freeway and arterial management systems to the analyst. Transit ridership and real-time schedule data also is available.

3.8 AMS Approach

The analysis scenarios represent the transportation activities and operations in the NCNJ region along with certain predictable recurring or nonrecurring stresses to the transportation system. The approach to evaluation of the scenarios from the ATDM perspective involves creation of a model to analyze the demand and supply during the time period of analysis along with a predictive component to forecast future traffic conditions. The analysis framework is shown in Figure 3-1 and consists of the following components:

- Scenario Generator

- Data Generator
- Network Simulator
- Decision Gate.

Figure 3-1: ATDM AMS Framework

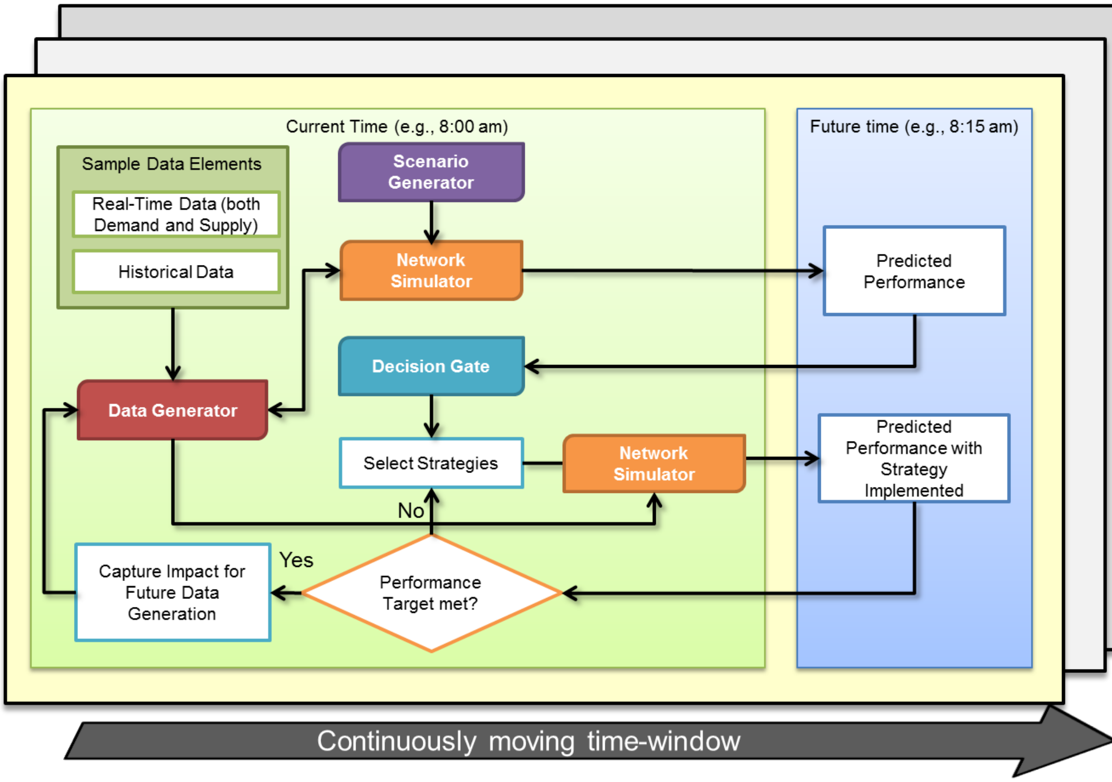


Figure 3-1 shows how the various components of the ATDM AMS system interface with each other to support simulated real-time analysis. The analysis approach consists of the following phases:

- Monitor the system
- Assess system performance with the use of a predictive moving window
- Evaluate dynamic actions and capture the impact-dynamic action for the next moving window.

The ATDM AMS process flow is presented in the paragraph that follows. The time steps, time periods, and time windows are presented for illustrative purposes only. The local agency would choose these settings as it deemed appropriate for the analysis it was conducting.

- The Scenario Generator creates multiple scenarios (e.g., lane closures that result from incidents, work zone conditions) of interest to the analyst.
- The Data Generator collects real-time and historical data from multiple sources and modes, creates the necessary inputs for analysis and to monitor the system, and provides the inputs to the Network Simulator.
- The Network Simulator replicates the real world in a simulation setting. Upon the successful monitoring of the system in real time with simulation tools, and the generation of the necessary performance measures with the use of the Performance Interpreter within the Network Simulator, a prediction window for future forecasted conditions is

created (e.g., at the current time step [08:00], network conditions are evaluated for the time period 08:00 to 08:30).

- After this prediction window is established (i.e., a forecast of conditions is performed), the Performance Interpreter generates predicted performance metrics (e.g., travel time reliability, travel times) of interest to assess the system.
- These predicted future conditions are compared with the agency's goals at the Decision Gate (at the current time step) to determine if an ATDM action is warranted. If the performance goals are met for the prediction window, no action is taken, and the Network Simulator is used to continuously monitor the system.
- If the forecasted performance does not meet the agency's goals, a set of dynamic actions is selected, and those strategies are implemented in the Network Simulator to forecast a new performance metric with the strategy implemented.
- The net impact of strategy on various elements of the trip chain are captured, and the Data Generator uses them to adjust the estimated demand in the next time step.
- The process is progressively repeated during desired time durations.

The following section describes the components within the ATDM AMS cycle.

Components

The AMS approach to evaluate the impact of implementation of ATDM in the NCNJ region requires the following, four components:

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

Each component is described in the following sections.

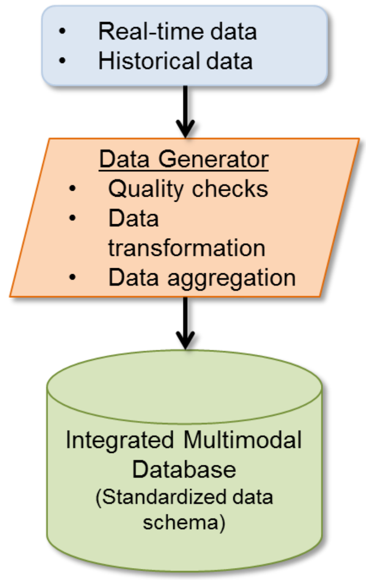
Scenario Generator

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 that result from incidents; work zone conditions; and special events, such as game days and inclement weather conditions, as they occur in the real world. An AMS system user may use the Scenario Generator to create situations of interest to test the impact of the ATDM action. The Scenario Generator provides the necessary demand and supply updates to the Network Simulator component, which creates the real world in a simulated environment.

Data Generator

The Data Generator component of the AMS system serves as an interface between the real world and the Network Simulator component. To support this analysis, data from various types of sensors in the NCNJ region 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 for use by the Network Simulator. Figure 3-2 shows how the data is processed in the Data Generator.

Figure 3-2: Data Processing and Integration



To monitor the system, the Data Generator—

- Collects real-time traffic data and historical traffic data
- Collects real-time weather-related data that affects traffic flow, including—
    - Visibility
    - Icy and slippery conditions
    - Roadway segments treated for snow
    - Debris that blocks roadways
    - Traffic sign visibility
- Generates the data that the Network Simulator needs
- Feeds data to the Network Simulator
- Receives and processes data from the Network Simulator to prepare data for the next time step.

It is assumed that the following data elements for the NCNJ region are available at a minimum.

Roadway Data

- Sensor detector data (vehicle counts and speeds)—
    - Link-based counts for 5-minute intervals (or an interval chosen by the local agency) from data-collection points located on both freeway and arterial facilities
- CCTV data—
    - Vehicle occupancy
    - Vehicle type
- System control data—
    - Shoulder lane use (e.g., access time, accessibility rules)
    - HOV lane restrictions (e.g., location, time)
    - Traffic signal control (e.g., locations, signal phase cycles, signal directions, algorithms for adaptive control)
    - Toll pricing data—
        - Pricing structure

    - Toll access demand data
    - Toll price sensitivity data.

Transit Data

- Ridership data
- Transit schedule and operations data.

The following list details data quality issues:

- Roadway and transit data for the NCNJ region collected in real time is likely to have several data quality issues, such as missing observations and erroneous values. These issues will be addressed in real time by—
    - A real-time quality check algorithm that treats the incoming data and flags the values that are implausible or that are clear outliers
    - Statistical data interpolation techniques used to estimate the missing values (The interpolation techniques will account for scheduled shutdown of the sensors for maintenance and measurement errors caused by calibration issues.)
- Postprocessed data from various sources will be converted to a standardized format that includes geographical and temporal information to create a single, integrated database. The tasks involved in post-processing the data are the following:
    - **Temporal Aggregation.** The multimodal demand and supply data for the NCNJ region will be aggregated into 5-minute increments (or an increment chosen by the local agency).
    - **Geographical Aggregation.** Processed roadway sensor data for the NCNJ region is available by lane. For mesoscopic analysis, these observations will be aggregated to the roadway link level. For example, vehicle count and speed data over distinct sensor detector locations in the NCNJ region will be aggregated over individual links to generate link flow and average speed data.

In addition to differences in geographical and temporal data granularity, other issues include missing values and incompatibility of data file formats across the various data sources. It is imperative that a standardized data schema for the integrated database be defined. The Data Generator processes real-time data into a standardized data schema, and creates an 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 in real time. When the modeling is completed in the Network Simulator, the Data Generator receives the window of current movement of vehicles from the Network Simulator. The Data Generator uses this data to capture driver behavior and traveler choices as modeled in the Network Simulator and to update the data for the next time step.

Network Simulator

The 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 the impact of dynamic actions. The Network Simulator component re-creates the real world in a simulation environment and supports simulated real-time analysis. To monitor, assess, or evaluate the system, the Network Simulator—

- Receives data from the Data Generator in real time
- Uses the data to generate time-dependent demand for the NCNJ region
- Executes the macroscopic, mesoscopic, and microscopic simulation models

- Computes performance measures and interprets these measures
- Creates a moving window to forecast network conditions, and predicts network conditions anticipated in the near future
- If ATDM actions are to be implemented, re-estimates the future network conditions with the ATDM action in place
- Supports continuous the monitoring of the transportation system
- Feeds data back to the Data Generator to generate data for the next time step.

Data from the Data Generator, input to the Network Simulator, consists of a multiresolution model that includes a macro model, a DTA model, and a microscopic simulation model. In addition, the Network Simulator includes a Performance Interpreter that postprocesses the simulation results to generate the desired performance measures. The data generated by the Data Generator is input to the virtual/simulation world. The Network Simulator uses the data from the Data Generator to create time-dependent demand data, and network supply data and to conduct multimodal integrated analysis. The Network Simulator will support a multiresolution analysis framework that includes a macro model for demand estimation and traffic assignment models, with the demand estimation and traffic assignment components completely integrated. An advanced demand estimation model (which generates time-dependent activity patterns) and advanced traffic assignment models need to be linked in a completely integrated manner to capture the dynamic nature of the ATDM concept. This process ensures that there is a constant stream of communication between the demand model and traffic assignment model within the time period. This integration ensures that trips are routed on the network, because they are generated by the activity model and are dynamically updated on the basis of real-time traffic conditions to capture the dynamic nature of the ATDM concept.

Decision Gate

The measures of excellence (MOE), generated by the Network Simulator during the prediction phase, are compared with the agency's objectives to decide whether or not dynamic actions are needed to meet the performance goals in the future time period. If the performance goals are not met without an intervention, the set of ATDM actions to test are selected. For real-time operations, a decision support system (DSS) will be used to evaluate and suggest the best strategies to use. For simulated real-time analysis, however, it is envisioned that the analyst will input the strategies to test (i.e., a human DSS).

Analysis Phases

The analysis approach is detailed in the following sections. This approach includes the following, three phases:

- Monitor the system
- Assess system performance
- Evaluate dynamic actions and capture the impact of the dynamic action for the next moving window.

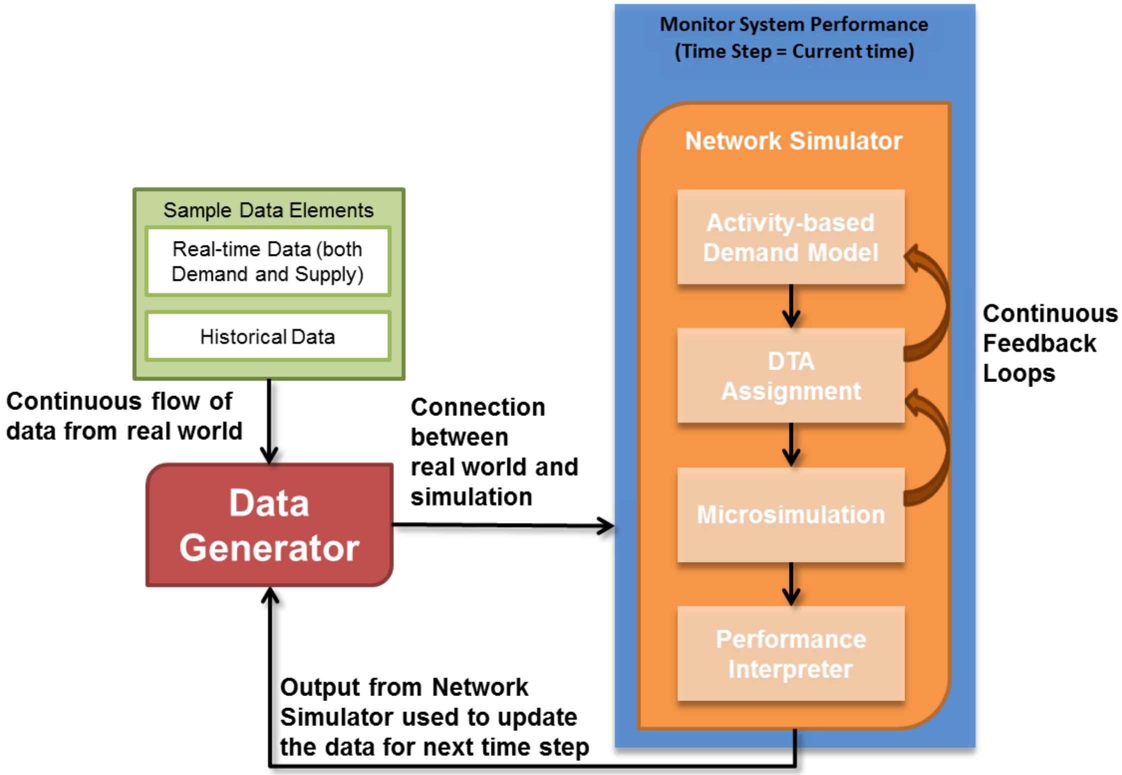
The following sections detail each of the aforementioned three phases.

Monitor the System

The monitoring of the transportation system in real time for the NCNJ region is the first step in the ATDM AMS cycle. During this phase, the system is monitored continuously with the use of real-time and historical data in conjunction with AMS tools. Data collected from various sources is filtered, cleaned, integrated, and processed to make it usable for dynamic management. For the purpose of this Analysis Plan, the assumption is that a steady stream of real-time data and a database of historical data are available. The raw input data is transformed with stored procedures into desired data formats.

Figure 3-3 shows the overall process flow to monitor the system in simulated real-time. It also shows how the Network Simulator component interfaces with the Data Generator.

Figure 3-3: Overall Process to Monitor the System



The following presents the tasks to be performed sequentially to monitor the system. The time steps, time periods, and time windows are presented for illustrative purposes only. The local agency would choose these settings as it deemed appropriate for the analysis it was conducting.

- **Data Generation.** The Data Generator continuously receives data from the real world in real time. It processes the real-time and historical data in real time to monitor and assess the transportation system with use of the virtual/simulation world.
- **Preliminary Demand Creation.** The travel demand model for the NCNJ region produces the time-dependent origin–destination (O-D) demand matrix or activity patterns (i.e., creates a list of vehicle and transit trips, including drive-alone and carpool, with departure and arrival times for the entire day). For example, 5-minute-interval, time-dependent matrices are generated from 00:00 to 23:55 (24 hours) by each mode. This task is performed by the Network Simulator with historical data, and is input to the simulated, real-time analysis.
- **O-D Estimation Based on Real-Time Data.** The sensor detector counts for the NCNJ region provide location- and time-specific vehicle movement data. The Data Generator processes this real-time data for use during the O-D estimation process by the Network Simulator. The O-D estimation process within the Network Simulator uses the demand

model's activity patterns and the real-time count data to refine the time-dependent O-D trip tables and produce activity patterns by mode (e.g., drive alone, carpool, and transit) with individual traveler departure and arrival times. This step accounts for the variability in day-to-day demand or the variability that results from a specific incident, such as an accident on the freeway, and ensures that the activity patterns generated are representative of the current day for the system monitoring time window. For example, the Network Simulator uses the observed counts between 07:55 and 08:00 to adjust the trip table between 08:00 and 08:05.

- **Traffic Simulation.** It is assumed that simulation time is several times faster than the real time, and the simulation time is kept in sync with the real clock time (i.e., the 08:00 simulation occurs at 08:00, and the data from the real world is continuously used by the Network Simulator). The refined demand from the previous step (i.e., trips by individual trip start and end times and mode) is used as input to assign passenger car/transit trips onto the network to generate flow distributions as a result of time-varying congestion throughout the entire network. A DTA is performed on the regional network to establish flow distributions and route diversions caused by time-varying congestion throughout the entire network. It is important to perform a DTA assignment to capture the dynamic aspect of the ATDM concept. Static traffic assignments used in traditional, four-step models will not support this analysis. The DTA assignment produces flow distributions and route diversions that will be used to compute congested travel times for every highway link by time of day. The flow distributions and route diversions from the mesoscopic model are used by the microscopic model, which simulates traffic and performs detailed operational analysis. This microscopic model outputs vehicle movements on the network. These outputs from the microscopic model are fed back to the DTA tool to update the systemwide flow distributions. This process is repeated until convergence is achieved (i.e., both models produce similar results).
- **Feedback Loop.** The output from the traffic assignment model will result in travel times for all links in the entire region for the current time step (e.g., 08:00). The traffic assignment results (i.e., congested travel times) are fed back to the demand model to adjust activity patterns until convergence is achieved between network conditions and activity generation in real time. This iterative process continues until reasonable convergence is achieved, and the simulated link volume between 07:55 and 08:00 is within the acceptable error range (e.g., 5 percent). Standard user-equilibrium assignment procedures will have to be replaced with more sophisticated dynamic user optimal algorithms.
- **Validation.** The outputs from the traffic assignment are validated with the real-time data for the same time period, and demand and traffic assignment tools are calibrated to produce vehicle flows that match the ground conditions. A validation module compares the output link flows with the counts from real-world data and ensures that the models and tools used to monitor system performance are calibrated for each time step.
- **Simulation Output Creation.** After each simulation is completed, the current movement of vehicles on the network is created. The movement of vehicles is then fed back to the Data Generator to refine the data required for subsequent time steps. The outputs of this simulation include link-level traffic flows and average speeds.
- **Performance Interpretation.** The Performance Interpreter within the Network Simulator uses the output from the traffic assignment after every simulation to produce a variety of anticipated performance measures, such as speed, mobility delay, crash rates,

emissions, and travel time reliability at a roadway segment, corridor, or regional level as desired and applicable.

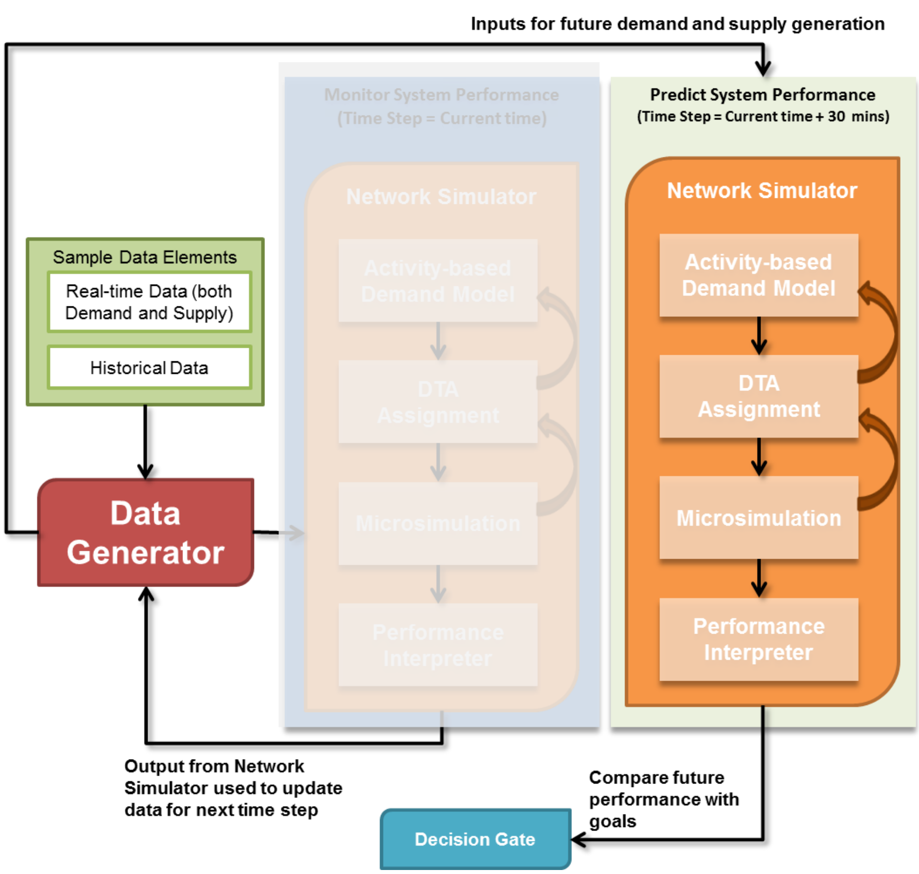
Various parts of the multi-resolution model capture impacts on different parts of the trip chain. For example, although the macroscopic model captures the impacts on destination- and mode-choice, the mesoscopic DTA model captures the impact on route-choice, and the microscopic model captures the impact on lane-choice. To capture the impacts on every part of the trip chain, a multi-resolution model has been proposed to analyze system performance during the monitoring phase.

When the aforementioned steps are complete, the system monitoring phase for the current time step is complete, and the system assessment phase begins. The following section details the system assessment phase.

Assess System Performance

Use of a predictive window to assess performance facilitates early detection of impending congestion, and enables preemptive traffic management measures. The requirements of this step of the ATDM AMS cycle warrant the need for a predictive capability in the AMS framework (see Figure 3-4). This predictive capability will use historical and real-time data, supply characteristics of the network, and knowledge about the short-term changes in demand and supply (from historical data) to generate demand for the next time step.

Figure 3-4: Overall Process for Assessing the System



The tasks presented as follows are to be performed sequentially to assess system performance in the immediate future. Time steps, time periods, and time windows are presented for illustrative purposes only. The local agency would choose these settings as it deemed appropriate for the analysis it was conducting.

- **Preliminary Demand Creation.** The travel demand model for the NCNJ region produces the time-dependent O-D demand matrix or activity patterns (i.e., creates a list of vehicle and transit trips, including drive alone and carpool, with departure and arrival times) for the future time window (e.g., 08:00 to 08:30). The Network Simulator performs this task.
- **Real-Time Count Data Extrapolation.** It is necessary to ensure that demand is consistent with the observed count data to predict and assess the system for the future time step (08:00 to 08:30) through its simulation at 08:00. Although it is possible to procure real-time count data for the previous time periods, the current time step's real-time data is not yet available. Because historical data for the next time step (08:00 to 08:30) and real-time data up to the current time point (08:00) are available, it would be possible to perform an estimation of counts for the current time step (08:00 to 08:30) to account for the variation in demand. The Data Generator performs this extrapolation of count data.
- **O-D Estimation Based on Real-Time Data.** The sensor detector counts and speed data for the NCNJ region provide location- and time-specific (08:00) vehicle movement data; the O-D estimation process uses the activity patterns that the demand model generates with real time that the Data Generator provides to refine the time-dependent O-D trip tables for the next time step (08:00 to 08:30) and produces activity patterns by mode (drive alone, carpool, and transit) with individual traveler departure and arrival times. Thus, this step accounts for the variability in day-to-day demand and ensures that the activity patterns generated are representative of the current day and real-time data. The Network Simulator performs this task.
- **Traffic Simulation.** The refined demand from the previous step (i.e., trips by individual trip start and end times and mode) is used to assign passenger car/transit trips onto the network to generate flow distributions caused by time-varying congestion throughout the entire network for the next time step (08:00 to 08:30). A DTA is performed on the regional network to establish flow distributions and route diversions caused by time-varying congestion throughout the entire network. It is essential to perform a DTA to capture the dynamic aspect of the ATDM concept. Static traffic assignments used by traditional, four-step models will not support this analysis. The DTA produces flow distributions and route diversions that will be used to compute congested travel times for every highway link by time of day. The flow distributions and route diversions from the mesoscopic model are used by the microscopic model, which simulates traffic and performs detailed, operational analysis. This microscopic model outputs vehicle movements on the network. The DTA tool uses these outputs from the microscopic model to update the systemwide flow distributions. This process is repeated until convergence is achieved (i.e., both models produce similar results).
- **Feedback Loop.** The output from traffic assignment model will result in travel times for all links in the entire region for the current time step. These travel times are not the same travel times that the activity-based model uses to generate activity patterns. Therefore, outputs from the traffic assignment model (congested travel times) are fed back to the demand model to adjust activity patterns until convergence is achieved between network conditions and activity generation in real time. This iterative process continues until reasonable convergence is achieved. Convergence is achieved when the travel times used to generate activity patterns and the travel times output by the traffic assignment

module are consistent. Standard user-equilibrium assignment procedures will have to be replaced with more sophisticated dynamic user optimal algorithms.

- **Performance Interpretation.** The Performance Interpreter within the Network Simulator will use the output from the traffic assignment tools after the simulation (08:00 to 08:30) to produce anticipated performance measures, such as speed, mobility delay, crash rates, emissions, and travel time reliability at a roadway segment, corridor, or regional level as desired and applicable. The anticipated future performance for the next time window (e.g.,08:00 to 08:30) is compared against the performance goals at the Decision Gate component to determine whether or not dynamic actions are to be implemented to improve future performance.

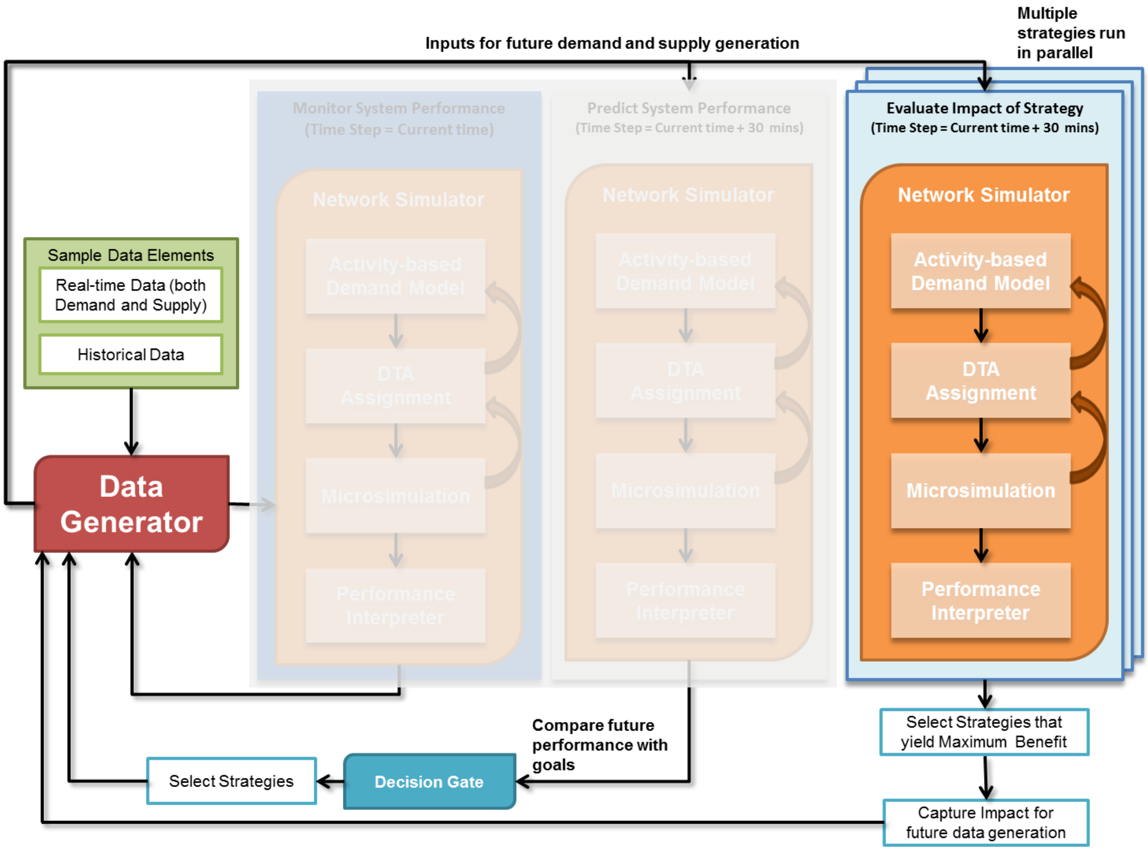
Different parts of the multi-resolution model capture the impacts on the various parts of the trip chain. For example, although the macroscopic model captures the impacts on destination- and mode-choice, the mesoscopic DTA model captures the impact on route-choice, and the microscopic model captures the impact on lane-choice. To capture the impacts on every part of the trip chain, a multi-resolution model has been proposed to analyze system performance during the assessment phase. During the assessment phase, the macroscopic model captures changes in demand as the result of daily variation (e.g., a baseball game, or a blizzard) while the mesoscopic model uses this demand and captures the impacts on route choice as a result of events such as closure of roadways because of a blizzard or to accommodate special event traffic and parking. The microscopic model captures the impacts of details such as parking availability in the vicinity of the baseball stadium.

When the aforementioned steps are complete, the system assessment phase for the current time step is complete, and the system evaluation phase begins. The system assessment phase provides the “baseline” for the analysis package, while the system evaluation phase provides the “”alternative scenario, which is compared with the baseline to evaluate whether or not the chosen strategies were effective. The following section details the system assessment phase.

Evaluation of the Impact of ATDM Strategies

The most important step of the analysis is to evaluate the impact of various strategies. This process to evaluate the impact of ATDM strategies is identical to the process used to assess system performance. A demand and Strategy Generator will create a set of ATDM strategies for evaluation and identify or choose the ATDM strategies (either individual or a collection of strategies) to be implemented to improve network performance. In addition, it will identify network locations and the strategy to be implemented at each network location. The changes to network and demand anticipated as a result of implementation of the strategies should be explicitly considered in the Network Simulator. Once the strategy is implemented in the multi-resolution network, the macro model adjusts the trip tables in accordance with the strategies implemented. The mesoscopic simulation tool will perform a DTA and generate flows and vehicle movements. Finally, vehicle movements will be simulated in the microsimulation (i.e., to perform detailed operational strategy analysis). The outputs from this simulation will be used as inputs to the mesoscopic and macroscopic models for the next iteration of the feedback process. This process continues until convergence is achieved. Traditional convergence criteria do not apply, and sophisticated convergence criteria are required. Figure 3-5 shows the overall approach to evaluate the impact of strategies. The steps involved in the evaluation of the impact of ATDM actions are detailed in this section.

Figure 3-5: Overall Approach to Evaluate the Impact of ATDM Actions

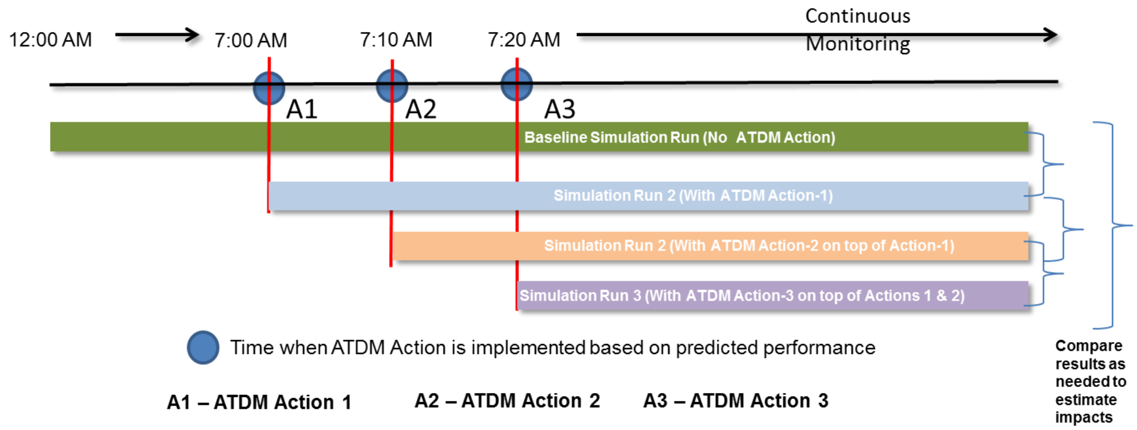


The following tasks are to be performed sequentially to evaluate the impact of ATDM actions.. The time steps, time periods, and time windows are presented for illustrative purposes only. The local agency would choose these settings as it deemed appropriate for the analysis it was conducting.

- **Problem Identification.** The creation of a current and predictive moving window allows for the monitor of the transportation system in virtual real time. If a problem is not identified in the predictive moving window and the performance goals for the time step are met, no action is taken, and system monitoring will continue, with a moving window in place for prediction. If a problem is identified, then the Decision Gate chooses dynamic actions to be implemented.
- **Implementation of a Dynamic Action.** If a potential issue is identified in the predictive moving window, a dynamic action needs to be implemented in advance to prevent the breakdown. The dynamic actions are implemented in the multiresolution model, and the model outputs are used to evaluate the new performance measures in the predictive moving window. These dynamic actions or strategies are manually implemented for analysis purposes in the multiresolution model as part of the simulated real-time analysis. The Data Generator creates the necessary data to implement changes to the demand and supply characteristics as they relate to the selected strategy. The changes to the multiresolution network include changes to network elements, such as roadway segments, roadway lanes, transit schedules, dynamic pricing, and dynamic parking.

  To quantify the impact of a new ATDM strategy implemented at any given time (e.g., 08:00), the performance measures from the simulation outputs with new ATDM action implemented at the next time step (e.g., 08:00 to 08:30) should be compared with the baseline condition that the Network Simulator predicted without implementation of that strategy. As a result, two sets of simulation should be carried out in parallel in real time—one with the ATDM action implemented and one with no action implemented. Similarly, if the analysis needs to capture the impact of every ATDM action (e.g., 09:30, 10:00), the simulation runs from the previous scenario should continue, and a new model run with the current strategy should be implemented. Figure 3-6 shows this concept.

Figure 3-6: Multiple Parallel Simulations



- **Captured Impacts on the Trip Chain.** The impact of dynamic actions on various elements of the trip chain are captured to predict how the network performance changes once the action is implemented. Dynamic action changes traveler behavior, and thus affects various parts of the trip chain. For example, dynamic tolls definitely affect route choice and may also affect mode choice. If a traveler is aware of an increase in tolls, he or she may either change the mode of transit or the route to avoid the higher toll. To capture such impacts effectively, it is necessary to estimate the effect of dynamic actions on the various components of the trip chain. The ATDM AMS framework will be implemented as a self-learning system. The framework uses historical data to estimate the sensitivity that a given dynamic action imposes on the components in the trip chain. In addition, stated preference survey data will be used to estimate model sensitivity initially.
- **O-D Estimation.** The impacts of ATDM actions on the trip chain warrant the refinement of activity patterns for the NCNJ region. The changes in travel behavior, as described earlier, will be used to re-estimate demand for the NCNJ region after dynamic actions have been implemented. These changes include changes to traveler mode-, route-, and facility-choice. The ATDM AMS system will capture the impacts of dynamic actions on the trip chain, and it will store the data to be extracted for use in the future. In time, the database will contain data that reflects the effects of every dynamic action.
- **Traffic Simulation.** The refined demand from the previous step (i.e., trips by individual trip start, and end times and mode) is used as an input to assign passenger car/transit trips onto the network to generate flow distributions caused by time-varying congestion throughout the entire network for the current time step (08:00 to 08:30). A DTA is performed on the regional network to establish flow distributions and route diversions caused by time-varying congestion throughout the entire network. It is important to perform a DTA to capture the dynamic aspect of the ATDM concept. Because static

traffic assignments used in traditional, four-step models will not support this analysis, a DTA is used. The DTA produces flow distributions and route diversions that will be used to compute congested travel times for every highway link by time of day. The flow distributions and route diversions from the mesoscopic model are used by the microscopic model, which simulates traffic and performs detailed operational analysis. This microscopic model outputs vehicle movements on the network. The DTA tool uses these outputs from the microscopic model to update the systemwide flow distributions. This process is repeated until convergence is achieved (i.e., both models produce similar results).

- **Feedback Loop.** The output from traffic assignment models will result in travel times for all links in the entire region for the current time step. These travel times are different from the travel times that the activity-based model used to generate activity patterns. Therefore, the traffic assignment results (i.e., congested travel times) are fed back to the demand model to adjust activity patterns until convergence is achieved between network conditions and activity generation in real time. This iterative process continues until reasonable convergence is achieved. Convergence is achieved when there is consistency between the travel times used to generate activity patterns and the travel time output by the traffic assignment module. Standard user-equilibrium assignment procedures will be replaced with more sophisticated dynamic user optimal algorithms.
- **Simulation Output Creation.** After each simulation is completed, the 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 refine the data that the Network Simulator uses for the next time step (e.g., 08:10). The outputs of this simulation yield link-level traffic flows and average speeds.
- **Performance Interpretation.** The Performance Interpreter within the Network Simulator will use the output from the traffic assignment tools after every simulation (08:00 to 08:30) to produce a variety of anticipated performance measures (e.g., speed, mobility delays, crash rates, emissions; travel time reliability at a roadway segment, corridor, or regional level) as desired and applicable with the ATDM action implemented in the AMS system.
- **Impact Estimation.** Multiple strategies will run in parallel for the next time window. The forecasted performance measures are compared with the objectives for that time period. If the measures do not meet the objectives, new ATDM strategies will be implemented in the AMS system and the impact evaluated. In real-world ATDM implementation, a DSS or automated process will select the best set of strategies to be implemented. For this analysis, the set of strategies to be tested was preselected to effectively test and enhance the ATDM AMS processes.
- **Captured Impact of Strategies on the Next Time Step.** In real-world implementation, in which strategies are implemented in the field, behavioral changes are captured through direct observation, the real-time data feed will reflect the impact of ATM strategies, and real-time monitoring for the next time step will directly capture the impact of ATDM strategy implementation. In this simulated real-time analysis, however, the strategies are implemented only in the AMS system (Network Simulator). Therefore, , as soon as the first strategy is implemented, the real-world data is will no longer be in-sync with the model/AMS world, and it will not be sufficient to use the raw real-time data in the Data Generator to prepare the data for the next time step. The modeled behavioral changes from the Network Simulator will be fed to the Data Generator, and the Data Generator will

use the changes to update the real-world data and create "adjusted real-time data" as inputs for the next time step.

An implementation of ATDM strategies is likely to affect the traveler's decisionmaking process. This decisionmaking process occurs at different times during a traveler's trip chain. The parts of the trip chains affected by the ATDM strategies in this scenario are presented in the next four chapters.

Various parts of the multi-resolution model capture the impacts on various parts of the trip chain. For example, the macroscopic model captures the impacts on destination- and mode-choice, the mesoscopic DTA model captures the impact on route-choice, and the microscopic model captures the impact on lane-choice. To capture the impacts on every part of the trip chain, a multi-resolution model has been proposed to analyze system performance during the evaluation phase. During that phase, the macroscopic model will capture the impact on modal shift in response to such strategies as dynamic rider-sharing and dynamic transit service. The mesoscopic model will capture the impacts on route-choice in response to such strategies as queue warning systems. The microscopic model will capture the impacts on route-choice of strategies such as adaptive traffic signals.

The analysis approach to evaluate the impact of each scenario-specific ATDM strategy is presented in the next four chapters, which describe each package's analysis plan.

3.9 Model Calibration

The simulation models used by the analysis packages include the following models, which are critical to the development of the ATDM AMS framework. These models include—

- Trip generation
- Destination choice
- Mode choice
- Time-of-day choice
- Route choice
- Facility choice.

It is essential to ensure that these models reflect traveler behavior for the region. Typically, the models use a set of user-defined factors or parameters that reflect traveler behavior. They include—

- Propensity to make certain type of trip
- Propensity to choose a destination over another
- Propensity to choose a mode
    - Propensity to ride-share
    - Propensity to use transit
- Propensity to choose a time of day
- Propensity to choose a route or a facility
- Traveler income level
- Traveler household size
- Number of cars within the household
- Traveler value of time.

These model parameters or coefficients need to be calibrated to ensure that model sensitivities to demand and supply changes are accurate. Existing revealed preference surveys will be used for that purpose. Most local agencies often conduct household surveys to understand which traveler behavior factors influence trip making, and by how much. Such survey data will be used to calibrate the existing models within the ATDM framework. Data on short-term responses of travelers to dynamic actions should be used to calibrate the models.

In addition, both highway and transit path building will be compared to individual survey records to ensure that path building is accurate and reflects how travelers in the region choose either highway or transit routes. Path-building parameters will be adjusted, and to calibrate the model. Travelers will be segmented into markets on the basis of such traveler characteristics as income, auto-availability, and household size. For example, travelers' choices whether or not to use a toll facility depends heavily on their income levels. To ensure that the model is sensitive to tolls, travelers would need to be segmented by income, and each segment would have a different sensitivity to toll.

In addition to traveler behavior, the model needs to be calibrated to replicate recurring or nonrecurring incidents that cause fluctuations or variations in the system. Such incidents include accidents, sports or entertainment events, inclement weather, and the like. Historical data for incidents will be used to calibrate the supply-side model to replicate observed conditions.

It is also important to calibrate traveler responses to ATDM strategies, such as—

- Predictive traveler information
- Dynamic transit pricing
- Queue warning
- Response to variable speed limits.

The calibration of the models for the aforementioned strategies is enhanced by historical data (if available and applicable) to estimate model sensitivity to these strategies, or to conduct revealed or stated preference traveler surveys to understand and estimate model sensitivity to these strategies.

3.10 Modeling Requirements

Generic modeling requirements for the analysis package are presented in the following sections.

Monitoring the System

The following presents the generic (analysis package-independent) modeling requirements to monitor the system:

- The Data Generator shall be able to receive continuous feed for real-time data (transportation and nontransportation) from a variety of sources, such as sensor detectors, video cameras, and weather stations.
- The Data Generator shall include geospatial and temporal aggregation procedures to process the incoming data in real time and convert to a standardized data schema that can be stored in an integrated multimodal database.
- The Data Generator shall be able to receive historical data (transportation and nontransportation) from a variety of sources.
- The Data Generator shall use O-D matrix estimation procedures to refine the trip tables from the activity-based models. It shall use real-time and historical count data to refine these tables.
- The simulation models in the Network Simulator shall also add uncertainty to the network supply side in terms of operational up or downtime of roadway sensors, and probability of failure of traffic signals and DMS.

- The models in the Network Simulator shall add a randomness component, or assign some inherent uncertainty to the input variables received from the Data Generator. to account for the uncertainties that trickle through all the steps from data gathering to data processing.
- The Data Generator shall receive the data on network supply from a variety of sources, such as GIS resources, traffic signal locations and phase plans, transit schedules and routes.
- The Data Generator shall conduct a preliminary validation of the processed real-time data against the historical data to check for unrealistic patterns. The Data Generator shall support algorithms that can detect and flag erroneous or missing values in the real-time data, and fill the data gaps with the help of imputation techniques.
- The Performance Interpreter in the Network Simulator module shall include supporting algorithms that can translate the simulation outputs to scenario-specific performance measures.
- The Network Simulator shall include an integrated framework, where a travel demand model such as an activity-based model generates the travel demand and modal split for the network. The Network Simulator shall have a feedback framework through which the results from one model are used as inputs for other models to reach convergence.
- The models and tools shall comprehensively capture the demand–supply interactions at all levels of analysis.
- The models in the Network Simulator shall be able to access the characteristics of various modes and their interactions (e.g., proximity, competitive modes).
- The Network Simulator shall include tools to visualize the simulation of individual vehicles, and aggregate measures (e.g., person throughput, speeds as thematic network renderers). These tools shall assist in the identification and tracking of problem locations visually.

Assessing System Performance

The following presents the generic (analysis package-independent) modeling requirements to assess system performance with a predictive window:

- The modeling framework shall support the prediction of future performance in a moving time window.
- The travel demand model in the Network Simulator shall use the historical and real-time data to forecast time-dependent travel demand for the forecast time window.
- The Network Simulator shall update the supply parameters in the models to incorporate the anticipated changes in the network supply (i.e., either controlled by the agency or affected by network conditions).
- The Data Generator shall estimate traffic counts for the predictive time window with heuristic procedures.
- The Data Generator shall use O-D procedures to refine the trip tables from the activity-based models. It shall use estimated count data to refine these tables.
- The models in the Network Simulator shall forecast performance measures, which reflect the anticipated traffic conditions in the next time window (e.g., 30 minutes).

- The DTA-based mesoscopic simulation model in the Network Simulator shall use the travel demand forecasts for the next time window, which are generated by the travel demand model, as inputs to predict the traffic flow patterns in the forecast window.
- The microscopic simulator in the Network Simulator shall be able to simulate traffic conditions for the forecast period in smaller regions at a detailed level.
- The feedback structure of data flow within the Network Simulator shall support convergence of outputs from the various simulation models.
- The travel demand models in the Network Simulator shall include advanced traveler behavior models that account for traveler decisions, such as destination choice, time-of-day choice, and mode choice in response to the changes in network conditions.
- The models in the Network Simulator shall add a randomness component, or assign some inherent uncertainty to the input variables received from the Data Generator, to account for the uncertainties that trickle through all the steps from data gathering to data processing.
- The Network Simulator shall include tools to calibrate and validate data. The functionality of such tools will include iterative proportional fitting, curve fitting techniques, and regression.
- The Network Simulator shall include tools to visualize the simulation of individual vehicles, and aggregate measures (e.g., person throughput, speeds as thematic network renderers). These tools shall be used to assist in the identification and tracking of problem locations visually

Evaluating the Impact of ATDM Strategies

The following presents the generic (analysis package-independent) modeling requirements to evaluate the impact of ATDM strategies:

- The Performance Interpreter shall be able to compute simulated performance measures (e.g., traveler throughput, travel time reliability, and emissions specific to the ATDM strategy implementation scenario) on the basis of simulation outputs from the Network Simulator.
- The travel demand model in the Network Simulator shall use the historical and real-time data to forecast time-dependent travel demand for the forecast time window.
- The Network Simulator shall be able to update the supply elements in the models to incorporate the anticipated changes in the network supply (i.e., either controlled by the agency or affected by network conditions).
- The Data Generator shall estimate traffic counts for the predictive time window after chosen strategies have been implemented with the use of heuristic procedures.
- The Data Generator shall use O-D matrix estimation procedures to refine the trip tables from the activity-based models. It shall use estimated count and historical data to refine these tables.
- The Data Generator shall be able to generate a multimodal network with the dynamic actions implemented. It shall generate a network with changes to the network elements.
- The DTA-based mesoscopic simulation model in the Network Simulator shall use the travel demand forecasts for the next time window, which are generated by the travel demand model, as inputs to predict the traffic flow patterns in the forecast window.

- The microscopic simulator in the Network Simulator shall be able to simulate traffic conditions for the forecast period in smaller regions at a detailed level to capture driving behavior changes and the impact of operational improvements.
- The “feedback” structure of data flow within the Network Simulator shall support convergence of outputs from the different simulation models.
- The Network Simulator shall include algorithms and models, which can use the simulation outputs for the next time period to compute performance measures such as traveler throughput, travel time reliability, and travel time delay as defined by the agency goals.
- The travel demand models in the Network Simulator shall include advanced traveler behavior models, which can account for traveler decisions such as destination choice, time-of-day choice, and mode choice in response to the changes in network conditions with high fidelity.
- The models in the Network Simulator shall include the interactions between the transit and automobile options while they capture the modal split of travel demand. These mode choice models shall be sensitive to the transit operations and fare structure.
- The mesoscopic and microscopic simulation models in the Network Simulator shall include traveler behavior models that replicate effects such as user acceptance and user trust in the technology.
- The simulation framework in the Network Simulator module and the database and query structure in the Data Generator module shall support parallel computing of multiple strategies simultaneously.
- All models in the Network Simulator shall be able to account for heterogeneity of the traveler population in different steps of decisionmaking, such as likelihood to take transit, elasticity toward congestion, and pricing.
- The Network Simulator shall include tools to calibrate and validate data. The functionality of these tools will include iterative proportional fitting, curve fitting techniques, and regression.
- The Network Simulator shall include tools to visualize the simulation of individual vehicles, and aggregate measures (e.g., person throughput, speeds as thematic network renderers). These tools shall assist in the identification and tracking of problem locations visually.

Chapter 4: Analysis Plan Elements Specific to Package 1

Analysis Package Name: Normal Operations—No Incidents

4.1 Analysis Plan Scope

Section 3.1 presents the scope of the analysis plan for all the analysis packages. The scope of this package—the Normal Operations, No Incidents package—does not require any additional items.

4.2 Regional and Existing Operational Conditions

Chapter 2 of this document presents an overview of a hypothetical region, and details the various transportation demand and supply elements for that region.

4.3 Analysis Scenario and ATDM Strategies To Be Analyzed

This analysis package represents a typical weekday morning without any incidents and under normal operating conditions (i.e., there are no extenuating circumstances such as inclement weather). The overarching goal for this analysis scenario *(normal operation, no incident)* is to influence travel demand and supply for each component in the trip chain. Since this analysis scenario is predictable and recurs every weekday, the transportation system has been prepared to implement predictive measures to proactively deal with the situation.

The key goals of the operating agency are to—

- Influence drivers/travelers to make informed decisions at every step of the trip chain, beginning with destination choice and time-of-day choice
- Manage the road network based on anticipated changes in traffic volume.

The key objectives of the operating agency are to—

- Improve travel time reliability by reducing travel time variance to less than 20 percent of the average travel time
- Maintain predetermined throughput across selected screen lines.

The transportation system in the NCNJ region uses a combination of multimodal demand and supply-side strategies to improve travel in the region. It is 07:00 on a regular weekday morning, and traffic has started to build up as expected and in accordance with historical data. Commuters are driving to their places of work in Octagon City, Edge City, Old Town, and other regions.

The objective of this scenario is to illustrate the use of dynamic ATDM strategies to manage travel in the region during the AM peak period. This is a common operational scenario because it represents a normal weekday without any incidents. This analysis package is built to show how ATDM can overcome the typical daily challenges of changing demand during peak periods. In this recurring and predictable situation, the goal is to use ATDM strategies to manage the system efficiently and meet goals by affecting all the components of the traveler trip chain.

ATDM Strategies

In order to overcome the predicted stress on the transportation system, the operator could use a variety of dynamic traffic management strategies, such as the ATDM strategies identified in the AMS CONOPS report. In this analysis package, the following ATDM strategies are expected to be useful for traffic management (for illustrative purposes):

- Predictive Traveler Information
- Dynamic pricing (transit and toll)
- Dynamic shoulder lanes
- Adaptive traffic signals.

The following sections present a discussion of the aforementioned strategies.

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 (Roadway and Transit)

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.

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.

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.

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.

The following section describes how the above strategies impact different elements of the trip chain.

Impact of ATDM Strategies on Trip Chain

During the typical weekday AM peak period, dynamic actions are expected to have very little impact on destination or time-of-day choice as most of the trips are likely to be commuter trips. Travelers typically choose the time of day of travel cognizant of travel time reliability and desired time to reach the destination. The following sections detail how the strategies chosen for this analysis package potentially affect the components of the trip chain.

An implementation of ATDM strategies is likely to impact the traveler's decisionmaking process. This decisionmaking process occurs at different times during the traveler's trip chain. The parts of the trip chains affected by the ATDM strategies in this scenario are shown in Table 4-1.

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

		Trip Chain Affected				
No	**ATDM Strategy**	**Destination Choice**	**Mode Choice**	**Time-of-Day Choice**	**Route Choice**	**Lane/Facility Choice**
1	Predictive Traveler Information	◔	◑	●	●	◔
2	Dynamic Pricing (Roadway and Transit)		◑	●	●	●
3	Dynamic Shoulder Lanes		◔	◑	◑	●
4	Adaptive Traffic Signal Control		◔	◔	●	

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.

The following sections detail how the strategies chosen for this analysis package potentially affect the components of the trip chain.

Destination Choice

Destination choice is a function of needs and options. As a consequence of ATDM strategies, travelers—are expected to and—can choose destinations based on the probability of reaching the destination on time. It is to be noted that commuters do not typically have the choice of changing their destination. Destination choice for other trip purposes such as social recreation or shopping could, however, be changed. While a portion of the PM peak period travel includes social recreation or shopping trips, trips of this nature rarely occur during the AM peak period. While predictive traveler information marginally influence destination choice, the other strategies have no influence on a traveler's choice of destination. Travelers making a discretionary trip such as a shopping trip for groceries may choose a different destination based on information about levels of congestion along their route. To summarize, destination choice would barely be affected by ATDM strategies for this analysis package.

Mode Choice

A transit system that dynamically prices trips based on roadway congestion levels increases the propensity to use transit before the trip starts. Transit, however, needs to be conveniently available, and travelers need to be informed about their options in real-time. In addition, the parking provisions at park-and-ride lots need to be available to travelers who might want to change modes en-route to their destination. If the parking is available at end-of-line metro stations (e.g., Prague), and this information along with dynamic transit fare information and a comparison of expected arrival to various locations in New Camden by using highway and transit is presented to travelers who traveling inbound on I-6, some travelers will choose to change modes and use transit instead of driving on the congested I-6.

It should, however, be noted that transit in the region could already be at capacity and may not be able absorb additional demand. Additional transit service will have to be provided to accommodate additional demand. While predictive traveler information and dynamic transit pricing schemes partially influence mode choice, the other strategies do not have significant influence on a traveler's choice of mode. To summarize, it is important that a plan be created to test the impact of ATDM strategies on mode choice.

Time-of-Day Choice

While predictive traveler information, and dynamic pricing schemes definitely influence time-of-day choice, priced dynamic shoulders have a partial influence on time-of-day choice, and adaptive traffic signal controls have a marginal influence on time-of-day choice. Travelers will choose to reduce their trip cost by using facilities when the cost of either transit or a tolled facility or lane (or HSR) is low. The implementation of dynamic pricing influences time-of-day choice. A traveler will choose to adapt to the availability of HSR and will try to reduce the amount of tolls paid. Better information dissemination will help the traveler plan his/her trip better. Information pertaining to highway congestion levels, current toll rates will enable the traveler to choose when he/she will begin travel. Information pertaining to adaptive traffic signals may not be transparent to travelers; however, information pertaining to roadway congestion that is relayed to travelers using multimodal traveler information and trip planning systems reflect the effects of adaptive traffic signals. To summarize, it is important to create a plan to test the impact on time-of-day choice effectively.

Route Choice

During the morning peak hours, travelers in the NCNJ region who follow the real-time information stream change their routes accordingly. While predictive traveler information, and dynamic pricing definitely influence route choice, dynamic shoulder lanes have a partial influence a traveler's choice of route. A traveler may not be able to perceive the effects of adaptive traffic signal controls on the first day that it is implemented; however, over time, travelers will perceive that the route is faster, and they will start using this route instead of a parallel route. In addition, it is necessary to ensure that agencies inform travelers about adaptive traffic signals and how these signals will help travel along key corridors. To summarize, the analysis approach should be created so that the ATDM can test the impact and effectiveness of the real-time information stream on route-choice and how this improves system performance.

Lane/Facility Choice

Lane or facility choice is similar in nature to route choice described above. HOT lane facilities are similar to alternate routes that are less congested; however, the traveler would need to either pay a toll or choose to increase his/her vehicle occupancy in order to comply with the high occupancy specifications of the facility. The implementation of HOT lanes presents a faster travel choice to travelers. While a portion of the travelers will choose to pay a toll and use these facilities, a large portion of traveler will choose to carpool in order to use these facilities. Thus, this strategy increases vehicle occupancy and reduces the number of vehicles in the transportation system and thus improves the quality of travel in the NCNJ region. To summarize, the analysis plan should be created so that the ATDM can test the impact and effectiveness of dynamic tolling and HSR.

4.4 Data Needs

Section 0 presents the preliminary data needs for the analysis packages. This package—the normal operations, no-incidents package—does not require any additional data.

The transportation network is managed based on analysis of historical data, and based on the continuous collection and processing of data, which supports updates to AMS tools as well as overall system performance measurement. System input is gathered from arterials and other sensors on the freeway to rapidly detect unusual conditions due to fluctuations in demand.

4.5 Performance Measures

Well-defined performance measures are required to monitor system performance. The following have been selected as illustrative examples of performance measures that can be used for this analysis package.

Vehicle/Person Throughput

Vehicle/person throughput is a good measure for reflecting the load or demand for travel met by the system in unit time and can be measured as the number of vehicles or travelers completing their journeys through the corridor in unit time (e.g., 1 hour). The goals for this performance measure will be set by the local agency for each period of analysis based on historical data, and performance goals can vary by time of the day, day of the week, and seasonal fluctuation.

This analysis package will use person throughput as the performance measure, as some of the strategies chosen for this analysis package involve the implementation of HOV restrictions and providing incentives to use transit. Person throughput will be measured for this analysis package as the number of persons crossing a screen line or an imaginary line intersecting either North-South or East-West roadways. Figure 4-1 presents the region with four screen-lines. The number of persons crossing each screen-line during a given time window (e.g., 08:00 to 08:30) represents a movement of persons from population centers to employment centers. A comparison of this statistic for the analysis time period (e.g., 08:00 and 08:30) before and after ATDM strategies are implemented will provide insight into the benefits of the strategies.

Figure 4-1: Screen Lines

In addition, the average speed of travel for persons crossing these screen-lines during the given time period is also important. While increasing person throughput is a goal for this analysis package, this goal should be achieved without reducing the quality of service. The average trip time for the persons crossing the screen-line before and after the implementation of the ATDM strategies during the given time period will be computed and compared. For this analysis, travel time between five population centers and five employment centers in the NCNJ region will be computed. These five population and employment centers will be chosen by the local agency. The time required to travel from each population center to each employment center will be multiplied with the total number trips between the two centers. This provides a statistic of the total person-hours traveled for each combination of activity centers.

Trip Travel Time Reliability

Travel time reliability is a significant measure for travelers. It is sometimes represented as the variance of travel time from expected travel time to complete a trip. Statistical terms that represent the spread or consistency of travel times can be calculated to indicate travel time reliability. Higher travel time reliability reflects higher level of service and user trust in the transportation system. The objectives for the travel time reliability performance measure will be set by the local agency for each time window of analysis.

Travel time reliability is the consistency of travel time as compared to average travel time during a given time period. This is typically measured using a statistical index such as standard deviation. A high standard deviation indicates that travel time is less reliable. Reliability could also be measured by calculating the buffer index[2] using 95th percentile travel time. The equation for estimating travel time reliability is shown below.

$$Travel\ time\ reliability\ (or\ 95th\ percentile\ buffer\ index) = 100 \times \frac{(95^{th}\ percentile\ travel\ time) - (average\ travel\ time)}{(average\ travel\ time)}$$

The buffer index measure is easy to relate to travelers; hence, this index will be used by this analysis package to measure travel time reliability Travel time reliability will thus be computed for the NCNJ region to monitor system performance, assess or predict system performance, and evaluate ATDM implementation for the following corridors:

- I-6 (HOV) between Old Reston and New Camden
- General Sherman Highway (SOV) between Old Reston and New Camden
- I-106 and I-6 between Little Reston and New Camden
- I-3 between Quasar and New Camden
- I-403 between Edge City and Gridlock Heights
- I-403 between Gridlock Heights and Edge City

In order to compare travel time reliability before and after the implementation of the ATDM strategies, it is essential to simulate and replicate observed travel time reliability. For example, it is observed that the 95th percentile buffer index for travel between Old Reston and New Camden is around 40 percent and the average travel time is 45 minutes. The base or existing conditions simulation is calibrated to the average day (i.e., the travel time between Old Reston and New Camden is 45 minutes). It is, however, necessary for the simulation to replicate travel time reliability (i.e., a 95th percentile buffer index of 40 percent for the existing conditions).

In order to compute travel time reliability, average or mean travel time between two locations in region is to be computed. In addition, the variation of travel times around the mean is to be computed. These statistics will be computed as an aggregate zone-to-zone travel skims. Travel times for all travelers traveling between two zones (e.g. Old Reston to New Camden) during the forecast time period (e.g. 7:30 AM to 8:00 AM) will be extracted from the simulation output. These travel times will be used to compute both the average travel time and the 95^{th} percentile travel time. Once these two statistics are computed, travel time reliability will be computed as described above.

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[2] The *buffer index* represents the extra time (or time cushion), expressed as a percentage of average travel time, that travelers must add to their average travel time when planning trips to ensure on-time arrival 95% of the time. Source: http://ops.fhwa.dot.gov/publications/tt_reliability/brochure/

Once travel time reliability index is replicated for the existing conditions simulation, the same process is used to compute travel time reliability during the predictive phases of each analysis package. The goal of the ATDM strategies is to ensure that 95-percentile buffer index is less than 20 percent for travel along the aforementioned corridors. ATDM strategies will be adjusted or modified if this goal is not met and the simulations will be rerun.

4.6 Tools Needed for Analysis

Section 3.6 presents the generic tool needs for the analysis packages. Table 4-2 provides illustrative examples of tools.

Table 4-2: Examples of AMS Tools

Model/Model Category	Description of Models, with Examples
Travel Demand and Behavior Models	
Activity-based models	These models consider interaction among 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.
Traffic Operations Models and Tools	
Mesoscopic models	These models are typically used to model regional networks. Most mesoscopic analysis tools include DTA procedures that replace the traffic assignment procedures in the traditional four-step travel demand models to achieve higher accuracy in speed estimates. Examples include DYNASMART and DYNAMIT.
Microscopic models	Microscopic simulation models track individual vehicular movements and generate detailed estimates of network performance. Examples include CORSIM, Paramics, VISSIM, SimTraffic, and Aimsun.

4.7 Analysis Settings

Table 4-3 describes the analysis settings and assumptions. It is to be noted that the time steps, time periods, and time windows are presented for illustrative purposes only. The local agency would chose these settings as it deems appropriate for the analysis it is conducting.

Table 4-3: Analysis Settings for Analysis Package 1

Analysis Setting	Description
Simulation Time Period	00:00 to 23:59 (all day)
Time Period of Analysis	07:00 to 10:00 is the primary analysis time period
Forecast Period	For this analysis, a 30-minute forecast of future conditions in 5-minute increments will be made once every 10 minutes
Data	It is assumed that traffic count data is continuously fed from the freeway and arterial management systems to the analyst. Transit ridership and real-time schedule data are also available.

4.8 AMS Approach

This analysis scenario represents typical weekday transportation activities and operations in the NCNJ region along with certain predictable recurring stresses to the transportation system. The approach to investigate this scenario from the ATDM perspective involves creating a model to analyze the demand and supply during the morning peak hours on an average weekday, along with a predictive component to track traffic conditions in the forecasted future. The analysis framework has been presented in Section 3.8 in Figure 3-1.

The AMS approach for this analysis package follows the approach presented in Section 3.8. The analysis approach for this package (normal operations, no incident) is detailed in the following sections. This approach includes the following three components:

- Monitor the system
- Assess system performance
- Evaluate dynamic actions and capture the impact of the dynamic actions for the next moving window.

Monitoring the System

Monitoring the transportation system in real time for the NCNJ region is the first step in the ATDM AMS cycle. The simulation starts at midnight. The detailed system monitoring phase begins an hour before the analysis period (i.e., at 06:00) for this analysis package. During this period, the system is monitored for daily variability in demand and localized congestion issues. This monitoring phase captures the fluctuations in the system, and the objective of this analysis package is to ensure that the system performs as expected and is not affected largely by these variations or fluctuations. This analysis package's system monitoring task follows the process described in Section 3.8. This step includes the following two subprocesses: data processing and simulation.

Data Processing

During the regular weekday AM operations, the traffic condition patterns are very similar to the average day with some variance around the mean values. For example, the average speed and volume profiles for a particular location on the network for the AM peak hours follow trends that are similar to the average day's speed and volume profiles with minor daily variations, as shown in Figure 4-2. From the ATDM perspective, the unanticipated variations in the traffic conditions during regular weekday operations are the key action areas in this scenario. The data processing approach for this scenario is described below.

The Data Generator tracks the incoming data and generates time profiles of predetermined variables such as average speed and volume at different locations on the network. These profiles based on real-time data are continuously compared to historical trends for the same location at the current time step. Variations within a certain buffer margin from the historical average are considered inherent day-to-day variations in the dynamics of the transportation system. However, the variations beyond this buffer margin indicate onset of an unanticipated event. Such variations are marked for analysis. The Data Generator tracks traffic conditions at this location as additional real-time data becomes available. The performance measures for these tracked locations are used to check for the variation from the historical average. The confirmation of unanticipated deteriorating conditions is then used for a detailed forecasting of traffic conditions in the concerned locations. Figure 4-3 illustrates how the speeds and volume on critical facilities are monitored in real time against historical averages.

Figure 4-2: Traffic Volume and Speeds Before and After the Onset of Unanticipated Conditions

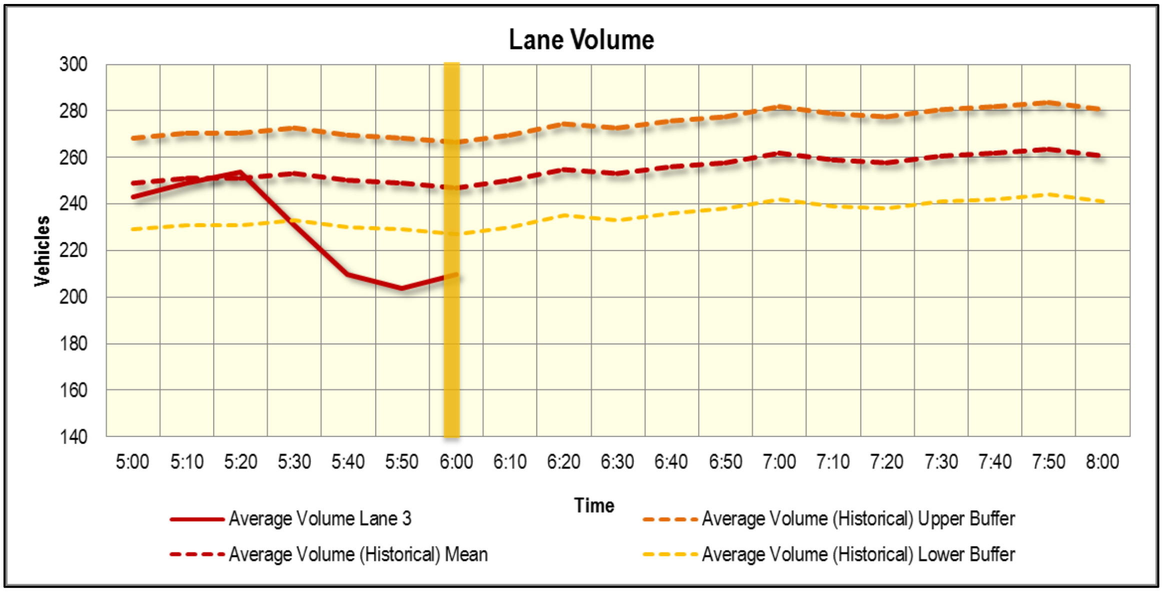
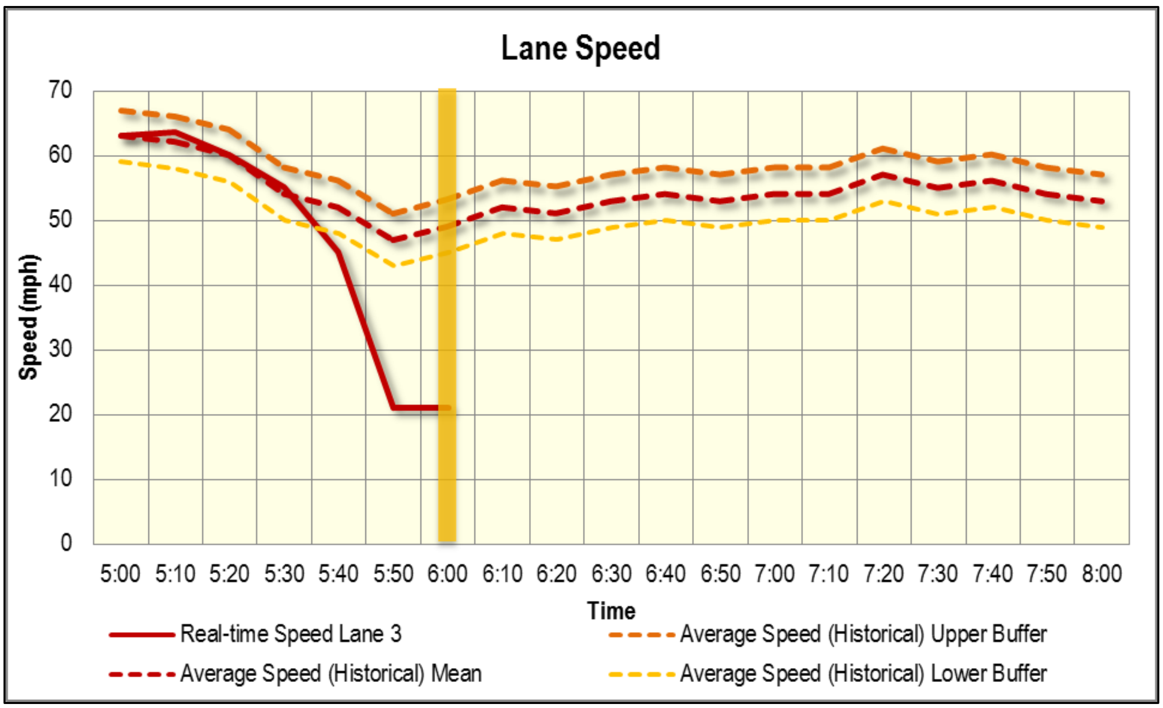


Figure 4-3: Traffic Speeds and Volumes Monitored in Real Time Against Historical Averages



Simulation

The simulation task has been described in detail in Section 3.8. This analysis package's data simulation task follows that process.

Performance Measures

For this particular analysis package, person throughput and travel time reliability are selected as the two regional performance measures of interest to the agency. Brief definitions of these performance measures are presented below. The process used to generate the performance measures has been described in Section 4.5.

Vehicle and Person Throughput

Throughput is computed as an aggregate measure of the number of persons crossing the screen-lines during the time period of interest. The throughput for the forecast time period (e.g. 07:30 AM to 08:00 AM) is compared to historical averages and the goals set by the local agency for the same time period. If this comparison informs the ATDM AMS system that the system is performing as expected, then dynamic actions are not warranted.

Trip Travel Time Reliability

This travel time reliability for the system monitoring time period (e.g. 07:30 AM to 08:00 AM) is compared to historical averages and the goals set by the local agency for the same time period. If this comparison informs the ATDM AMS system that the system is performing as expected, then dynamic actions are not warranted.

Assessing System Performance

The simulation of this scenario starts at midnight. The detailed system assessment phase begins at 07:00 for this analysis package. During this period, a forecast or a prediction of the system that accounts for the current day's variability in demand is performed. This assessment phase predicts how the fluctuations in the system affect system performance, and which parts of the system are affected. The objective of this analysis package is to ensure that the system performs as expected and is not largely affected by these variations or fluctuations This analysis package's performance assessment task follows the process described in Section 3.8. The input data from the Data Generator is used by the Network Simulator for analysis. The simulation models, both mesoscopic and microscopic, are calibrated to the most recent observations from real-time data to account for recent unanticipated patterns in the traffic conditions. The models simulate the traffic conditions for the next 30-minute time period (using a continuous moving window) and replicate traveler movements in that period. The performance interpreter translates the simulated traffic conditions into performance measures that are used to assess system performance in the immediate future.

Performance Measures

For this particular analysis package, person throughput and travel time reliability are selected as the two regional performance measures of interest to the agency. Brief definitions of these performance measures are presented below. The process used to generate the performance measures has been described in Section 4.5. The performance measures computed during the assessment phase without any strategies implemented will be the baseline performance measures for this analysis package.

Vehicle and Person Throughput

The throughput for the next time window (e.g., 08:00 to 08:30) is compared to historical averages and the goals set by the local agency for the same time window. If this forecasted performance meets or exceeds the target performance measures, then dynamic actions are not warranted.

Trip Travel Time Reliability

Travel time reliability for the next time window (e.g., 08:00 to 08:30) is compared to historical averages and the goals set by the local agency for the same time step. If this forecasted performance meets or exceeds the target performance measures, then dynamic actions are not warranted.

Evaluating the Impact of ATDM Strategies

The simulation of this scenario starts at midnight. The detailed system evaluation phase begins at 07:00 for this analysis package, as the analysis period is between 07:00 and 10:00. The objective of this analysis package is to ensure that the system performs as expected and is not largely affected by these variations or fluctuations. The system performance evaluation task has been described in detail in Section 3.8. This analysis package's performance evaluation task follows the process described in Section 3.8. For this analysis package, forecasted person throughput and travel time reliability measures are compared to the goals set by the local agency and to the performance measures generated during the system assessment phase (baseline). The goal of this analysis package is to maintain a person throughput predetermined by the local agency across the screen-lines shown in Figure 4-1 and to ensure that travel time reliability buffer index is less than the goal set by the local agency. If the forecasted performance measures do not meet the objectives, ATDM strategies will be reevaluated and the impact of implementing the selected strategies will be tested. It is to be noted that in real-world ATDM implementation, the best set of strategies to be implemented will be selected by a Decision Support System or an automated process. As presented and discussed in Section 4.3, the strategies chosen for this analysis scenario are:

- Predictive Traveler Information
- Dynamic pricing (transit and toll)
- Dynamic shoulder lanes
- Adaptive traffic signals.

The following section discusses how each strategy would be implemented and tested for its effectiveness for the AM peak normal operations scenario.

Predictive Traveler Information

Under the ATDM approach, the following types of information are shared with individual travelers:

- Traffic information
- Transit schedule
- Projected travel times by auto mode.

This information dissemination helps the traveler make optimal choices for mode, route, or time of departure. It is assumed that the information disseminated to the travelers include both real-time and predicted guidance information on the route alternatives and the expected travel times on key routes in the region. The guidance information will be disseminated to travelers in the region using various channels including mobile devices, DMS, and an enhanced 511 system. The DMS are used to convey HOV lane use information during the peak hours along I-6 and I-3 to travelers between 07:00 and 10:00. The information presented to the travelers will include average travel time information, and the presence of bottlenecks. The section of I-6 to the west of the beltway provides uni-directional HSR during peak hours (AM: eastbound; PM: westbound). The DMS at locations upstream to the beltway convey the HSR operational timings and rules to the travelers. The DMS along I-6 and I-106 publish the projected average travel times, along with the information about accessibility to nearby transit stations on the commuter rail and metro rail, respectively.

In order to model this strategy, data on the location of the DMS infrastructure and other messages disseminating ITS infrastructure will be coded in the Network Simulator. This involves associating virtual infrastructure with travel information, the location of these signs, and the operational “up-time” of these signs. In addition, the response of the traveler (e.g., route choice, lane choice) in response to DMS will be tracked.

Modeling Predictive Traveler Information in a simulation model requires a thorough understanding and interpretation of traveler response to these information systems. It is essential to obtain data to calibrate traveler response to these systems. Either revealed preference survey data or stated preference survey data will be used to calibrate this discrete choice model. Once calibrated, this model will successfully predict the percentage of travelers who will choose to modify their mode, route or lane/facility. The following questions need to be answered by the data obtained from historical data, revealed preference surveys, or stated preference surveys:

- Will travelers change their behavior or choice (e.g., route, mode) based on the information presented?
    - What percentage of travelers will modify their choice?
- Will travelers choose a route mid-trip?
    - What percentage of travelers will modify their route mid-trip?

Current tools do not possess the capabilities or possess very limited capabilities to model the operation and the impacts of a dynamic travel information system. The foundation of a predictive traveler information system is presently available; however, the components of the system are at various stages of development. While the traveler information systems possess the ability to distribute accurate traveler information across various modes, the ability to provide multimodal traveler information for a single trip is rather limited.

Dynamic Shoulder Lanes (Hard Shoulder Running)

The 5-mile section of I-6 to the west of the beltway can support hard shoulder running. During normal operations hard shoulder running is permitted during the peak hours (i.e. eastbound during AM peak and westbound during PM peak) to temporarily add additional capacity on these routes. Several DMS points are located along the I-6 which can be used to inform drivers about the dynamic rules about the opening or closure of the shoulder lanes for regular traffic. The robust analysis of HSR requires an understanding of the effects of travel demand choices (departure mode, time, and path) on network performance and vice versa across multiple spatial and temporal regimes. HSR strategy involves the opening of either the left or right shoulder for vehicle traffic under certain time-of-day or operational criteria. In order to implement this strategy, the Data Generator creates an multimodal network that includes additional capacity or travel lane elements for HSR along the chosen routes. The network simulator uses this network to simulate traffic and to generate demand using the feedback process. Since the existing models are already calibrated and validated for HSR running, additional calibration or validation is not required.

Dynamic Pricing

In this scenario, the toll policy is implemented on the I-106; however, it does not have a strong competing alternative route for the travelers. Other arterial options of commute to avoid toll charges are to use the Elvis highway to reach I-6 or take a relatively longer detour along Harry Reston

Parkway to meet I-6 near Old Reston. In addition, a metro rail line runs parallel to I-6 and can be used as a parallel transit alternative to get into the Central Business District. Thus, the elasticity of the travel demand for I-6 with respect to the toll pricing structure will determine the travel demand modal split and subsequent route choice made by the motorist travelers. On the other hand, I-3 and I-403 operate under HOT lane policies, with HOT lanes on each of them accessible to respectively HOV-3 and HOV-2 only. Dynamic pricing will have a potential impact on the travel demand on these corridors, especially across different modes. In order to implement this strategy, the Data Generator creates an multimodal network that includes dynamic tolling information. The network simulator uses this network to simulate traffic and to generate demand using the feedback process. Since the existing models are already calibrated for value of time and validated for vehicles traveling on toll roads, additional calibration or validation is not required.

Adaptive Traffic Signal Control

Particular to this scenario, the modeler shall replicate the physical locations and functionalities of the roadway sensors in the NCNJ region in the simulated world. It is critical to precisely represent the sensors on the virtual world network geometry, as it affects the input data for the ATSC algorithms. In addition, the modeler shall specifically address the uncertainties in sensor operations such as mechanical downtime and reliability of the sensor readings. The sensor data along with the added noise (uncertainty) shall pass through the Data Generator component to be treated with all the data processing techniques as implemented by the NCNJ authorities. As described in Section 4.8, the timing plans for the traffic signals along General Sherman highway, Elvis Highway, Gridlock Highway, State Route 99 (Harry Reston Parkway), and Earl street will be updated by the Data Generator and this information will be provided to the Network Simulator to perform a simulation with the updated network information. For the macroscopic model, the percentage green time attribute for each approach is updated. This information is used to compute capacity which is in turn used to compute congested travel speeds during the traffic assignment process. The microscopic model uses the updated signal plans to perform a microsimulation. Since the existing tools used for analysis are already calibrated and validated, additional calibration or validation is not required.

Performance Measures

For this particular analysis package, person throughput and travel time reliability are selected as the two regional performance measures of interest to the agency. Brief definition of these performance measures is presented below. The process used to generate the performance measures has been described in Section 4.5. The performance measures computed during the evaluation phase with strategies implemented will be compared to the baseline performance measures computed during the assessment phase.

Vehicle and Person Throughput

This throughput is computed as an aggregate measure of the number of persons crossing the screen-lines during the time period of interest. The throughput for the next time window (e.g., 08:00 to 08:30) is compared to both the goal set by the agency and the throughput generated during the assessment phase. This comparison informs the ATDM AMS system if the system has performed according to expectations, and if goals were met.

Trip Travel Time Reliability

This travel time reliability for the next time window (e.g., 08:00 to 08:30) is compared to historical averages, travel time reliability generated during the assessment phase, and the goals set by the local agency for the same time step. This comparison informs the ATDM AMS system if the system has performed according to expectations, and if the goals were met.

4.9 Model Calibration

Section 3.9 details how the models for the analysis packages will be calibrated and presents the data requirements for model calibration. In addition, Section 4.8 (subsection: Evaluating the Impact of ATDM Strategies) presents a discussion on how the models that capture the impacts of each ATDM strategy will be calibrated.

4.10 Modeling Requirements

The modeling requirements for this analysis package are described below.

Monitoring the System

The overall modeling requirements to monitor the system have been presented in Section 3.9. Additional modeling requirements are not necessary for this analysis package: the normal operation, no-incident package.

Assessing System Performance

The overall modeling requirements to assess system performance have been presented in Section 3.9. Additional modeling requirements are not necessary for this analysis package: the normal operation, no-incident package.

Evaluating the Impact of ATDM Strategies

The overall modeling requirements to evaluate the impact of ATDM strategies are presented in Section 3.9. The following sections present the modeling requirements to evaluate each strategy chosen for this analysis package.

Predictive Traveler Information

The following presents the modeling requirements to evaluate the impact of predictive traveler information:

- The models in the Network Simulator component of the AMS framework shall include utility-based discrete choice models to capture destination choice, mode choice, time-of-day choice, and route choice affected by the traveler information.
- The models in the Network Simulator component of the AMS framework shall capture the impact of the information conveyed to travelers on travel demand.
- The models in the Network Simulator component of the AMS framework shall anticipate user reactions to the information conveyed to the traveler using DMS.
- The models shall explicitly consider the transmission of predictive traveler (both pre-trip and en route) and capture the traveler behavior changes (mode choice, route choice and time-of-day choice) and driving behavior changes (lane changing, lane choice, gap acceptance) associated with information available to the traveler.
- The dynamic O-D matrix estimation procedures shall enable the user to readjust the O-D matrices to capture the change in time-dependent demand.

- The models shall enable multimodal (both auto and transit modes) analysis.
- The mesoscopic DTA models shall be used to capture the network impacts of the anticipated behavior changes.
- The models shall consider user acceptance and compliance as they affect total impact.
- Rigorously tested logit models shall be used to predict behavior changes.
- The models shall be able to replicate individual travelers and their decisionmaking processes regarding when to travel, the mode selected, and the route chosen. An activity-based model (or similar) is needed.
- The models shall be able to accurately represent the operation and availability of multiple transportation modes and the relationship amongst the various modes.
- Procedures shall be created to determine multimodal performance metrics that will then be used as a part of a traveler's decisionmaking process.
- The models shall be able to replicate some of the more intricate transportation concepts such as real-time parking availability and real-time ride-sharing behavior and impacts, in addition to high-fidelity modeling of the various transportation modes and traffic behavior.
- Procedures shall be created to quantify the amount of information available from the predictive traveler information system and that which is transmitted to the traveler.
- Procedures shall be created to extract network performance measures during run time and represent the transmission of such information to the traveler within the modeling framework.

Dynamic Shoulder Lanes

The following presents the modeling requirements to evaluate the impact of dynamic shoulder lanes:

- The models in the Network Simulator component of the AMS framework shall capture the impact of dynamic pricing in mode choice, time-of-day choice, and lane/facility choice.
- The models shall make use of the demographic data to determine the price sensitivity of the population.
- The models in the Network Simulator component of the AMS framework shall use the price sensitivity of the traveler population to determine the demand elasticity, and subsequent impact of pricing on the travel demand.
- The mode choice and route choice models in the Network Simulator component of the AMS framework shall include the anticipated traveler response to the pricing strategy.
- The lane/facility choice models in the Network Simulator component of the AMS framework shall capture the impact of added lane capacity on lane/facility choice. The mode choice and route choice models may also capture the impact of dynamic shoulder lanes. The modeler shall especially consider the safety concerns of the shoulder lane use while modeling driving behavior.
- Dynamic Shoulder Lanes strategy is conducted to add extra supply/capacity to the road network under congestion levels. The algorithms behind the control system operations of shoulder lanes shall be replicated in the simulation framework.
- Dynamic shoulder lanes will change the microscopic details of the driving behavior. Hence, microscopic simulation models such as car-following, lane changing, and lane merging, shall be components of the simulation framework.

- The models shall capture time-of-day choice in response to the implementation of HSR.
- The models shall accurately model travelers' lane choice.
- High-fidelity simulation of traffic operations shall be modeled.
- Route choice as it relates to application of HSR strategy shall be modeled.
- Capacity/speed relationship on HSR shall be modeled accurately.
- HSR strategies and the resulting changes to traffic operations shall be implemented and modeled.

Dynamic Pricing

The following presents the modeling requirements to evaluate the impact of dynamic pricing strategy:

- Travelers' real-time and pre-trip decisionmaking process with respect to changes in pricing strategy shall be represented.
- Flexible and dynamic pricing strategies that appropriately assign pricing to roadway facilities that match traffic conditions both on the priced facility and on alternate routes, modes, and facilities shall be developed.
- Available and feasible pricing alternatives to the traveler and their decisionmaking process/change in behavior due to this information during run-time shall be represented.
- Multiple transportation modes, alternative routes, availability and selection of roadway facility types, and time-of-day options shall be modeled accurately.
- Microscopic traffic simulation tools shall be used as the base model to simulate dynamic pricing strategies, while considering the use of other software packages with lower traffic resolution for the evaluation of specific impacts on the transportation system operation.

Adaptive Traffic Signal Control

The following presents the modeling requirements to evaluate the impact of ATSCs:

- The Network Simulator in the AMS framework shall capture the impact of added capacity of shoulder lane use in attracting more demand.
- The traveler behavior models in the Network Simulator of the AMS framework shall use the anticipated traveler behavior in the analysis of the effectiveness of the strategy.
- The driving behavior models in the Network Simulator of the AMS framework shall be responsive to the ATSC implementation.
- The supply component of the Network Simulator of the AMS framework shall incorporate the ATSC algorithms to be implemented in the analysis.
- The ATSC algorithms in the Network Simulator of the AMS framework shall include the anticipated traveler response to changes in signal timings in designing the traffic signal cycles.
- Travelers and their decisionmaking processes shall be modeled, primarily as they relate to route choice, given that their travels may involve an arterial corridor.
- Inherent flexibility to implement various adaptive traffic control algorithms shall be considered.
- Development of API to directly read link counts and optimize based on the observed volume shall be supported.

Chapter 5: Analysis Plan Elements Specific to Package 2

Analysis Package Name: Rear-End Collision on Freeway During the AM Peak

5.1 Analysis Plan Scope

Section 3.1 presents the scope of the Analysis Plan for all analysis packages. The Analysis Plan for this package—Incident in the AM Peak—is designed to address the following additional question:

What AMS steps are required to—

- Monitor the system for incidents?
- Predict the possible impact of an incident on regional network performance?
- Evaluate the impact of ATDM dynamic strategies to support incident management?

5.2 Regional and Existing Operational Conditions

Chapter 2 of this document presents an overview of a hypothetical region and details the various transportation demand and supply elements for the region.

5.3 Analysis Scenario and ATDM Strategies To Be Analyzed

This analysis package represents a typical weekday morning with an incident during the peak time period. The overarching goal for this analysis scenario *(incident)* is to influence travel demand and supply for each component in the trip chain. Although the exact time and location of the occurrence of the scenario incident is unpredictable, 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 goals of the operating agency are to—

- Resolve the current situation and provide dynamic incident management
- Alert travelers about the incident
- Prevent follow-on incidents from occurring (e.g., reduce rear-end crashes)
- Manage the road network accordingly.

The key objectives of the operating agency are to—

- Ensure that mobility delays are below the threshold set by the local agency
- Improve travel time reliability by reducing travel time variance to less than 40 percent of the average travel time
- Ensure that the quantity of emissions is below the threshold set by the local agency.

The simulation starts at midnight. Near the start of the AM peak period, a rear-end collision occurs on the eastbound left lane of I-106 when the lead vehicle unexpectedly slows to let another vehicle merge into 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.

The objective of this scenario is to illustrate the use of ATDM applications for managing travel in the project corridor during the AM peak, with additional challenges resulting from an incident on the freeway that affects the transportation network. This scenario investigates the benefits of employing ATDM strategies on a large-scale basis in response to a geographically constrained situation. It covers an unpredictable, 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.

ATDM Strategies

To overcome the predicted stresses on the transportation system, active traffic management strategies such as the dynamic ATDM strategies identified in the AMS CONOPS Report are required. In this analysis package, the following ATDM strategies are expected to be useful for traffic management:

- Predictive traveler information systems
- Dynamic speed limits
- Queue warning
- Adaptive ramp metering.

The following sections present a discussion of the aforementioned strategies.

Predictive Traveler Information Systems

Provides traveler information services specific to a multimodal corridor or region, including personalized services such as comparative travel time information amongst different travel modes, provision of parking information, and direct links to rideshare providers in order to assemble specific trips using one or more modes and connection points as needed. Advanced journey planning capabilities may compare driving, using transit, and carpooling/ridesharing based on available ridematch options.

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.

Impact of Strategies on the Trip Chain

An implementation of ATDM strategies is likely to affect the traveler's decisionmaking process. This decisionmaking process occurs at different times during the traveler's trip chain. The parts of the trip chains affected by the ATDM strategies in this scenario are shown in Table 5-1.

Table 5-1: Influence of ATDM Strategies on Elements of the Trip Chain

		Trip Chain Affected				
No	**ATDM Strategy**	**Destination Choice**	**Mode Choice**	**Time-of-Day Choice**	**Route Choice**	**Lane/Facility Choice**
1	Predictive traveler information	◔	●	◑	●	◔
2	Dynamic Speed Limits				◑	●
3	Queue Warning				◑	●
4	Adaptive Ramp Metering				◑	

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.

The following sections detail how the strategies chosen for this analysis package potentially affect the components of the trip chain.

Destination Choice

Alerting the public early (as soon as the incident occurs) about the traffic conditions affects destination choice only marginally, because most of the travel during the AM peak period is likely to be commuter trips. Destination choice for other trip purposes, such as social recreation or shopping, could, however, change. Although a portion of the PM peak period travel includes social recreation or shopping trips, trips of this nature rarely occur during the AM peak period. Adaptive ramp metering marginally affects destination choice, because travelers making a discretionary trip will choose a different destination or choose to not make the trip at all. So, destination choice would barely be affected by ATDM strategies for this analysis package.

Mode Choice

A small portion morning commuters may change their mode in the morning. Instead of using extremely congested roadways in the vicinity of the incident, they may choose to use the rail service to downtown, or they may drive to the nearest bus station. Although predictive traveler information definitely influence mode choice, the other strategies have no influence on a traveler's choice of mode. Because the changes to the system are only in the vicinity of the incident, mode choice is not affected.

Time-of-Day Choice

Time-of-day choice is marginally affected. Because 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. Although predictive traveler information definitely influence time-of-day choice, dynamic speed limits and queue warning systems do not. Travelers who are aware of adaptive ramp metering may, however, choose to change when during the day they would like to make the discretionary trip. Because the changes to the system are only in the vicinity of the incident, time-of-day choice is not greatly affected by dynamic speed limits and queue warning systems.

Route Choice

During the morning peak hours, travelers who are informed of the network disruption will likely change their route to avoid the accident zone. As a result, route choice will be the most heavily affected component of the trip chain. During the morning peak hours, travelers in the NCNJ region who follow the real-time information stream change their routes accordingly. Although predictive traveler information definitely influence route choice, the other strategies influence a traveler's choice of route only partially. Because the changes to the system are only in the vicinity of the incident, these strategies do not greatly effect a traveler's choice of route. So, the analysis approach should be created so that the ATDM can test the impact and effectiveness of the real-time information stream on route choice and how it improves system performance.

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. The implementation of queue warning services enables travelers to be aware of closed lanes and shift to an open lane before they approach the congested sections. If travelers are made aware of the incident in advance—miles ahead of the location of the incident—and they start merging into open lanes in advance, lane merges near the location of the incident are reduced. In addition, dynamic speed limits after lane/facility choice, because travelers will choose to use a faster lane. The analysis plan should therefore be created so that the ATDM can capture lane change and gap acceptance behavior.

5.4 Data Needs

Section 0 presents the preliminary data needs for the analysis packages. This package requires additional data related to the exact location of the incident, the number of lanes to be closed, and the duration of closure.

5.5 Performance Measures

Well-defined performance measures are required to keep a pulse check on system performance. The following quantities have been selected as examples of what can be used as performance measures for this analysis package.

Mobility Delays

Mobility delay can be defined as the additional travel time that a driver or passenger experiences because of circumstances that impede the desirable movement of traffic. It is measured as the time difference between actual travel time and ideal or free-flow travel time. For this analysis package, *mobility delays* will be defined as the additional travel time that a traveler experiences because of the occurrence of an incident. For example, mobility delays will be high in the vicinity of the incident; however, although the regions that are not in the vicinity of the incident do not experience direct mobility delays from the incident, they are likely to experience cascading delays.

For this analysis package, mobility delays will be defined as the additional travel time experienced by a traveler due to the occurrence of an incident during a given time period. Real-time travel times for roadway segments will be compared to historical averages for the same segments (during the same time period) in order to compute mobility delays.

$$Mobility\ delay = (current\ travel\ time)\ -(historical\ average\ travel\ time)$$

Mobility delays will be computed for the NCNJ region before and after ATDM implementation for the following corridors, which are either directly affected by the incident or are corridors to which traffic would be diverted:

- I-6 (HOV) between Old Reston and New Camden
- General Sherman Highway (single-occupancy vehicle [SOV]) between Old Reston and New Camden
- I-106 and I-6 between Little Reston and New Camden.

The local agency will set goals for this performance measure for each time step of analysis.

Travel Time Reliability

Travel time reliability is a derived parameter that is significant from the traveler's point of view. It is sometimes represented as the variance of travel time to complete a trip. Statistical terms that are more evolved and represent the spread or consistency of travel times can be calculated to indicate travel time reliability. Higher travel time reliability reflects a higher LOS and user trust in the transportation system. The local agency will set the goals for this performance measure for each time step of analysis.

Travel time reliability is the consistency of travel time variation when compared to average travel time during a given time step. It is typically measured as a statistical index, such as standard deviation. A high standard deviation indicates that travel time is less reliable. In addition, reliability could be measured as the 95th percentile travel time or buffer index.[3]

$$Travel\ time\ reliability\ (or\ 95th\ percentile\ buffer\ index) = 100 \times \frac{(95^{th}\ percentile\ travel\ time) - (average\ travel\ time)}{(average\ travel\ time)}$$

The buffer index measure is easy to relate by travelers; hence, this analysis package uses this index to measure travel time reliability. The buffer index will be computed for the NCNJ region before and after ATDM implementation for the following corridors, which are either directly affected by the incident or are corridors to which traffic would be diverted:

- I-6 (HOV) between Old Reston and New Camden
- General Sherman Highway (SOV) between Old Reston and New Camden
- I-106 and I-6 between Little Reston and New Camden.

Quantity of Emissions

This measure quantifies the amount of vehicle emissions generated in the region. The quantity of emissions includes both mobile and idle emissions and is inversely proportional to the travel speed. Note that the amount of emissions a vehicle traveling at high speeds (say, 65 mph) generates is higher than the amount of emissions the vehicle generates if it were traveling at lower speeds (about 45 mph). A transportation system that operates with vehicles moving smoothly without stop-and-go movements generates a lower quantity of emissions than the same transportation system with a significant amount of stop-and-go traffic. The NJMPO is charged with conforming to emissions standards and implements strategies to reduce the quantity of emissions.

The amount of emissions from vehicles is a measure used to track the environmental impact of the transportation system. The quantity of these vehicular emissions is measured in terms of the amount of greenhouse gases, such as carbon dioxide, and poisonous gases, such as sulfur dioxide, emitted from the vehicles during the course of their trip operations. The quantity of emissions is lower under uniform traffic flow instead of the stop-and-go traffic, as is the case in this incident scenario. Hence, the degradation of the environmental efficiency of the transportation system as a result of the incident can be captured in terms of increased amounts of vehicular emissions per mile travelled.

In the simulation setup, the quantity of vehicular emissions is captured by re-creating the vehicular movements in a microscopic traffic simulator platform and feeding the outputs from the simulation runs into an emissions model such as the Motor Vehicle Emissions Simulator (MOVES). The microscopic simulation model should be calibrated with respect to the normal operating conditions during AM peak traffic. If possible, the calibration process should replicate the individual vehicle trajectories in the simulation runs. The simulated vehicle trajectories are input to the vehicular emissions model along with the vehicle specifications (e.g., type, mileage). The emissions model uses the trajectory data to

[3] The *buffer index* represents the extra time (or time cushion), expressed as a percentage of average travel time, that travelers must add to their average travel time when planning trips to ensure on-time arrival 95% of the time. Source: http://ops.fhwa.dot.gov/publications/tt_reliability/brochure.

estimate the quantity of vehicular emissions, which should be normalized by the number of miles traveled.

5.6 Tools Needed for Analysis

Section 3.6 presents the generic tool needs for the analysis packages. Table 5-2 provides examples of tools.

Table 5-2: Examples of AMS Tools

Model/ Model Category	Description of Models, with Examples
Travel Demand and Behavior Models	
Activity-based models	These models consider interaction among 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.
Traffic Operations Models and Tools	
Mesoscopic models	These models are typically used to model regional networks. Most mesoscopic analysis tools include DTA procedures that replace the traffic assignment procedures in the traditional four-step travel demand models to achieve higher accuracy in speed estimates. Examples include DYNASMART and DYNAMIT.
Microscopic models	Microscopic simulation models track individual vehicular movements and generate detailed estimates of network performance. Examples include CORSIM, Paramics, VISSIM, SimTraffic, and Aimsun.
Emissions Model	
Microscopic Emissions Model	MOVES is a modal emission model that derives emissions estimates based on second-by-second vehicle performance characteristics for various driving modes and geographic areas ranging from the nation down to link. MOVES received inputs from traffic simulation/traffic assignment models to generate emissions estimates.

5.7 Analysis Settings

Table 5-3 describes the analysis settings and assumptions. It is to be noted that the time steps, time periods, and time windows are presented for illustrative purposes only. The local agency would chose these settings as it deems appropriate for the analysis it is conducting.

Table 5-3: Analysis Settings for Analysis Package 2

Analysis Setting	Description
Simulation Time Period	00:00–23:59
Time Period of Analysis	05:00–08:00 is the primary analysis time period
Forecast Period	For this analysis, a 30-minute forecast of future conditions in 5-minute increments will be made once every 10 minutes
Data	It is assumed that traffic count data is continuously fed from the freeway and arterial management systems to the analyst. Transit ridership and real-time schedule data is also available

5.8 AMS Approach

This analysis scenario represents a typical weekday's transportation activities and operations in the NCNJ region along with certain predictable recurring stresses to the transportation system. The approach for investigating this scenario from the ATDM perspective involves creating a model to analyze the demand and supply during the morning peak hour on an average weekday, along with a predictive component to track traffic conditions in the forecasted future. The analysis framework has been presented in Section 3.8 as Figure 3-1.

The analysis approach for this package (Normal Operations—No Incident) is detailed in the following sections. This approach includes the following three phases:

- Monitor the system.
- Assess system performance.
- Evaluate dynamic actions and capture the impact of the dynamic action for the next moving window.

Monitoring the System

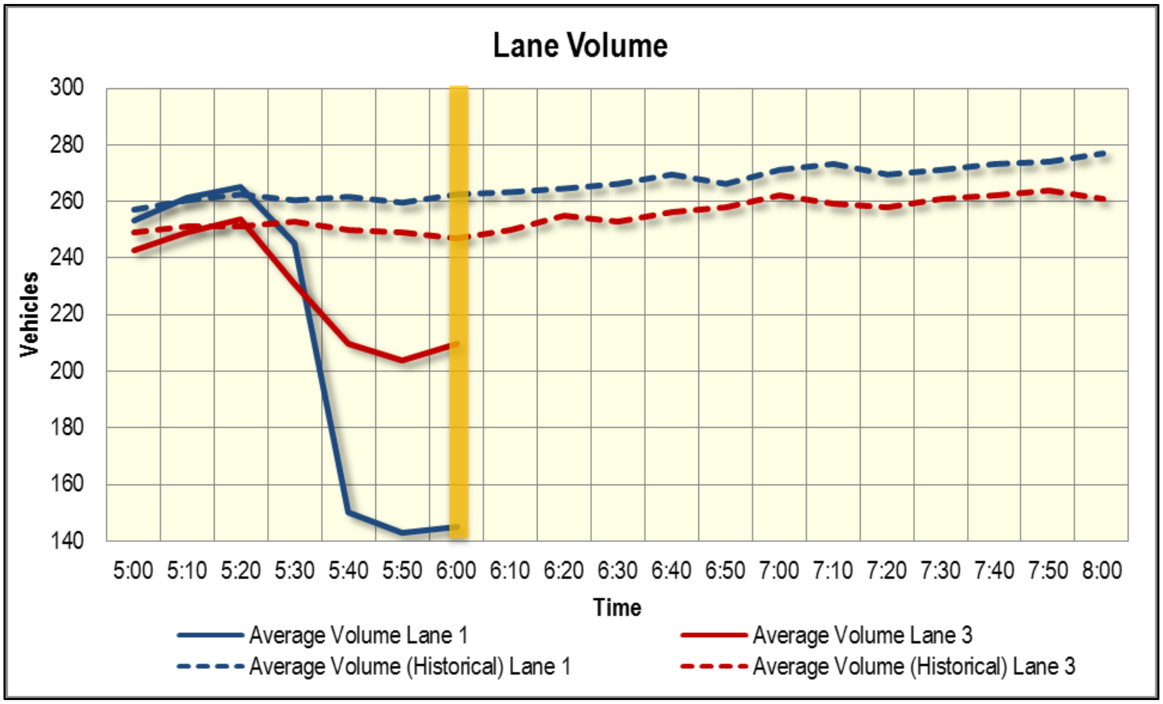
Monitoring the transportation system in real time for the NCNJ region is the first step in the ATDM AMS cycle. The simulation starts at midnight. The system monitoring phase begins an hour before the analysis period (05:00 to 08:00)—that is, at 04:00 for this analysis package. During this period, the system is monitored for major incidents. This monitoring phase captures how a major incident affects system performance and which parts of the system are affected. The objective of this analysis package is to ensure that the system performs as expected and is not affected largely by an incident such as a vehicle collision on a freeway. The system monitoring task has been described in detail in Section 3.8, and this analysis package's system monitoring task follows that process. This step includes two subprocesses: data processing and simulation.

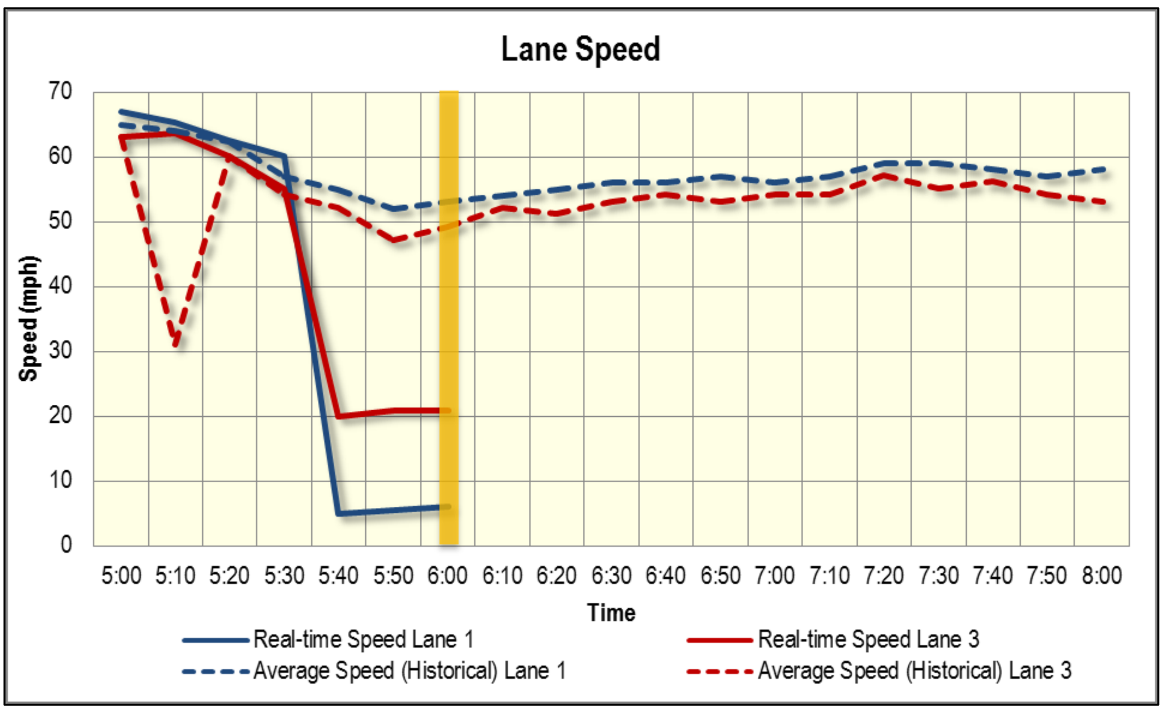
These two subprocesses are described in the following sections, which present an overview of how the system is monitored and the interactions between the Data Generator and the Network Simulator.

Data Processing

This analysis package's data processing and integration tasks follow the process described in Section 3.8. The real-time information when compared to historical data presents a clear indication of the occurrence of an incident. For example, the rear-end collision on I-106 will cause traffic in the vicinity to slow down i.e. traffic volumes are lower and speeds are lower. The Data Generator will automatically flag such locations for further review. Figure 5-1 presents a comparison of real-time and historical average speeds and volumes on the I-106 in the vicinity of the incident location before, during and after the incident. The orange bar on the chart indicates the current time. This chart indicates high likelihood of occurrence of an incident. The output from the Data Generator will be used to identify the sub-region that requires careful monitoring. Figure 5-1 shows how real-time monitoring of speed and volume profiles can be used to flag a potential problem in the network due to an incident.

Figure 5-1: Traffic Volumes (10 min) and Speeds Before, During, and After the Incident





Network Simulator

This analysis package's data simulation task follows the process described in Section 3.8. Once the occurrence of an incident has been identified by the Data Generator, the Data Generator generates the data needed to simulate the effects of this incident for the current time period of analysis. This data set includes—

- Lane closure information
- Changes to demand that occur as a consequence of the incident.

Performance Measures

For this particular analysis package, mobility delays and travel time reliability are selected as the two regional performance measures of interest to the agency. The Network Simulator has a performance measure computing component that computes these performance measures during the monitoring phases of the ATDM AMS cycle. A brief description of these performance measures is presented below. The process used to generate the performance measures has been described in Section 5.5.

Mobility Delays

For this analysis package, mobility delays will be defined as the additional travel time experienced by a traveler due to an incident on the freeway for the current system monitoring time period (e.g. 5:00 AM to 5:30 AM). Travel times for roadway segments will be compared to historical averages for the mobility delays due to an incident on the freeway and goals set by the local agency in order to compute mobility delays. If this comparison indicates that the predicted performance meets the agency goals, then dynamic actions are not warranted.

Trip travel time reliability

The travel time reliability for the current system monitoring time period (e.g. 5:00 AM to 5:30 AM) is compared to historical averages of travel time reliability due to an incident on the freeway and the goals set by the local agency for the same time period. If this comparison indicates that the predicted performance meets the agency goals, then dynamic actions are not warranted.

Quantity of Emissions

For this analysis package, the quantity of vehicular emissions is captured by recreating the vehicular movements on a microscopic traffic simulator platform and feeding the outputs from the simulation runs into an emissions model such as Motor Vehicle Emissions Simulator (MOVES) for the current system monitoring time period (e.g. 5:00 AM to 5:30 AM). The quantity of emissions for the current system monitoring time period (e.g. 5:00 AM to 5:30 AM) is compared to historical averages and the goals set by the local agency for the same time step. If this comparison indicates that the predicted performance meets the agency goals, then dynamic actions are not warranted.

Assessing System Performance

The system assessment phase begins during the analysis period (05:00 to 08:00)—that is, at 05:00 for this analysis package. During this period, a forecast or a prediction of the system because of an incident on the freeway is performed. This assessment phase predicts how a major incident affects system performance and which parts of the system are affected. The system performance assessment task has been described in detail in Section 3.8, and this analysis package's performance assessment task follows that process. For this analysis package, system performance assessment involves—

- Predicting traveler locations and movements for the next time step
- Assessing system performance measures for the next time step.

To predict travel locations and movements for the next time step, the Data Generator needs to generate the inputs that the Network Simulator requires to be able to accurately simulate traveler movements for the next time step. As detailed in Section 3.8, the Data Generator provides the Network Simulator data pertaining to lane closures. Using this information that replicates the effects of the occurrence of the incident on the multi-resolution network, the Network Simulator performs a simulation of traveler movements in the region. The outputs from this simulation are used to generate performance measures, as detailed in the previous section. After the performance measures are computed, they are compared to ATDM objectives to determine whether the objectives were met.

Performance Measures

For this particular analysis package, mobility delays and travel time reliability are selected as the two regional performance measures of interest to the agency. The Network Simulator has a component that computes these performance measures during both the monitoring and the assessment of the system phases of the ATDM AMS cycle. A brief description of these performance measures is presented below. The process used to generate the performance measures has been described in Section 5.5. The performance measures computed during the assessment phase without any strategies implemented will be the baseline performance measures for this analysis package.

Mobility Delays

For this analysis package, *mobility delay* is defined as the additional travel time a traveler experiences because of an incident on the freeway for the next time window (e.g., 05:30 to 06:00). Travel times for roadway segments will be compared to historical averages for the mobility delays caused by an incident on the freeway and goals the local agency sets to compute mobility delays. If this comparison indicates that the predicted performance meets the agency goals, then dynamic actions are not warranted.

Trip Travel Time Reliability

The travel time reliability for the next time window (e.g., 05:30 to 06:00) is compared to historical averages of travel time reliability caused by an incident on the freeway and the goals the local agency sets for the same time period. If this comparison indicates that the predicted performance meets the agency goals, then dynamic actions are not warranted. If this comparison indicates that the predicted performance meets the agency goals, then dynamic actions are not warranted.

Quantity of Emissions

For this analysis package, the quantity of vehicular emissions is captured by recreating the vehicular movements on a microscopic traffic simulator platform and feeding the outputs from the simulation runs into an emissions model such as Motor Vehicle Emissions Simulator (MOVES) for the next time window (e.g. 5:00 AM to 5:30 AM). The quantity of emissions for the next time window (e.g. 5:00 AM to 5:30 AM) is compared to historical averages and the goals set by the local agency for the same time step. If this comparison indicates that the predicted performance meets the agency goals, then dynamic actions are not warranted.

Evaluating the Impact of ATDM Strategies

The system evaluation phase begins during the analysis period (05:00 to 08:00)—that is, at 05:00 for this analysis package. During this period, a forecast or a prediction of the system because of an incident on the freeway along with the dynamic actions implemented to alleviate conditions is performed. This evaluation phase predicts how a major incident affects system performance and how the dynamic actions improve system performance. This analysis package's performance evaluation task follows that process. For this analysis package, the performance measures mobility delays, travel time reliability, and quantity of emissions are compared to the goals set by the local agency and to the performance measures generated during the system assessment phase (baseline). If the forecasted performance measures do not meet the objectives set by the local agency, ATDM strategies will be reevaluated and the impact of implementing the selected strategies tested. Note that in real-world ATDM implementation, a DSS or automated process selects the best set of strategies to be implemented. For this analysis, the set of strategies to be tested have been for illustrative. As presented and discussed in Section 5.3, the strategies chosen for this analysis scenario include—

- Predictive traveler information
- Dynamic speed limits
- Queue warning
- Adaptive ramp metering.

The following section presents a discussion on how each strategy would be implemented and tested for its effectiveness for the AM peak incident scenario.

Predictive Traveler Information

The use of this strategy under regular operations has been described in Section 4.8.In this section, we discuss how this strategy can be used and tested for its effectiveness under the AM peak incident scenario. Under the ATDM approach, as soon as the incident occurs, the following types of information are shared with individual travelers:

- Nature of the incident (location, number of lane closures, duration of impact, and expected increase in travel time)
- Traffic information
- Transit availability
- Transit schedule
- Projected travel times by auto mode
- Travel time on alternative routes.

This information dissemination helps the traveler make optimal choices for mode, route, or time of departure. It is assumed that the information disseminated to the travelers includes both real-time and predicted guidance information on the route alternatives and the expected travel times on key routes in the region. The guidance information will be disseminated to travelers in the region using various channels, including mobile devices, DMSs and an enhanced 511 system.

In this scenario, the traffic coming from the Hinterlands in the north encounters a higher amount traffic disruptions than the traffic on both I-403 and McGeorge Bundy Parkway has historically shown. I-403 carries a heavy traffic of truck vehicles, whereas the Bundy Parkway carries a significant proportion of tourist travelers who are unfamiliar to the region. Hence, the predictive traveler information services along the Bundy Parkway needs to be used to provide route alternatives to unfamiliar travelers.

The application of this strategy for incident management is used to inform drivers of the congestion conditions on the network and alternative routes to avoid taking the congested route. This route choice is made en route and needs to be modeled on a mesoscopic or a microscopic simulation framework, depending on the level of detail the analysis requires. If the information is conveyed via mobile devices, the time-of-day choice and mode choice may also be affected. These changes in the traveler behavior will have to be incorporated at the travel demand modeling level. Modeling Predictive Traveler Information in a simulation model requires a thorough understanding and interpretation of traveler response to these information systems, especially when notified about the cause of delays (e.g., an incident). It is essential to obtain data for calibrating traveler response to information pertaining to incidents along his or her path. The following questions need to be answered by the data obtained from historical data, revealed preference surveys, or stated preference surveys:

- Will travelers change their behavior or choice (e.g., route, mode) based on the information presented?
    - What percentage of travelers will modify their choice after they are made aware of delays caused by an incident?
- Will travelers choose a route mid-trip?
    - What percentage of travelers will modify their route mid-trip after they are made aware of delays caused by an incident?

Current tools do not possess the capabilities or possess limited capabilities to model the operation and the impacts of a dynamic travel information system. The foundation of an predictive traveler information system is presently available; however, the components of the system are at various stages of development.

Dynamic Speed Limits

The impacts of dynamic speed limits are realized only at the en route driving level. The route choice and lane choice models incorporate the elements that are responsive to the speed limit information. The traveler is made aware of the dynamic speed limits about 5 miles in advance on I-6, and the traveler has to make any route choice and subsequent lane changing maneuvers. The distance from the decision-critical point on the roadway downstream is a critical variable in the utility-based discrete choice models for the route choice and lane choice. Other important variables include driver characteristics and roadway conditions. The models can be calibrated, especially for the human factor variables, by using vehicle trajectory data.

In order to evaluate this strategy, the Data Generator creates an multimodal network with dynamic or time-dependent speed limits. The Data Generator creates this network for each time step. The network simulator uses this network to simulate traffic, and also to generate demand using the feedback process. The speed limits appropriate to resolve incident conditions can be derived by the modeler from empirical experience. Once the dynamic speed limits are set up along I-6, the driving behavior models in the mesoscopic or microscopic simulation models will respond to the speed advisories and the subsequent traveler decisions would be simulated accordingly. Since the traffic analysis tools used for analysis are already calibrated and validated for traffic speeds in the network, additional calibration or validation is not required.

Queue Warning

Queue warning is an active management method using which the queues along the freeway facility are detected and an automatic warning advisory issued to the upstream travelers. In this scenario, the DMSs are located about 1.5 miles ahead of the decision points along I-6, I-106, and I-403. This DMS infrastructure will be used to post queue warning along these freeways, ensuring that travelers are aware of the incident on I-6 and enabling them to choose either a different route or a different lane or facility (such as toll lanes).

The queue buildup in the NCNJ region is expected to occur mostly along the I-6 corridor during the morning peak period because of the incident. Because I-6 is equipped with both roadway detectors and CCTV installation, issuance of queue warning is an effective strategy against incident events along I-6.

The supporting AMS framework will include a multiresolution simulation framework. The time-dependent travel demand tables are fed into the mesoscopic simulation model. The changes in the travel demand caused by information conveyed via the predictive traveler information systems are incorporated into the travel demand, and the adjusted trip tables are fed to the mesoscopic simulator. The mesoscopic simulator might have to be further integrated with a microscopic simulator to capture the detailed interactions on the incident affected corridor. These different models will be interconnected via feedback loops.

The route choice and lane choice models incorporate the elements that are responsive to the queue warning information. The traveler is made aware of the dynamic speed limits about 1.5 miles in advance, and the traveler needs to make route choice and subsequent lane changing maneuvers within this 1.5 mile distance buffer. The distance from the decision-critical point on the roadway downstream is a critical variable in the utility-based discrete choice models for the route choice and lane choice, as it reflects the urgency with which the driver makes a decision. Other important variables include driver characteristics and roadway conditions. It is essential to obtain data to calibrate traveler response to queue warning systems incidents along his or her path. Either revealed preference survey data or stated preference survey data will be used to calibrate this discrete choice model. When calibrated, this model will successfully predict the percentage of travelers who will choose to modify their route or lane/facility.

Adaptive Ramp Metering

The sections of I-6 and 1-106 within the beltway are equipped with the infrastructure required to support ramp metering. These sections also have an extensive network detectors that are connected back to the STMC via a reliable ring network of fiber-optic communication. Thus, the supporting ITS infrastructure on these sections of I-6 and I-106 is capable of implementing adaptive ramp metering. After the incident occurs, the ramps on I-6 and I-106 are adaptively metered to reduce the amount of vehicles entering these two freeways. This strategy is particularly important for facilitating better dispersion of incoming morning traffic to supporting arterials approaching the central business district. Adaptive ramp metering can also help to support route diversions during incident conditions along the arterials or freeways.

For this scenario, the supporting AMS framework will include a multiresolution simulation framework. In order to implement this strategy, the Data Generator creates an multimodal network with adaptive ramp metering rates. Based on the system assessment phase, the Data Generator creates the network with time-dependent metering rates for the chosen ramps. The Network Simulator uses this network to simulate traffic, and also to generate demand using the feedback process. Capacities for the ramps chosen to for dynamic metering are modified in the network database to reflect this strategy in the macroscopic model, while the ramp flow rate is modified in the mesoscopic and microscopic models. These capacities and flow rates are dynamic by nature (i.e., they change temporally).

The problem the modeler must address is the selection of an appropriate ramp-metering algorithm for the current scenario. The behavior for the travelers who experience ramp metering changes only at the ramp metering site and their driving behavior can sufficiently be captured by using existing car following, lane changing, and lane merging models. Refining the ramp-metering algorithm would require reliable inputs about the freeway and incoming ramp traffic (volume and speed). Hence, the simulation framework should tie up the ramp-metering algorithm with the Data Generator component, from which the algorithm can receive real-time data about the traffic flow parameters. Since the tools used for analysis are already calibrated and validated for metered ramps in the NCNJ region, additional calibration or validation is not required.

Performance Measures

For this particular analysis package, mobility delays and travel time reliability are selected as the two regional performance measures of interest to the agency. The Network Simulator has a performance measure computing component that computes these performance measures both during the evaluating impact phase of the ATDM AMS cycle. A brief description of these performance measures is presented below. The process used to generate the performance measures has been described in Section 5.5. The performance measures computed during the evaluation phase with strategies implemented will be compared to the baseline performance measures computed during the assessment phase.

Mobility Delays

For this analysis package, mobility delays will be defined as the additional travel time experienced by a traveler due to an incident on the freeway for the next time window (e.g. 5:30 AM to 6:00 AM). Travel times for roadway segments will be compared to historical averages for the mobility delays due to an incident on the freeway, mobility delays generated during the assessment phase, and goals set by the local agency in order to compute mobility delays. If this comparison indicates that the predicted performance with the dynamic action meets the agency goals, then dynamic actions are implemented and the system is continuously monitored.

Trip travel time reliability

The travel time reliability for the next time window (e.g. 5:30 AM to 6:00 AM) is compared to historical averages of travel time reliability due to an incident on the freeway, travel time reliability generated during the assessment phase, and the goals set by the local agency for the same time period. If this comparison indicates that the predicted performance with the dynamic action meets the agency goals, then dynamic actions are implemented and the system is continuously monitored.

Quantity of Emissions

For this analysis package, the quantity of vehicular emissions is captured by recreating the vehicular movements on a microscopic traffic simulator platform and feeding the outputs from the simulation runs into an emissions model such as Motor Vehicle Emissions Simulator (MOVES) for the next time window (e.g., 5:30 AM to 6:00 AM). The quantity of emissions for the next time window (e.g., 5:30 AM to 6:00 AM) is compared to historical averages of quantity of emissions due to an incident on the freeway, quantity of emissions generated during the assessment phase, and the goals set by the local agency for the same time step. If this comparison indicates that the predicted performance with the dynamic action, meets the agency goals then dynamic actions are implemented and the system is continuously monitored.

5.9 Model Calibration

Section 3.9 details how the models for the analysis packages will be calibrated and presents the data requirements for that calibration.

5.10 Modeling Requirements

The modeling requirements for this scenario are mapped against the AMS needs identified in the CONOPS Report. They are presented in the following sections.

Monitoring the System

The overall modeling requirements for monitoring the system have been presented in Section 3.9. No additional modeling requirements are necessary for this analysis package, the Normal Operation—No Incident package.

Assessing System Performance

The overall modeling requirements for assessing system performance have been presented in Section 3.9. No additional modeling requirements are necessary for this analysis package, the Normal Operation—No Incident package.

Evaluating the Impact of ATDM Strategies

The overall modeling requirements for evaluating the impact of ATDM strategies have been presented in Section 3.9. The following sections present the modeling requirements for evaluating each strategy chosen for this analysis package.

Predictive Traveler Information

The following list presents the modeling requirements for evaluating the impact of predictive traveler information:

- The models in the Network Simulator component of the AMS framework shall include utility-based discrete choice models to capture the mode choice, time-of-day choice, and route choice affected by the traveler information. The models in the Network Simulator component of the AMS framework shall capture the impact of the information conveyed to travelers on the network conditions;
- The models in the Network Simulator component of the AMS framework shall anticipate user reactions to the information conveyed to the traveler,.
- Traveler’s route choice and lane choice decisions in response to the dissemination of en-route traveler information, especially as a function of the distance to the decision-critical point shall be modeled.
- Traveler’s trust and perceived reliability of the DMS advisories shall be modeled.

Dynamic Speed Limits

The following list presents the modeling requirements for evaluating the impact of dynamic speed limits:

- The traveler behavior models, especially the route choice and lane choice models, must capture the impact of dynamic speed limits.
- The design of dynamic speed limits must consider the anticipated user response to the advisories based on traveler behavior factors such as user acceptance and user reliability in travel advisories.

- Traveler response to speed limits, based on traffic or weather conditions, must be modeled.
- The traveler's car-following and lane choice behaviors in response to the dynamic speed limits must be modeled.
- Dynamic speed limits that alter relative utilities of different modes of travel must be communicated to the mode choice models.
- Various dynamic speed limit algorithms with an in-built capability of the simulation framework must be implemented.

Queue Warning

The following list presents the modeling requirements for evaluating the impact of queue warning:

- The route choice and lane choice model must be able to capture the urgency of the traveler to make a decision on route choice and lane choice in response to the queue warning. These models must consider each individual traveler's driving behavior characteristics, such as aggressiveness and compliance with advisories.
- The models must use queue warning information in conjunction with the dynamic speed limits in interaction terms to capture the compound effect of these strategies on travelers.
- The traveler's route choice and lane choice decisions in response to the queue warning, especially as a function of the distance to the decision-critical point, must be modeled.
- The drivers' human factors impact on the decisionmaking must be captured.

Adaptive Ramp Metering

The following list presents the modeling requirements for evaluating the impact of adaptive ramp metering:

- The traveler's driving behavior in response to ramp metered merging maneuvers must be modeled.
- The impact of ramp metering must be propagated to neighboring arterial facilities.
- Various ramp-metering algorithms must be available for testing and refining.

Chapter 6: Analysis Plan Elements Specific to Package 3

Analysis Package Name: A Baseball Game During the PM Peak

6.1 Analysis Plan Scope

Section 3.1 presents the scope of the analysis plan for all the analysis packages. The analysis plan for this package—PM Peak Baseball Game—is designed to address the following additional questions:

Which AMS steps are required to—

- Monitor the system for special event-related congestion?
- Evaluate the impact of ATDM strategies for special events in real time?

6.2 Regional and Existing Operational Conditions

Chapter 3 of this document presents an overview of a hypothetical region and details the various transportation demand and supply elements for that region.

6.3 Analysis Scenario and ATDM Strategies To Be Analyzed

The simulation starts at midnight. This analysis package represents a typical weekday evening with a baseball game scheduled to start at 7:00 PM and under normal operating conditions (i.e., there are no extenuating circumstances, such as inclement weather). 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 recurring situation for which the transportation system is prepared: The system can use measures to proactively deal with the situation and its consequences.

The goal of the operating agency is to—

- Manage the road network accordingly, balancing traffic toward the Back Yard Entertainment Complex with traffic departing Old Town and the Octagon and passing through on the way home or to other places.

The objectives of the operating agency are to—

- Maintain person throughput at predetermine levels set by the agency
- Reduce delays to predetermined levels set by the agency.

The scenario begins on a Wednesday evening at 5:00 PM. The New Camden Pit Bulls are playing the current champions, the Portland Green Sox, at the Back Yard at 6:00 PM. The objective of this scenario is to illustrate the 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 Complex. The project corridor is the NCNJ region. 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.

ATDM Strategies

To overcome the predicted stresses on the transportation system, the operator would require active traffic management strategies, such as the ATDM strategies identified in the AMS CONOPS Report. In this analysis package, the following ATDM strategies are expected to be useful for traffic management:

- Dynamic ridesharing
- On-demand transit
- Adaptive traffic signal control
- Dynamically priced parking
- Dynamic wayfinding.

The following sections present a discussion of the aforementioned 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.

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.

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.

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 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.

Impact of Strategies on the Trip Chain

An implementation of ATDM strategies is likely to affect the traveler's decisionmaking process. This decisionmaking process occurs at different times during the traveler's trip chain. The parts of the trip chains affected by the ATDM strategies in this scenario are shown in Table 6-1.

Table 6-1: Influence of ATDM Strategies on Elements of the Trip Chain

No	ATDM Strategy	Trip Chain Affected				
		Destination Choice	Mode Choice	Time-of-Day Choice	Route Choice	Lane/Facility Choice
1	Dynamic Ridesharing		●	◔	◑	●
2	On-Demand Transit		●	◑		
3	Adaptive Traffic Signal Control		◔	◔	◑	
4	Dynamically Priced Parking		●	◔		
5	Dynamic Wayfinding			◔		

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.

The following sections detail how the strategies chosen for this analysis package potentially affect the components of the trip chain.

Destination Choice

Destination choice is not affected: a person either goes to the game or does not. Commuters will leave their place of work to go home. Destination choice is a function of needs and options. As a consequence of ATDM strategies, travelers are expected to and can choose destinations based on the probability of reaching the destination on time A portion of the PM peak period travel includes social recreation or shopping trips. Travelers in the vicinity of the baseball stadium trying to make a discretionary trip for either shopping or social recreation will either avoid making those trips on a game day or choose a different destination that does not require the traveler to use facilities that carry a lot of game-day traffic. The strategies implemented for this scenario affect only the areas in the vicinity of the baseball stadium and do not affect destination choice much.

Mode Choice

Dynamic ridesharing, dynamic transit service, and dynamically priced parking in conjunction with dynamic wayfinding and pricing information affect mode choice greatly, while ATSC does not affect mode choice much. Travelers will choose either to ride-share or use additional dynamic transit service available to them instead of driving on that day. In addition, parking cost is typically part of the utility function used in mode choice. This cost clearly affects a traveler's choice of mode.

Time-of-Day Choice

Although time-of-day choice is marginally affected by dynamic ridesharing and adaptive traffic signals, dynamically priced parking definitely affects commuters' choice to depart earlier to avoid paying the steeper game-day parking costs. In addition, on-demand transit service affects time-of-day choice. Travelers will choose to change their time-of-day departure based on the availability of on-demand transit services.

Route Choice

Route choice is partially affected by ATSCs and dynamic ridesharing. Travelers who choose to ride-share will be able use HOV routes.

Lane/Facility Choice

Lane/facility choice is partially affected by dynamic ridesharing. Travelers who choose to ride-share will be able use HOV facilities.

6.4 Data Needs

Section 0 presents the preliminary data needs for the analysis packages. This package (Normal Operations—No Incidents) does not require additional data.

6.5 Performance Measures

Well-defined performance measures are required to track check on system performance. The following quantities have been selected as examples that can be used as performance measures for this analysis package.

Vehicle/Person Throughput

This measure quantifies the amount of travel completed in a unit of time. It is a good measure for reflecting the load or demand for travel met by the system in a unit of time. It can be measured as the number of vehicles or travelers completing their journey through the corridor in a unit of time. The local agency sets the goals for this performance measure for each time step of analysis.

The objective is to maximize traveler throughput for the entire NCNJ region, with a specific focus on the region in the vicinity of the stadium. Although it is important to ensure that commuters can reach their destination, it is also important to ensure that fans can reach the stadium on time and that these two sets of travelers do not present challenges for each other. *Throughput,* or *flow rate,* is the amount of vehicles or people in a unit of time. Because some of the strategies chosen for this analysis package involve the implementation of HOV facilities and providing incentives to use transit, this analysis package will use person throughput as a performance measure. Person throughput will be measured for this analysis package as the number of people crossing a cordon screen line around Back Yard. Figure 6-1 presents the region with the cordon screen line. The number of people crossing this screen line represents a movement of people either into or away from Back Yard. A comparison of this statistic before and after ATDM strategies are implemented will provide insight into the benefits of the strategies.

In addition, the average speed of travel for people crossing this screen line is important. Although increasing person throughput is a goal for this analysis package, this goal should be achieved without reducing the quality of service or the average trip speed. The average trip time for the people crossing the screen line before and after the implementation of the ATDM strategies will be computed and compared. For this analysis, travel time between five population centers and five employment centers in the NCNJ region to Back Yard will be computed. The time required to travel from each population center or employment center to Back Yard will be multiplied with the total number of trips between the two centers, providing a statistic of the total person hours traveled for each combination of activity centers.

Figure 6-1: Back Yard Cordon Screen Line

Mobility Delays

Mobility delay is defined[4] as the additional travel time a driver, passenger, or pedestrian experiences because of circumstances that impede the desirable movement of traffic. It is measured as the time

[4] American Association of State Highway and Transportation Officials (AASHTO) Glossary.

difference between actual travel time and ideal or free-flow travel time. Although it is easy to compute actual travel time, computing ideal or free-flow travel time poses challenges. Free-flow travel time is computed for a freeway facility by dividing the distance travelled by the speed limit or the free-flow travel speed. Off-peak travel speeds are typically used as free-flow or uncongested travel speeds to compute mobility delays.

For this analysis package, *mobility delay* is defined as the additional travel time a traveler experiences because of the occurrence of an incident during a given time step. Real-time travel times for roadway segments will be compared to historical averages for the same segments to compute mobility delays.

$$Mobility\ delay = (current\ travel\ time)\ - (historical\ average\ travel\ time)$$

Mobility delays are typically calculated as the deviation of actual travel time from desired or free-flow travel times. In this scenario, the planned sports event alters the traffic conditions along the I-6, I-3, I-106, McGeorge Bundy Parkway, and other arterials connecting to the Back Yard Entertainment Complex near Octagon City. The additional demand on these facilities during the PM peak period might incur additional travel time for the travelers. Thus, the mobility delay must be seen as the difference between the travel times under regular PM peak operations and under PM peak operations on a game day for the same traveler.

To compare the mobility delays before and after the implementation of the ATDM strategy, the baseline PM peak scenario must be simulated in a simulation framework. The simulation models need to be calibrated to consistently replicate the travel times observed in the field with regular day PM peak traffic conditions and no sports event. In other words, the baseline model from Scenario 1 can be used as the baseline model. The simulations are run for each scenario: baseline, sports event during PM peak, and sports event during AM peak with the ATDM strategy in place. The travel demand for the sports event scenarios and the ATDM strategy scenario need to be computed to account for the additional traffic going to and coming from the Back Yard Entertainment Complex. To account for the stochastic nature of the travel demand models, the departure times of each traveler are varied within a buffer amount. For example, across different simulation runs, traveler A might leave the origin location at any time between 5:00 and 5:20 PM. The travel times from each set of simulation runs are used to calculate the mobility delays under incident conditions and under incident with ATDM strategy conditions. These quantities are averaged over the multiple simulation runs. The goal of the ATDM strategies for this scenario is to cut down the mobility delays under the sports event scenario by more than 50 percent. The local agency sets the goals for this performance measure for each time step of analysis.

6.6 Tools Needed for Analysis

Section 3.6 presents the generic tool needs for the analysis packages. Table 6-2 provides examples of these tools.

Table 6-2: Examples of AMS Tools

Model/ Model Category	Description of Models, with Examples
Travel Demand and Behavior Models	
Activity-based models	These models consider interaction among 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.
Traffic Operations Models and Tools	
Mesoscopic models	These models are typically used to model regional networks. Most mesoscopic analysis tools include DTA procedures that replace the traffic assignment procedures in the traditional four-step travel demand models to achieve higher accuracy in speed estimates. Examples include DYNASMART and DYNAMIT.
Microscopic models	Microscopic simulation models track individual vehicular movements and generate detailed estimates of network performance. Examples include CORSIM, Paramics, VISSIM, SimTraffic, and Aimsun.

6.7 Analysis Settings

Table 6-3 describes the analysis settings and assumptions. It is to be noted that the time steps, time periods, and time windows are presented for illustrative purposes only. The local agency would chose these settings as it deems appropriate for the analysis it is conducting.

Table 6-3: Analysis Settings for Analysis Package 3

Analysis Setting	Description
Simulation Time Period	Midnight to 11:50 PM
Time Period of Analysis	5:00 PM to 8:00 PM is the primary analysis time period
Forecast Period	For this analysis, a 30-minute forecast of future conditions in 5-minute increments will be made once every 10 minutes
Data	It is assumed that traffic count data is continuously fed from the freeway and arterial management systems to the analyst. Transit ridership and real-time schedule data is also available

6.8 AMS Approach

This analysis scenario represents a typical weekday's transportation activities and operations in the NCNJ region along with certain predictable recurring stresses to the transportation system. The approach to investigating this scenario from the ATDM perspective involves creating a model to analyze the demand and the supply during the morning peak hour on an average weekday along with a predictive component for tracking traffic conditions in the forecasted future. The analysis framework has been presented in Section 3.8 as Figure 3-1.

The AMS approach for this analysis package follows the approach presented in Section 3.8. The analysis approach for this package (Normal Operations—No Incident) is detailed in the following sections. This approach includes the following four components:

- Monitor the system.
- Assess system performance.
- Evaluate dynamic actions.
- Capture the impact of the dynamic action for the next moving window.

Monitoring the System

Monitoring the transportation system in real time for the NCNJ region is the first step in the ATDM AMS cycle. The system monitoring phase begins an hour before the analysis period (5:00 to 8:00 PM)—that is, at 4:00 PM for this analysis package. During this period, the system in the vicinity of the Back Yard is monitored for mobility delays and reduced speeds. This monitoring phase captures how game-day traffic affects system performance and which parts of the system are affected. The objective of this analysis package is to ensure that the system performs as expected and is not affected largely by game-day traffic, especially because it coincides with the evening peak period. An overview of the system monitoring task has been described in detail in Section 3.8, and this analysis package's system monitoring task follow that process. This step includes two subprocesses: data processing and simulation.

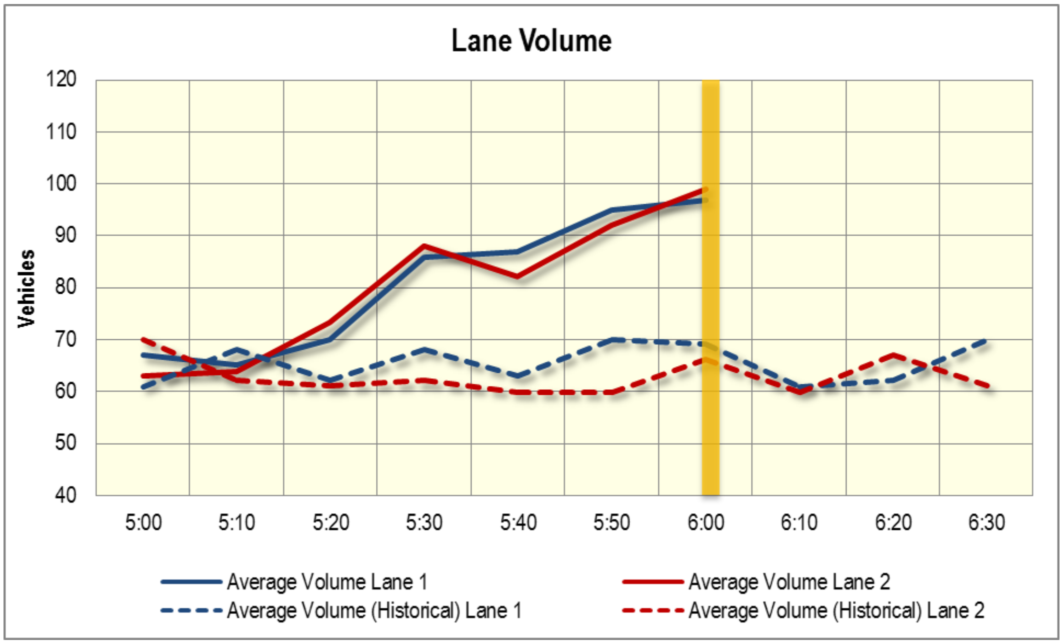
These two subprocesses are described in the following sections, which present an overview of how the system is monitored and the interactions between the Data Generator and the Network Simulator.

Data Processing

It is assumed that traffic counting devices collect the information necessary to be able to monitor the area around the stadium. These devices will collect traffic volume information during the time period when commuters are returning to work and fans are traveling towards the stadium and transmit this information to the Data Generator in real-time. The Data Generator analyzes this information and identifies the locations that are experiencing un-expected levels of congestion.

Figure 6-2 presents a comparison of real-time and historical average speeds and volumes on the Pittbulls Blvd., a major thoroughfare that provides access to the baseball stadium. The orange bar on the chart indicates the current time. The chart clearly shows that traffic volume on this roadway is much higher than historical game-day averages indicating the need for dynamic actions to mitigate congestion.

Figure 6-2: Traffic Volumes Before the Baseball Game Begins



Network Simulator

This analysis package's data-simulation task follows the process described in Section 3.8. After the Data Generator confirms that the traffic patterns around the vicinity of the stadium do not match normal day traffic patterns, it uses real-time traffic volume data to update the normal day demand. The Network Simulator uses this updated demand from this time point onwards to simulate traffic for monitoring the system. In addition, the Data Generator creates and provides the following data sets to the Network Simulator:

- Parking cost information for each area within the NCNJ region
- Additional parking availability information
- Ride-sharing information as part of the updated demand
- Additional event day-specific transit route, schedule, and fare information
- Updated traffic signal cycle information.

This simulation will reveal how Back Yard and areas in the vicinity of Back Yard in simulated real-time.

Performance Measures

For this particular analysis package, person throughput and travel time reliability are selected as the two regional performance measures of interest to the agency. Brief definition of these performance measures is presented below.

Person throughput

Person throughput will be measured for this analysis package as the number of persons crossing a screen line or an imaginary line drawn intersecting either North-South or East-West roadways. Figure 6-1 presents the region with four screen-lines. The number of persons crossing each screen-line during the current time window (e.g., 5:00 to 5:30 PM) represents a movement of persons from population centers to an employment centers. This throughput is computed as an aggregate measure of the number of persons crossing the screen-lines during the time period of interest. The throughput for the current time window (e.g., 5:00 to 5:30 PM) is compared to historical averages during baseball game traffic and the goals set by the local agency for the same time window. If this comparison informs the ATDM AMS system that the system will perform as expected, then dynamic actions are not warranted.

Mobility Delays

For this analysis package, mobility delays will be defined as the additional travel time experienced by a traveler due to the baseball game traffic for the current time period (e.g.,4:30 to 5:00 PM). Travel times for roadway segments will be compared to historical averages for the mobility delays during baseball game traffic and goals set by the local agency in order to compute mobility delays. If this comparison informs the ATDM AMS system that the system will perform as expected, then dynamic actions are not warranted.

Assessing System Performance

The system assessment phase begins during the analysis period (3:00 to 10:00 PM). During this period, a forecast or a prediction of the system during game day traffic is performed. This assessment phase predicts how game day traffic affects system performance, and which parts of the system are affected. This analysis package's performance assessment task follows the process described in Section 3.8. For this analysis package, system performance assessment involves:

- Predicting traveler movements for the next time period, and
- Assessing system performance measures for the next time period.

In order to predict traveler movements for the next time period, the Data Generator needs to generate the inputs required by the Network Simulator. As detailed in Section 3.8, the Data Generator provides the Network Simulator data pertaining to ridesharing, and transit service. Once the Data Generator updates information based on the levels of congestion in and around Back yard and also the overall NCNJ region, the Network Simulator generates traveler movements in the region. The outputs from this simulation are used to generate performance measures as detailed in the previous section. Once the performance measures are computed, they are compared to ATDM objectives in order to check if the objectives are met. If the objectives are not met, the dynamic actions selected for this analysis package are implemented.

Performance Measures

For this particular analysis package, person throughput and travel time reliability are selected as the two regional performance measures of interest to the agency. Brief definition of these performance measures is presented below. The performance measures computed during the assessment phase without any strategies implemented will be the baseline performance measures for this analysis package.

Person throughput

Person throughput will be measured for this analysis package as the number of persons crossing a screen line or an imaginary line drawn intersecting either North-South or East-West roadways. Figure 6-1 presents the region with four screen-lines. The number of persons crossing each screen-line during the next time window (e.g., 5:00 to 5:30 PM) represents a movement of persons from population centers to an employment centers. This throughput is computed as an aggregate measure of the number of persons crossing the screen-lines during the time period of interest. The throughput for the next time window (e.g., 5:00 to 5:30 PM) is compared to historical averages during baseball game traffic and the goals set by the local agency for the same time step. If this comparison indicates that the predicted performance meets the agency goals, then dynamic actions are not warranted.

Mobility Delays

For this analysis package, mobility delays will be defined as the additional travel time experienced by a traveler due to the baseball game traffic for the next time window (e.g., 5:00 to 5:30 PM). Travel times for roadway segments will be compared to historical averages for the mobility delays during baseball game traffic and goals set by the local agency in order to compute mobility delays. If this comparison indicates that the predicted performance meets the agency goals, then dynamic actions are not warranted.

Evaluating the Impact of ATDM Strategies

The system assessment phase begins during the analysis period (5:00 to 8:00 PM)—that is, at 5:00 PM for this analysis package. During this period, a forecast or prediction of the system during game-day traffic is performed. This assessment phase predicts how game-day traffic affects system performance and which parts of the system are affected. The system performance evaluation task has been described in detail in Section 3.8, and this analysis package's performance evaluation task follows that process. For this analysis package, the forecasted person throughput and travel time reliability measures are compared to the goals set by the local agency and to the performance measures generated during the system assessment phase (baseline). The goal of this analysis package is to ensure that person throughput across the screen lines shown in Figure 6-1 meets the goals set by the local agency and to ensure that the travel time reliability buffer meets the goals set by the local agency. If the forecasted performance measures do not meet the objectives, ATDM strategies will be reevaluated and the impact of implementing the selected strategies tested. Note that in real-world ATDM implementation, a DSS or automated process will select the best set of strategies to be implemented. For this analysis, the set of strategies to be tested has been preselected for illustrative purposes. As presented and discussed in Section 6.3, the strategies chosen for this analysis scenario include—

- Dynamic ride-sharing
- Dynamic transit service
- ATSC
- Dynamically priced parking
- Dynamic wayfinding.

The following section presents a discussion on how each strategy would be implemented and tested for its effectiveness for the baseball game during the PM peak scenario.

Dynamic Ride-Sharing

Dynamic ride-sharing is the practice of offering a formal or informal service whereby travelers arrange one-time shared rides on short notice by using advanced technologies such as smart phones and social networks. It facilitates real-time and dynamic carpooling to reduce the number of auto trips/vehicles trying to use the major facilities. In this scenario, the Back Yard Entertainment Complex near Octagon City will be hosting a planned sporting event in the PM peak period. This means a higher-than-an-average travel demand on I-6, I-3, and I-403 along with the supporting arterials during the evening peak hours. In particular, the I-3 corridor faces extensive reverse-congestions during evening peak hours because of the additional travel demand toward the Back Yard Entertainment Complex on game days. Hence, the goal of dynamic ride-sharing will be to reduce the travel demand for the event.

Current methodologies are limited in modeling the dynamic ride-sharing concept. The dynamic ride-sharing strategy has been modeled as a “carpool” mode in the traffic stream. However, the algorithms for matching a “ride-seeker” to a “ride-giver” and all the involved dynamics are too complicated to be captured in a model. In this scenario, the modeler should treat the strategy as an increased carpool mode scenario rather than a dynamic ride-sharing scenario.

The macro-level travel demand model in the ATDM AMS framework must extrapolate the regular weekday evening peak demand, including travel demand to go to the Back Yard Entertainment Complex. The dynamic ride-sharing strategy must be implemented as mode choice option “carpool.” The algorithms for dynamic matching of ride-sharing demand and supply have not been satisfactorily modeled in the current research work. Hence, the modeler must improvise on segregating the traveler population across different modes of commuting, including ride-sharing. The updated trip tables for the evening peak hour should then be fed into the mesoscopic simulation model to generate predicted traffic conditions. . In order to calibrate the dynamic ride-sharing models, either reveled preference survey data or stated preference survey data will be used. These preference surveys are to be constructed so that they can answer the following questions:

- Will travelers change their behavior or choice (route, mode) based on the availability of dynamic ride-sharing?
    - What percentage of travelers will modify their choice?
- Will travelers choose to modify their trip en-route in order to dynamically ride-share?
    - What percentage of travelers will modify their route mid-trip?
- What is the impact of HOV facilities (routes/lanes) and the ability to choose one using dynamic ride-sharing?
    - What percentage of travelers will choose dynamic ride-sharing in order to be able to use HOV facilities?

On-Demand Transit

On-Demand Transit is a service that allows users to request a specific transit trip based on their individual trip origin and destination and their desired departure or arrival time. It requires transit services with flexible routes and schedules that would enable travelers to make real-time trip requests through personal mobile devices. The intent is to encourage more travelers to use transit. Because the NCNJ region has an extensive public transit network, there is wide scope for use of this strategy.

The metro rail and the commuter rail provide additional parallel mode options for travelers taking I-106 and I-6, respectively, to get to the Back Yard Entertainment Complex. The commuter rail network in the NCNJ region is supported by an extensive bus network along the General Sherman Highway. Also, the Gridlock Highway connecting areas from Prince Harry County to Octagon City carries numerous bus services. These transit networks can be used to dynamically augment the supply side of the transportation system during game days. In order to implement this strategy, the Data Generator creates an multimodal network with dynamic transit service based on the system assessment phase. The network simulator uses this network to simulate traffic, and also to generate demand using the feedback process.

To evaluate the impact of this strategy, the travel demand component in the multiresolution framework should include a population of travelers “demanding” dynamic transit service. The mode choice models should incorporate dynamic transit service as a separate mode of transportation. The utility of the dynamic transit service mode would heavily depend on the availability of the transit service to the traveler at the desired location at the desired time. In the simulated world, the supply side of the transportation network must keep track of the dynamic scheduling and dynamic routing of the transit service. The availability of the transit service to the traveler demanding the transit service can be calculated as the expected waiting time and the subsequent travel time on the transit mode. Since the analysis tools used are already calibrated and validated for transit service in the region, additional calibration or validation is not required.

Adaptive Traffic Signal Control

To evaluate this strategy, the model should replicate the physical locations and functionalities of the roadway sensors and the traffic signals in the arterials and streets leading to the Back Yard Entertainment Complex near Octagon City. The traffic brought in by I-6, I-3, Elvis Highway, and Gridlock Highway will be dispersed along the supporting arterials and streets leading to the Back Yard. A significant spike in conflicting flows along these streets would be expected during a relatively short time period. ATSC implementation can be used to optimally direct the incoming traffic to the Back Yard Entertainment Complex. The ATSC algorithms should be incorporated in the supply control component of the microscopic simulator platform. As described in Section 6.8, the timing plans for the traffic signals along, Elvis Highway, and Gridlock Highway, will be updated by the Data Generator and this information will be provided to the Network Simulator to perform a simulation with the updated network information. For the macroscopic model, the percentage green time attribute for each approach is updated. This information is used to compute capacity which is in turn used to compute congested travel speeds during the traffic assignment process. The microscopic model uses the updated signal plans to perform a microsimulation. Since the analysis tools used are already calibrated and validated, additional calibration or validation is not required.

The goal of this strategy in this scenario would be to streamline conflicting traffic flows going to the game and coming back from the game to make optimal use of the limited roadway capacity in managing the higher-than-usual travel demand. Hence, the ATSC algorithms should be tested for their optimal use in this scenario in simulation settings. The activity-based travel demand model should be used to generate the travel demand and the mode-split for the PM peak period. This travel demand will then be fed into the mesoscopic simulation model for the NCNJ region, generating time-dependent traffic flows across the region. The ATSC would be implemented along the arterials and streets in the vicinity of and leading to the Octagon City area. The microscopic simulation model with the ATSC algorithm should be used to analyze the traffic flows in this subregion to accurately capture the impact of ATSC in managing conflicting traffic flows. The results of the microscopic simulation runs can be fed back to other models for region-wide evaluation of the strategy. Since the analysis tools used are already calibrated and validated for traffic volumes and speeds along corridors with traffic signal controls, additional calibration or validation is not required.

Dynamically Priced Parking

Dynamically priced parking is a strategy which dynamically varies parking fees based on demand, and availability in order 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 the context of this scenario, a dynamically priced parking strategy will be used to alter the time-of-day choice, mode choice, and to some extent the destination choice of the traveler. The capacity of parking places in the central business district and parts of Old Town is stretched to its limits during weekday night games. Thus, the dynamic pricing design of the parking places would be used to deter demand for individual trips using private automobiles. Also, the strategy may alter destination choice by forcing the traveler to choose other parking facility options.

In order to implement this strategy, the Data Generator creates an multimodal network with dynamic parking costs based on the system assessment phase. The network simulator uses this network to simulate traffic, and also to generate demand using the feedback process The utility based time-of-day choice models shall consider the dynamic pricing design to differentiate between the utilities of different departure times. The mode choice model should reflect dynamic pricing as a driving factor in the utility of automobiles as a transportation mode. Since the existing mode choice models include parking costs as a destination variable that is used to compute utility and these models are already calibrated and validated for traffic speeds in the network, additional calibration or validation is not required.

Dynamic Wayfinding

A dynamic parking information strategy is used to provide parking availability information to travelers en route, reducing the time motorists take to search for parking spaces. It is particularly important in this scenario because of a severe lack of parking spaces in the central business district and parts of Old Town. In order to effectively simulate traveler response to parking availability information and possible way finding, it is essential to understand traveler behavior using either revealed preference or stated preference surveys. These surveys will be constructed to answer the following questions:

- What percentage of travelers will use and following the directives from parking availability information?
- How far will travelers park from their final destination?
    - How does the distance to final destination co-relate with a traveler's choice to follow the directives presented using dynamic wayfinding?

Performance Measures

For this particular analysis package, person throughput and travel time reliability are selected as the two regional performance measures of interest to the agency. Brief definitions of these performance measures follow. The performance measures computed during the evaluation phase with strategies implemented will be compared to the baseline performance measures computed during the assessment phase.

Vehicle and Person Throughput

Person throughput will be measured for this analysis package as the number of people crossing a screen line or an imaginary line drawn intersecting either north–south or east–west roadways. Figure 6-1 presents the region with four screen lines. The number of people crossing each screen line during the next time period (e.g., 5:00 to 5:30 PM) represents a movement of people from population centers to employment centers. This throughput is computed as an aggregate measure of the number of people crossing the screen lines during the time period of interest. The throughput for the next time period (e.g., 5:00 to 5:30 PM) is compared to both the goal the agency set and the throughput generated during the assessment phase.

Mobility Delays

For this analysis package, *mobility delay* is defined as the additional travel time a traveler experiences because of baseball game traffic for the next time window (e.g., 5:00 to 5:30 PM). Travel times for roadway segments will be compared to historical averages for the mobility delays during baseball game traffic, mobility delays generated during the assessment phase, and goals the local agency sets.

6.9 Model Calibration

Section 3.9 details how the models for the analysis packages will be calibrated and presents the data requirements for model calibration.

6.10 Modeling Requirements

The modeling requirements for this scenario are mapped against the AMS needs identified in the CONOPS Report. They are presented in the following sections.

Monitoring the System

The overall requirements for monitoring the system have been presented in Section 3.9. No additional modeling requirements are necessary for this analysis package, PM Peak Baseball Game.

Assessing System Performance

The overall modeling requirements for assessing system performance have been presented in Section 3.9. No additional modeling requirements are necessary for this analysis package, the Normal Operation—No Incident package.

Evaluating the Impact of ATDM Strategies

The overall modeling requirements for evaluating the impact of ATDM strategies is presented in Section 3.9. The following sections present the modeling requirements for evaluating each strategy chosen for this analysis package.

Dynamic ridesharing

The following presents the modeling requirements to evaluate the impact of dynamic ridesharing:

- The mode choice models in the Network Simulator component shall include dynamic ridesharing as a carpool mode option.
- The algorithms for matching the ride-request demand to the ride-offering supply within the geographically and temporally practical context shall be used in the mode choice model to generate the mode splits of traveler population.
- Shall be able use activity-based travel demand models which can be used to segregate the traveler population into travelers “attending the baseball game after work” and “not attending the baseball game-travelling back home” categories.
- Shall be able to incorporate geographical proximity of work places, residential locations into the activity-based models which can then assign travelers to carpooling mode.

- Shall be able to include the benefits of HOV lane use during peak hours in determining travelers' tendency to choose ridesharing.

Dynamic transit service

The following presents the modeling requirements to evaluate the impact of dynamic transit service:

- The dynamic scheduling algorithms for the regional transit operations shall incorporated in the supply determination
- Shall be able to represent the flexible transit schedules, routes and OD pairings as driven by the travel demand for dynamic transit service
- Shall be able to dynamically simulate the request of individual travelers for transit service
- Shall be able to model travelers' time-of-day choice based on availability of dynamic transit service
- Shall be able to capture dynamic multimodal travel options and choices

Adaptive traffic signal control

The following presents the modeling requirements to evaluate the impact of adaptive traffic signal control:

- The supply component of the Network Simulator component of the AMS framework shall incorporate the ATSC algorithms to be implemented in the analysis
- The ATSC algorithms in the Network Simulator component of the AMS framework shall include the anticipated traveler response to changes in signal timings, in designing the traffic signal cycles.
- Shall be able to support flexibility to implement various adaptive traffic control algorithms
- Shall be able to support development of API to directly read link counts and optimize based on the observed volume

Dynamically priced parking

The following presents the modeling requirements to evaluate the impact of dynamically priced parking:

- The time-of-day choice, mode choice and route choice models shall be linked to the dynamic price structure of the parking facilities to capture the changes in traveler behavior
- Shall be able to incorporate the dynamic pricing structure of the parking facilities in the time-of-day choice and mode choice of the traveler behavior.

Dynamic Wayfinding

The following presents the modeling requirements to evaluate the impact of dynamic wayfinding:

- The AMS framework shall maintain an updated inventory of available parking spaces.
- The information channel to disseminate dynamic parking information to travelers using mobile devices or DMS shall be considered.
- The route choice models for motorists shall include the parking space availability as one of the key driving factors towards the end of the trip.

- Shall be able to model the inventory of available parking Shall be able to include the parking information in the time-of-day choice and mode choice models.

Chapter 7: Analysis Plan Elements Specific to Package 4

Analysis Package Name: Major Weather Event—Blizzard During the AM Peak

7.1 Analysis Plan Scope

Section 3.1 presents the scope of the Analysis Plan for all the analysis packages. The Analysis Plan for this package—Blizzard—is designed to address the following additional questions:

What AMS steps are required to—

- Monitor the system during inclement weather conditions?
- Evaluate the impact of ATDM strategies during inclement weather conditions in real time?

7.2 Region and Existing Operational Conditions

Chapter 3 of this document presents an overview of hypothetical region and details the various transportation demand and supply elements for the region.

7.3 Analysis Scenario and ATDM Strategies To Be Analyzed

This analysis package represents a typical weekday morning with a forecast of heavy snowfall accompanied with strong winds. Given the history of receiving heavy snow, 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 goals of the operating agency include the following:

- Alert the traveling public of the impending blizzard and its effect on the transportation system
- 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.

The key objectives of the operating agency are to—

- Ensure that mobility delays are below the threshold set by the local agency
- Improve travel time reliability by reducing travel time variance to less than 50 percent of the average travel time
- Ensure that the crash rates are below the threshold set by the local agency.

The scenario begins at 5:00 AM with all roads are open. The weather forecast predicts a significant drop in temperatures and snowfall accompanied with strong winds starting at approximately 8:00 AM. The snowfall is expected to continue until the early afternoon and about five feet of snow is expected. Due to the dropping temperatures, the conditions will deteriorate as the frozen snow will be covered by new accumulation. The overarching goal is to influence travel demand and supply for all portions of the trip chain. 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 NCNJ region. 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. It is expected that the entire NCNJ region will experience unsafe travel conditions, and travel in icy conditions will slow down traffic significantly. It is not expected that ATDM AMS strategies will alleviate conditions to a normal day's levels; however, ATDM AMS strategies are expected to alleviate conditions from stand-still traffic to smooth—though slow—traffic flow.

ATDM Strategies

To overcome the predicted stresses on the transportation system, the operator would require active traffic management strategies, such as the ATDM strategies identified in the AMS CONOPS Report. In this analysis package, the following ATDM strategies are expected to be useful for traffic management:

- Predictive Traveler Information
- Dynamic shoulder lanes
- Dynamic speed limits
- Adaptive traffic signal control.

The following sections present a discussion of the aforementioned strategies.

Predictive Traveler Information

Provides traveler information services specific to a multimodal corridor or region, including personalized services such as comparative travel time information amongst different travel modes, provision of parking information, and direct links to rideshare providers in order to assemble specific trips using one or more modes and connection points as needed. Advanced journey planning capabilities may compare driving, using transit, and carpooling/ridesharing based on available ridematch options.

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 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.

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.

Impact of Strategies on Trip Chain

An implementation of ATDM strategies is likely to impact the traveler's decisionmaking process. This decisionmaking process occurs at different times during the traveler's trip chain. Table 7-1 shows the parts of the trip chains affected by the ATDM strategies in this scenario.

Table 7-1: Influence of ATDM Strategies on Elements of Trip Chain

		Trip Chain Affected				
No	**ATDM Strategy**	**Destination Choice**	**Mode Choice**	**Time-of-Day Choice**	**Route Choice**	**Lane/Facility Choice**
1	Predictive Traveler Information	◑	●	●	●	◔
2	Dynamic Shoulder Lanes				◑	●
3	Dynamic Speed Limits				◔	●
4	Adaptive Traffic Signal Control				◔	

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.

The following sections detail how the strategies chosen for this analysis package potentially affect the components of the trip chain.

Destination Choice

As a result of predictive traveler information systems strategy, a few travelers could delay the start of their trip in the morning because they have flexible schedules. They might decide to work from home once they see the weather deteriorating, affecting their trip-making pattern and destination choice for discretionary trips.

Time-of-Day Choice

As a result of predictive traveler information systems strategy, time-of-day choice is also likely to be affected. Due to the warnings during the days before the storm, a portion of the travelers have accommodated additional time to reach their destination on time. They have or plan to leave earlier than they usually do on a typical weekday. Others decide to let the blizzard pass through, judge the situation, and then make a decision about travel. While some of these travelers make a trip later in the day, others may choose to not make the trip if roadway conditions are unsafe.

Mode Choice

As a result of predictive traveler information systems strategy, some morning commuters change their mode in the morning. Instead of facing the increasing snow in their cars, they choose to use the rail—especially underground rail—to commute to work.

Route Choice

During the morning peak hours, travelers who follow the real-time information news change their routes accordingly based on information pertaining to predicted roadway traffic conditions. If travelers are provided information regarding which roadways have been treated with salt, or which roadways are unsafe due to ice and snow deposits, they will change their routes accordingly. In addition, dynamic shoulder lanes will make the facility more attractive due to additional capacity. Dynamic speed limits and adaptive traffic signal control is likely to have minor impact on the route choice.

Lane/Facility Choice

Implementation of HSR and dynamic speed limits will result in lane/facility choice change. predictive traveler information is also likely to have some impact on the lane/facility choice due to information on predicted traffic conditions.

7.4 Data Needs

Section 0 presents the preliminary data needs for the analysis packages. In addition to these needs, this package—the blizzard—needs weather information such as intensity of snow, road-weather conditions, and visibility. The weather information will be used by the Data Generator to filter relevant data for this analysis package.

The transportation network is managed based on modeling of historical data (snow days) 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 weather, alerts are automatically generated and disseminated to appropriate incident responders.

7.5 Performance Measures

Well-defined performance measures are required to keep a pulse check of the system performance. The following have been selected as illustrative examples of performance measures for this analysis package.

Mobility Delays

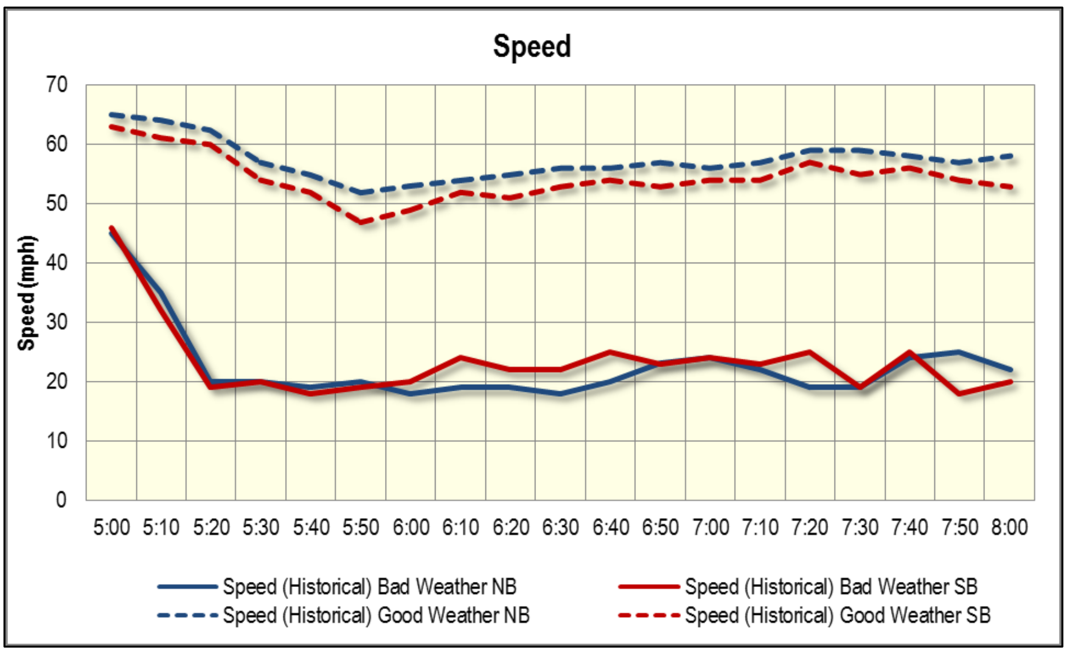
Mobility delay can be measured as the additional travel time experienced by a driver or passenger due to circumstances that impede the desirable movement of traffic. It is measured as the time difference between actual travel time and ideal or free-flow travel time.

For this analysis package, mobility delays will be defined as the additional travel time experienced by a traveler due to the deterioration in driving conditions during the blizzard. However, the severe weather conditions drastically alter the dynamic settings of the entire transportation system. Therefore, historical average of regular-day traffic patterns cannot be used as the baseline to determine the travel delays. The mobility delay in this scenario shall be computed as—

$$Mobility\ delay = (Current\ travel\ time\ during\ severe\ weather) - (Historical\ travel\ time\ during\ severe\ )$$

Figure 7-1 presents a comparison of travel speeds during good and bad weather. This chart clearly indicates that mobility delays are to be expected during inclement weather even though the total number of travelers on the transportation system is lower. The objective of this analysis package is not to reduce mobility delays to normal-day levels but to alleviate conditions so that travelers experience less mobility delays. In other words, the goal would be increase average speeds from 20 mph to around 30–40 mph but not to the normal-day level of 50–60 mph.

Figure 7-1: Comparison of Travel Speeds in Good and Bad Weather



Travel Time Reliability

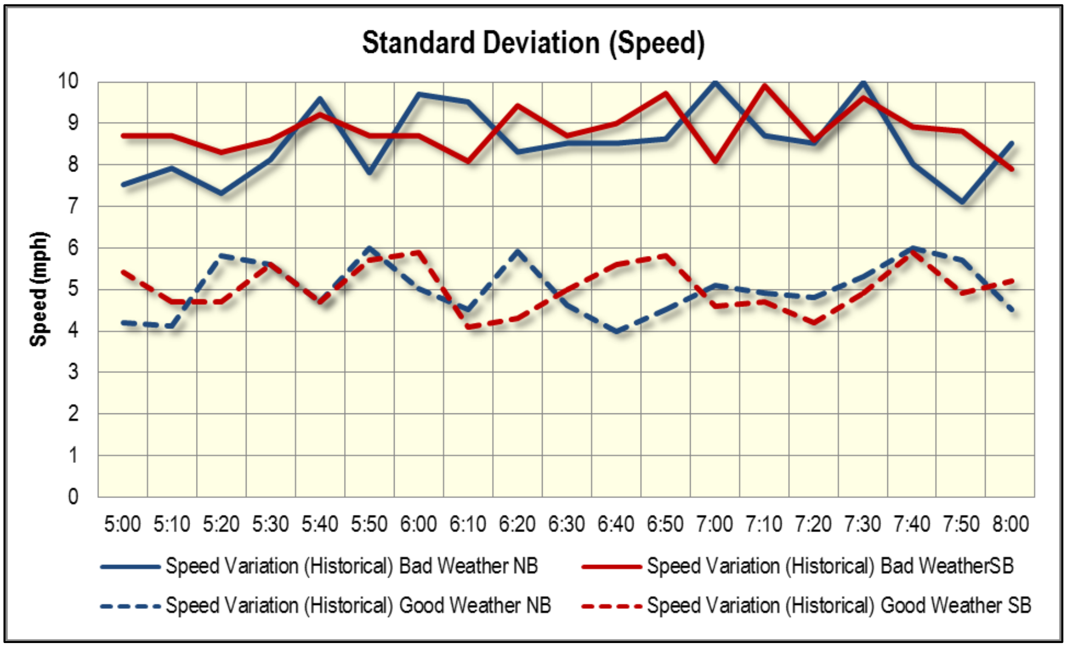
Travel time reliability is a derived parameter that is very significant from the traveler's point of view. It is sometimes represented as the variance of travel time to complete a trip. Statistical terms that are more evolved and represent the spread or consistency of travel times can be calculated to indicate travel time reliability. Higher travel time reliability reflects higher level of service and user trust in the transportation system.

Travel time reliability is the consistency of travel time variation when compared to average travel time during a given time step. This is typically measured as a statistical index such as standard deviation. A high standard deviation indicates that travel time is less reliable. In addition, reliability could also be measured as 95th percentile travel time or buffer index.

$$Travel\ time\ reliability\ (or\ 95th\ percentile\ Buffer\ Index) = 100 \times \frac{(95^{th}\ percentile\ travel\ time) - (Average\ travel\ time)}{(Average\ travel\ time)}$$

Figure 7-2 presents a presents a comparison of variation in speeds during good and bad weather. These charts clearly indicate that not only are the speeds lower during inclement weather but also the variation in speeds is much higher. This indicates that travelers will not only be able to reach their destination as quickly as on a day with good weather but also their travel time will not be as reliable as a normal day. Note that it is not only imperative that mobility delays be reduced but it is also important to ensure that travel is more reliable.

Figure 7-2: Comparison of Travel Speed Variation in Good and Bad Weather



The buffer index measure is easy to relate by travelers; hence, this index will be used by this analysis package to measure travel time reliability. Buffer index will be computed for the NCNJ region before and after ATDM implementation for the following corridors:

- I-6 (HOV) between Old Reston and New Camden
- General Sherman highway (SOV) between Old Reston and New Camden
- I-106 and I-6 between Little Reston and New Camden
- I-3 between Quasar and New Camden
- I-403 between Edge City and Gridlock Heights
- I-403 between Gridlock Heights and Edge City.

To compare travel time reliability before and after the implementation of the ATDM strategies, it is essential to simulate and replicate observed travel time reliability during inclement weather conditions. For example, it is observed that the 95th percentile buffer index for travel between Old Reston and New Camden is very high at 70 percent and the average travel time is 70 minutes. The base or existing conditions (blizzard without any strategies) simulation is calibrated to the average day (i.e., the travel time between Old Reston and New Camden is 70 minutes). It is, however, necessary for the simulation to be able to replicate travel time reliability (i.e., a 95th percentile buffer index of 70 percent for the conditions). This requires running the simulation multiple times with a slight variation in demand and examining how resilient the transportation system is to this variation. Although the amount of demand in the AM peak period will not be changed, the start time for travelers in the system will be randomly changed by at most 20 minutes. This process creates non-uniform demand over time and replicates the real world where travelers start times vary over the course of any given time frame such as a week or a month. The amount by which travelers vary their start time will be changed to calibrate the simulation to replicate the observed 95 percentile buffer index. Once the travel time reliability index is replicated for the base conditions simulation, the same random variations to start times are applied to the scenario with the ATDM strategies, and travel time reliability is computed. The goal of the ATDM strategies is to ensure that 95 percentile buffer index is less than 50 percent for travel along the aforementioned corridors. If this goal is not met, ATDM strategies will be adjusted or modified and the simulations will be rerun. The goals for this performance measure will be set by the local agency for each time step of analysis.

Safety

Safety on roadways can be easily quantified by crash rates classified by type of crashes. However, it is not feasible to simulate these crashes in a virtual world. To quantify safety in the virtual or simulation world, it is important to understand the causes for accidents. Factors that lead to unsafe roadways during inclement weather conditions include—

- Visibility
- Poor maintenance:
    - Failure to salt and sand
    - Potholes
    - Construction zones
    - Faded or covered signs
    - Debris.

Most of the aforementioned factors are qualitative in nature and it is not possible to quantify the benefits of implementing ATDM strategies. However, some of the factors are quantitative in nature and can be used as a proxy to measure safe or unsafe traffic conditions. These factors include—

- Number of vehicle-to-vehicle conflicts
- Number of lane changes
- Excessive speed
- Low stopping distance.

The implementation of dynamic actions or strategies requires safety to be measureable in order to gauge the effectiveness of a strategy. For this analysis package, vehicle-to-vehicle conflicts (such as left turn yield) will be used as a proxy to measure safety. The hypothesis behind using conflicts as a measure is that a lower number of vehicle-to-vehicle conflicts implies a lower number of possible crashes or collisions. The aforementioned changes in driver behavior will be implemented in the simulation, which in turn affects the number of conflicts. Section 7.6 presents additional detail on how conflicts are computed from the simulation output.

It is observed that the probability of a crash increases during inclement weather due to—

- Poor visibility
- Debris
- Slippery conditions.

The above parameters should be considered in the analysis. The objective of the safety goal for this analysis package is to reduce the number of crashes during a blizzard.

7.6 Tools Needed for Analysis

Section 3.6 presents the tool needs for the analysis packages. This package—the blizzard—requires additional tools to compute a measure for safety. This tool should be able to compute the number of vehicle-to-vehicle conflicts using simulation output. The number of conflicts, as detailed earlier, will be used as a proxy to measure safety. In addition, the AMS tools used for this analysis package will use weather information to modify traveler and driving behavior. This includes changes to total demand and how the travelers who choose to travel respond to the blizzard while driving. Table 7-2 provides illustrative examples of tools.

Table 7-2: Illustrative Examples of Analysis Modeling and Simulation Tools

Model/Model Category	Description of Models, With Examples
Travel Demand and Behavior Models	
Activity-based models	These models consider interaction among 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.
Traffic Operations Models and Tools	
Mesoscopic models	These models are typically used to model regional networks. Most mesoscopic analysis tools include DTA procedures that replace the traffic assignment procedures in the traditional four-step travel demand models to achieve higher accuracy in speed estimates. Examples include DYNASMART and DYNAMIT.
Safety Tools	
SSAM	Surrogate Safety Assessment Model (SSAM) is a FHWA tool to analyze vehicle-to-vehicle interactions to identify conflict events and calculate several surrogate safety measures of interest

7.7 Analysis Settings

Table 7-3 describes the analysis settings and assumptions. The time steps, time periods, and time windows are presented for illustrative purposes only. The local agency would chose these settings as it deems appropriate for the analysis it is conducting.

Table 7-3: Analysis Settings for Analysis Package 4

Analysis Setting	Description
Simulation Time Period	00:00 AM to 11:59 PM

Analysis Setting	Description
Time Period of Analysis	5:00 AM to 8:00 AM is the primary analysis time period
Forecast Period	For this analysis, a 30 minute forecast of future conditions in 5 minute increments will be made once every 10 minutes
Data	It is assumed that traffic count data is continuously fed from the freeway and arterial management systems to the analyst. Transit ridership and real-time schedule data is also available. Data is also available continuously from Road-weather monitoring systems.

7.8 AMS Approach

This analysis scenario represents a typical weekday's transportation activities and operations in the NCNJ region along with certain predictable recurring stresses to the transportation system. The approach to investigate this scenario from the ATDM perspective involves creating a model to analyze the demand and the supply during the morning peak hour on an average weekday, along with a predictive component to track traffic conditions in the forecasted future. The analysis framework has been presented in Section 3.8 as Figure 3-1.

The AMS approach for this analysis package follows the approach presented in Section 3.8. The analysis approach for this package (normal operations, no incident) is detailed in the following sections. This approach includes the following four components:

- Monitor system
- Assess system performance
- Evaluate dynamic actions
- Capture the impact dynamic action for next moving window.

Monitoring the System

Monitoring the transportation system in real time for the NCNJ region is the first step in the ATDM AMS cycle. The system monitoring phase begins an hour before the analysis period (5:00 AM to 8:00 AM), that is, at 4:00 AM for this analysis package. During this period, the system is monitored for mobility delays, and reduced speeds in the NCNJ region. This monitoring phase captures how the blizzard affects system performance, and which parts of the system are affected. It also captures how travel demand changes due the blizzard. The objective of this analysis package is to ensure that the system performs as expected and is not incapacitated due to the blizzard. This analysis package's system monitoring task follow the process described in Section 3.8. This step includes two subprocesses: data processing and simulation.

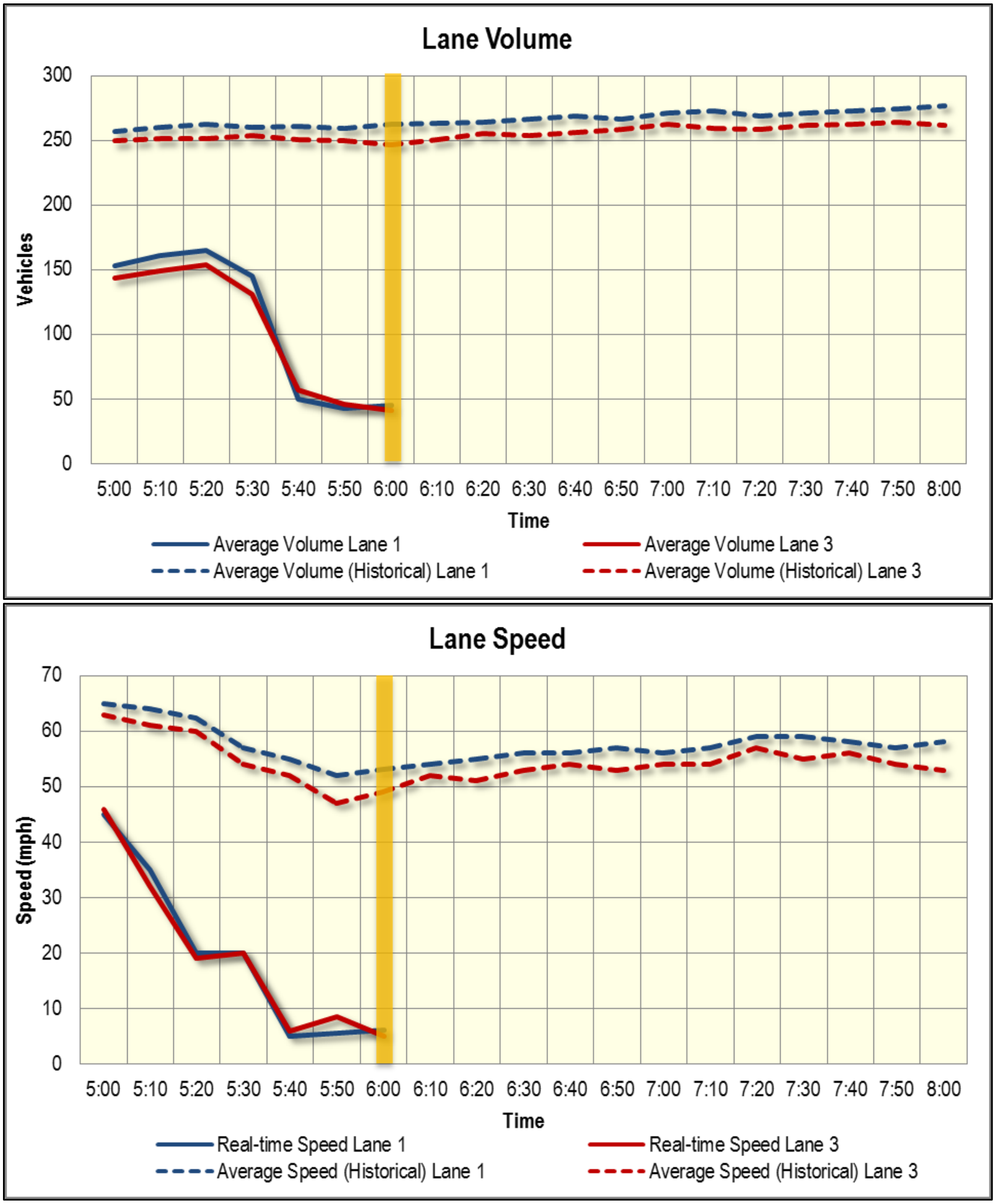
These two subprocesses are described in the following sections, which present an overview of how the system is monitored as well as the interactions between the Data Generator and the Network Simulator.

Data Processing

The ATDM AMS framework will use data that is already available from various sources or traffic-counting devices. These devices collect traffic volume information for roadway segments in the entire region, and are located not only on freeways and major arterials but also on minor arterials and collectors. These devices transmit traffic volume information to the Data Generator in real time, and the Data Generator analyzes this information and generates a report that presents locations that are experiencing unexpected levels of congestion.

Figure 7-3 presents a comparison of real-time and historical (similar snow-day) average volumes and speeds on I-3. The orange bar indicates the current time. The figure clearly shows that traffic volume on this roadway is much lower than historical averages and that the traffic speeds on this roadway are much lower than historical averages. It clearly indicates that traffic has come to a stand-still and that dynamic actions might be necessary to mitigate conditions and to ensure safety. For example, under inclement weather conditions, information propagation systems, including public media such as websites, the radio, and television channels should advise against travel unless it is absolutely necessary. In addition, other dynamic actions such as dynamically reduced speed limits assist in ensuring safety. Strategies such as dynamic shoulder lanes help provide additional capacity; however, shoulders on most roadways are relatively less safe when compared to the travel lanes. The ATDM AMS system needs to analyze available data in order to develop individual strategies for each roadway or type of roadway. The strategies to be implemented are envisioned to be dealt with on a case-by-case basis.

Figure 7-3: Traffic Volumes During the Blizzard



Network Simulator

The simulation task has been described in detail in Section 3.8. This analysis package's data simulation task follows the process described in Section 3.8.

Performance Measures

For this particular analysis package, person throughput and travel time reliability are selected as the two regional performance measures of interest to the agency. These performance measures are described below.

Mobility Delays

For this analysis package, mobility delays will be defined as the additional travel time experienced by a traveler due to the blizzard for the next time window (e.g., 7:30 AM to 8:00 AM). Travel times for roadway segments will be compared to historical averages for the mobility delays due to blizzards and goals set by the local agency in order to compute mobility delays. If this comparison informs the ATDM AMS system that the system is performing as expected, dynamic actions are not warranted.

Trip Travel Time Reliability

Travel time reliability will be measured for this analysis package as the buffer index for travel between a set of origin-destinations. To compute travel time reliability, average or mean travel time between two locations in the region is to be computed. In addition, the variation of travel times around the mean is to be computed. These statistics will be computed as an aggregate zone-to-zone travel skims. Travel times for all travelers traveling between two zones (e.g., Old Reston to New Camden) during the current system monitoring time step (e.g., 7:30 AM to 8:00 AM) will be extracted from the simulation output. These travel times will be used to compute both the average travel time and the 95th percentile travel time. Once these two statistics are computed, travel time reliability will be computed as described in Section 7.5. This travel time reliability for the current system monitoring time step (e.g., 7:30 AM to 8:00 AM) is compared to historical averages and the goals set by the local agency for the same time step. If this comparison informs the ATDM AMS system that the system is performing as expected, dynamic actions are not warranted.

Safety

For this analysis package, safety is defined to be inversely proportional to the number of vehicle-to-vehicle conflicts. Therefore, vehicle conflicts are used as a proxy for crash rates. This simulation will output vehicle trajectories at a second-by-second time interval for next time window (e.g., 7:30 AM to 8:00 AM). These individual trajectories will be used by a post-processing tool such as FHWA's Surrogate Safety Assessment Model (SSAM) to compute conflicts and, thus, crash rates, which will be used as a proxy to compute safety as a performance measure. The crash rates thus computed will be compared to historical averages for similar (blizzard) days and the goals set by the agency. If this comparison informs the ATDM AMS system that the system is performing as expected, dynamic actions are not warranted. In a simulation model, vehicle conflicts are typically used as a proxy for crash rates. As described above, the simulation model used for this analysis package will include a Weather Adjustment Factor (WAF), and the simulation will be able to replicate slippery and unsafe conditions. This simulation will output vehicle trajectories at a second-by-second time interval. These individual trajectories will be used by a post-processing tool such as a FHWA's SSAM to compute conflicts, which will be used as a proxy to compute safety as a performance measure. The ATDM strategies implemented will aim to reduce the number of vehicle-to-vehicle conflicts and, thus, the number of probably crashes during the blizzard. The goals for this performance measure will be set by the local agency for each time step of analysis.

Assessing System Performance

The system assessment phase begins during the analysis period (5:00 AM to 8:00 AM), that is, at 5:00 AM for this analysis package. During this period, a forecast or a prediction of the system during the blizzard is performed. This assessment phase predicts how the blizzard affects system performance, as well as which parts of the system are affected. It also predicts how travel demand changes due to the blizzard. The objective of this analysis package is to ensure that the system performs as expected and is not incapacitated due to the blizzard. This analysis package's performance assessment task follows the process described in Section 3.8.

Performance Measures

For this particular analysis package, person throughput and travel time reliability are selected as the two regional performance measures of interest to the agency. These performance measures are described below. The performance measures computed during the assessment phase without any strategies implemented will be the baseline performance measures for this analysis package.

Mobility Delays

For this analysis package, mobility delays will be defined as the additional travel time experienced by a traveler due to the blizzard for the next time window (e.g., 8:00 AM to 8:30 AM). Travel times for roadway segments will be compared to historical averages for the mobility delays due to the blizzard and goals set by the local agency in order to compute mobility delays. If this comparison informs the ATDM AMS system that the system is performing as expected, dynamic actions are not warranted.

Trip Travel Time Reliability

Travel time reliability will be measured for this analysis package as the buffer index for travel between a set of origin-destinations. To compute travel time reliability, average or mean travel time between two locations in the region is to be computed. In addition, the variation of travel times around the mean is to be computed. These statistics will be computed as aggregate zone-to-zone travel skims. Travel times for all travelers traveling between two zones (e.g., Old Reston to New Camden) during the next time window (e.g., 8:00 AM to 8:30 AM) will be extracted from the simulation output. These travel times will be used to compute both the average travel time and the 95th percentile travel time. Once these two statistics are computed, travel time reliability will be computed as described in Section 7.5. This travel time reliability for the next time window (e.g., 8:00 AM to 8:30 AM) is compared to historical averages and the goals set by the local agency for the same time step. If this comparison informs the ATDM AMS system that the system will perform as expected, dynamic actions are not warranted.

Safety

For this analysis package, safety is defined to be inversely proportional to the number of vehicle-to-vehicle conflicts. Therefore, vehicle conflicts are used as a proxy for crash rates. This simulation will output vehicle trajectories at a second-by-second time interval for the next time window (e.g., 8:00 AM to 8:30 AM). These individual trajectories will be used by a post-processing tool such as a FHWA's SSAM to compute conflicts and thus crash rates, which will be used as a proxy to compute safety as a performance measure. The crash rates thus computed will be compared to historical averages for similar (blizzard) days and the goals set by the agency. If this comparison informs the ATDM AMS system that the system is performing as expected, dynamic actions are not warranted.

Evaluating Impact of ATDM Strategies

The system evaluation phase begins during the analysis period (5:00 AM to 8:00 AM), that is, at 5:00 AM for this analysis package. During this period, a forecast or a prediction of the system during the blizzard along with the dynamic actions implemented to alleviate conditions is performed. This evaluation phase predicts how the blizzard affects system performance and how the dynamic actions affect improve system performance. It also predicts how travel demand changes due the dynamic actions. The objective of this analysis package is to ensure that the system performs as expected and is not incapacitated due to the blizzard. The system performance evaluation task has been described in detail in Section 3.8. This analysis package's performance evaluation task follows the process described in Section 3.8. For this analysis package, the performance measures mobility delays, travel time reliability, and safety index are compared to the goals set by the local agency and to the performance measures generated during the system assessment phase (baseline). If the forecasted performance measures do not meet the goals set by the local agency, ATDM strategies will be reevaluated and the impact of implementing the selected strategies is tested. It is to be noted that in real-world ATDM implementation, the best set of strategies to be implemented will be selected by a Decision Support System or an automated process. For this analysis, the set of strategies to be tested have been preselected so as to be to effectively test and enhance the ATDM AMS processes. As presented and discussed in Section 7.3, the strategies chosen for this analysis scenario include—

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

The travel time under severe weather conditions can be calculated from a series of offline simulations. One of the recent approaches of modeling weather impacts in traffic simulation is to include a Weather Adjustment Factor (WAF) for each of the parameters in the supply side of the simulation model, which include the free flow mean speed, jam density, and saturation rates. The WAF is defined as the ratio of the regular condition parameter to the severe weather condition parameter.

Studies have shown WAF to strongly depend on visibility and precipitation intensity (rain or snowfall). The calibration process involves determining the value of the coefficients and a constant in the relationship of WAF as the dependent variable, and visibility and precipitation intensity as the independent variables. The calibration process is described below:

- Historical data for regular days and severe weather days (e.g., snowstorm, heavy rainfall) is used to calibrate the underlying models such as the Greenshield[5] model in the simulation framework. This will result in different models under traffic conditions.
- WAF for each parameter is calculated as the ratio of regular weather parameter to severe weather parameter.
- Use these WAFs as the dependent variables and run a regression against visibility and precipitation intensity for each data point.

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[5] Greenshield's model is a widely accepted model in traffic flow theory. It provides a parabolic relationship for the speed-flow curve using traffic jam density and free flow speed as curve-defining parameters.

The calibrated equation for WAFs will be used to determine the baseline model under this scenario, and the results from this model would be treated as the baseline performance measures. The goals for this performance measure will be set by the local agency for each time step of analysis. The following section presents a discussion on how each strategy would be implemented and tested for its effectiveness for the blizzard during the AM peak scenario..

Predictive Traveler Information

The use of this strategy under regular operations has been described in Chapter 4. Safety aspects of the traffic flow become particularly important in this scenario for I-403, and McGeorge Bundy Parkway, which have been historically accident-prone corridors. Therefore, predictive traveler information will play a key part in managing traffic in this area. In this section, we discuss how this strategy can be used and tested for its effectiveness under severe snowfall conditions during the AM peak period.

The application of this strategy under severe weather conditions will inform travelers of the impending unfavorable traffic conditions, reduction in traffic and transit capacities, and altered speed limits. This information will impact destination choice, time-of-day choice, mode choice, route choice, and lane choice. The information pertaining to severe weather conditions drastically reduces the affinity to travel to the intended destination. The destination choice model in the activity-based travel demand model is to be sensitive to the weather information. Cancelling the trip is also to be seen as one of the destination options. The forecast of severe weather might shift most of the travel demand to earlier times during the day. This perceived increase of affinity to travel earlier and outside the AM peak hours is to be captured in the time-of-day choice models. Similarly, the affinity to travel on roadways decreases drastically during inclement weather conditions, as travelers prefer to use underground transit. This mode choice sensitivity of travelers should be captured in the discrete choice models. The modeler may consider inferring this tendency of travelers to avoid severe weather conditions based on the demographics data. The route choice model and lane choice model will depend on the changed road weather conditions, which can be captured in the mesoscopic or microscopic simulation models. The parts of the network severely impacted by the snowfall shall be modeled on the microscopic simulator platform for detailed analysis of the traffic operations.

It is essential to obtain data to calibrate traveler response to information pertaining to weather along his/her path. The following questions need to be answered by the data obtained from historical data, revealed preference surveys, or stated preference surveys:

- Will travelers change their behavior or choice (route, mode) based on the information presented?
    - What percentage of travelers will modify their choice once they are made aware of delays due to an weather conditions?
- Will travelers choose a route mid-trip?
    - What percentage of travelers will modify their route mid-trip once they are made aware of delays due to weather conditions?

Current tools do not possess the capabilities or possess very limited capabilities to model the operation and the impacts of a dynamic travel information system. The foundation of an predictive traveler information System is presently available; however, the components of the system are at various stages of development While the traveler information systems possess the ability to distribute accurate traveler information across various modes, the ability to provide multimodal traveler information for a single trip is rather limited.

Dynamic Shoulder Lanes

Shoulder lanes are available for use only along a 5-mile stretch of I-6 to the west of the beltway. Hard shoulder running will be used to temporarily add capacity during the blizzard conditions. Dynamic or time-dependant shoulder lanes are modeled using DTA tools to capture the route choice changes and in greater detail in the microscopic traffic simulation models to capture the driving behavior. The dynamic use of shoulder lanes in this scenario shall be evaluated on the microscopic simulation platform.

A robust analysis of HSR requires an understanding of the effects of travel demand choices such as departure mode, time, and path on network performance and vice versa across multiple spatial and temporal regimes. HSR strategy involves the opening of either the left or right shoulder for vehicular traffic under certain time-of-day or operational criteria. Although this strategy is expected to provide many operational benefits, established analysis guidelines are not available. On the analytical level, there are no provisions for HSR in the HCM2010. Although many of the commercially available microsimulation tools can simulate the opening and closure of travel lanes, these tools as they exist today are not capable of capturing the unique capacity characteristics of a lane with inferior geometric conditions and only temporary usability or capturing the potentially lower attractiveness of such a lane resulting in reduced lane use. The success of HSR strategy evaluation and deployment depends in large part on the ability to assess functional capacity and operational and safety performance at the network and corridor levels. Effective integration of different modeling tools is needed to estimate and predict network conditions and to analyze system performance for both strategic and tactical purposes.

In order to implement this strategy, the Data Generator creates a multimodal network that includes additional capacity, or travel lane elements for HSR along the chosen routes. The network simulator uses this network to simulate traffic, and also to generate demand using the feedback process. The modeling tools used for analysis should be calibrated and validated for HSR operations under inclement weather conditions.

Dynamic Speed Limits

The impacts of dynamic speed limits are realized only at the en route driving level for this scenario. The route choice, and lane choice models incorporate the elements that are responsive to the speed limit information. The traveler is made aware of the dynamic speed limits about 1.5 miles in advance, and this is the distance buffer the traveler has to make any route choice and the subsequent lane changing maneuvers. The distance from the decision-critical point on the roadway downstream is a critical variable in the utility-based discrete choice models for the route choice and lane choice. Other important variables include driver characteristics and roadway conditions. The models can be calibrated—especially for variables based on traveler behavior characteristics—using vehicle trajectory data. In addition, the lane changing and gap acceptance algorithm in the traffic simulation models should capture the weather impacts.

In order to implement this strategy, the Data Generator creates a multimodal network with dynamic or time-dependent speed limits. The Data Generator creates this network for each time period. The network simulator uses this network to simulate traffic, and also to generate demand using the feedback process. The speed limits appropriate to resolve weather conditions can be derived by the modeler from empirical experience. Once these speed limits are set up along I-6, the driving behavior models in the mesoscopic or microscopic simulation models will respond to the speed advisories and the subsequent traveler decisions would be simulated accordingly. While the existing analysis tools are already calibrated and validated for driving behavior response to dynamic speed limits, additional calibration or validation is needed to capture the weather impact.

Adaptive Traffic Signal Control

In this scenario the visibility distance of the traffic signals is lower than that during normal operations. This affects the motorists' response to the traffic signal control. This is to be captured using the driving behavior models from Analysis Package 1. The goal of this strategy is to grant appropriate amount of green times to the conflicting traffic flows at intersection along the entire NCNJ region. The ATSC algorithms for normal operations will have to be significantly altered to account for lower average speeds, slower turning maneuvers, and longer queues, which will demand longer cycle times for a unit of demand. It is to be noted, however, that the demand levels are lower than the average weekday. The new algorithms need to account for all of these factors. The model shall also account for the reduced reliability, accuracy, and coverage of the roadway sensors that provide the input data to the ATSC algorithms.

The implementation of ATSC across the entire NCNJ region cannot be evaluated on a microscopic traffic simulator platform. Therefore, a focused analysis of a critical subregion for ATSC implementation shall be used to support the regionwide mesoscopic analysis. For the macroscopic model, the percentage green time attribute for each approach is updated. This information is used to compute capacity which is in turn used to compute congested travel speeds during the traffic assignment process. The microscopic model uses the updated signal plans to perform a microsimulation. Since the existing models are already calibrated and validated, additional calibration or validation is not required.

Performance Measures

For this particular analysis package, person throughput and travel time reliability are selected as the two regional performance measures of interest to the agency. These performance measures are described below. The performance measures computed during the evaluation phase with strategies implemented will be compared to the baseline performance measures computed during the assessment phase.

Mobility Delays

For this analysis package, mobility delays will be defined as the additional travel time experienced by a traveler due to the blizzard for the next time period (e.g., 8:00 AM to 8:30 AM). Travel times for roadway segments will be compared to historical averages for the mobility delays due to the blizzard, mobility delays generated during the assessment phase, and goals set by the local agency in order to compute mobility delays. This comparison informs the ATDM AMS system if the system has performed according to expectations and if the goals were met.

Trip Travel Time Reliability

Travel time reliability will be measured for this analysis package as the buffer index for travel between a set of origin-destinations. To compute travel time reliability, average or mean travel time between two locations in the region is to be computed. In addition, the variation of travel times around the mean is to be computed. These statistics will be computed as an aggregate zone-to-zone travel skims. Travel times for all travelers traveling between two zones (e.g., Old Reston to New Camden) during the next time period (e.g., 8:00 AM to 8:30 AM) will be extracted from the simulation output. These travel times will be used to compute both the average travel time and the 95th percentile travel time. Once these two statistics are computed, travel time reliability will be computed as described in Section 7.5. This travel time reliability for the next time window (e.g., 8:00 AM to 8:30 AM) is compared to historical average, travel time reliability generated during the assessment phase, and the goals set by the local agency for the same time step. This comparison informs the ATDM AMS system if the system has performed according to expectations and if the goals were met.

Safety

For this analysis package, safety is defined to be inversely proportional to the number of vehicle-to-vehicle conflicts. Hence, vehicle conflicts are used as a proxy for crash rates. This simulation will output vehicle trajectories at a second-by-second time interval for the next time window (e.g., 8:00 AM to 8:30 AM). These individual trajectories will be used by a post-processing tool such as a FHWA's SSAM to compute conflicts and thus crash rates, which will be used as a proxy to compute safety as a performance measure. The crash rates thus computed will be compared to historical averages for similar (blizzard) days, crash rates generated during the assessment phase, and the goals set by the agency. This comparison informs the ATDM AMS system if the system has performed according to expectations and if the goals were met.

7.9 Model Calibration

Section 3.9 details how the models for the analysis packages will be calibrated and presents the data requirements for model calibration.

7.10 Modeling Requirements

The modeling requirements for this scenario are mapped against the AMS needs identified in the CONOPS Report and are presented in the following sections.

Monitoring the System

The overall modeling requirements to monitor the system have been presented in Section 3.9. Additional modeling requirements are not necessary for this analysis package: the normal operation, no incident package.

Assessing the System Performance

The overall modeling requirements to assess system performance have been presented in Section 3.9. Additional modeling requirements are not necessary for this analysis package: the normal operation, no incident package.

Evaluating Impact of ATDM Strategies

The overall modeling requirements to evaluate the impact of ATDM strategies in Section 3.9. The following sections present the modeling requirements to evaluate each strategy chosen for this analysis package.

Predictive Traveler Information

The following presents the additional modeling requirements to evaluate the impact of dynamic shoulder lanes for this analysis package:

- Shall be able to model travelers' propensity to cancel the trip or switch modes to transit under severe weather conditions.

- Shall be able to model the user trust in the advisories issued by the TMC.

Dynamic Shoulder Lanes

The following presents the additional modeling requirements to evaluate the impact of dynamic shoulder lanes for this analysis package:

- Shall be able to model the perceived suitability of the shoulder lanes for travel during severe weather conditions.
- Shall be able to model the appropriate safe speed limits to travel in the shoulder lanes.
- Shall be able to capture reduced capacity or throughput of shoulder lanes due to weather conditions.

Dynamic Speed Limits

The following presents the additional modeling requirements to evaluate the impact of dynamic shoulder lanes for this analysis package:

- Shall be able to determine safe driving speeds under the severe weather conditions.
- Shall be able to model the driving behavior under reduced visibility of DMS.
- Shall be able to capture the risk-avert driving behavior in the car-following and lane changing models.
- Shall be able to capture the read-weather impacts on driving behavior in the simulation models.

Adaptive Traffic Signal Control

The following presents the additional modeling requirements to evaluate the impact of dynamic shoulder lanes for this analysis package:

- Shall be able to modify the ATSC algorithms to account for significantly different traffic conditions, such as lower average speeds, slower turning maneuvers, and longer queues.
- Shall be able to account for limited data availability from the roadway sensors that affects the input data for the ATSC algorithms.

Chapter 8: Modeling Requirements Summary

This section presents the modeling requirements listed in the four analysis packages classified by ATDM AMS needs as identified in ATDM AMS CONOPS Report. Table 8-1, Table 8-2, and Table 8-3 list each modeling requirement along with the AMS need and the corresponding AMS component.

Table 8-1: Monitoring the System—AMS Needs versus Modeling Requirements

AMS Needs	Needs Description	ATDM AMS Component	Modeling Requirement
M.1	Collect and process real-time data from a variety of sources.	Data Generator	(1) The Data Generator shall be able to receive continuous feed of real-time data (transportation and non-transportation) from a variety of sources such as sensor detectors, video cameras, and weather stations.
			(2) The Data Generator shall include geospatial and temporal aggregation procedures to process the incoming data in real time and convert to a standardized data schema stored in an integrated multimodal database.
M.2	Collect and process historical data from a variety of sources.	Data Generator	(1) The Data Generator shall be able to receive historical data (transportation and non-transportation) from a variety of sources.
			(2) The Data Generator shall include geospatial and temporal aggregation procedures to process the historical data and translate it into an integrated multimodal database based on a standardized data schema.
M.3	Access transportation network supply (e.g., highway and transit) data from a variety of sources.	Data Generator	(1) The Data Generator shall receive the data on network supply from a variety of sources, such as GIS resources, traffic signal locations and phase plans, and transit schedules and routes.
			(2) The Data Generator shall be able to process this incoming data and convert them into a standardized format.
M.4	Generate the desired performance metrics to monitor the current traffic conditions of the system.	Data Generator and Network Simulator	(1) The Performance Interpreter in the Network Simulator module shall include procedures that will compute scenario-specific performance measures using simulation output.
M.5	Integrate data collected from different sources.	Data Generator	(1) The Data Generator shall include data processing algorithms that can organize the cleaned data from different sources in geospatially and temporally compatible data structures.

AMS Needs	Needs Description	ATDM AMS Component	Modeling Requirement
M.6	Visualization capabilities are needed to support analysis.	Network Simulator	The Network Simulator shall include tools to visualize the simulation of individual vehicles, and aggregate measures such as person throughput and speeds as thematic network renderers. These visualization tools shall assist in identifying and tracking problem locations visually.
M.7	Understand demand patterns.	Network Simulator	(1) The Network Simulator shall include advanced demand models that use the historical trends and the real-time data received from the Data Generator, along with the changes in the network supply (either controlled by the TMC or impacted by network conditions) to generate time-dependent travel demand matrices for the current conditions.
M.8	Validate the data prior to analysis.	Data Generator	(1) The Data Generator shall conduct a preliminary validation of the processed real-time data against the historical data to check for unrealistic patterns.
M.9	Process must support the required analysis scale, both temporal and spatial.	Network Simulator	(1) The Network Simulator shall include an integrated framework where a travel demand model such as an activity-based model generates the travel demand and mode shares for the network. This demand shall then feed to a mesoscopic simulation model where DTA techniques shall be used to generate traffic flow distribution. These traffic flows shall then be analyzed in detail for a specific sub-region using a microsopic traffic simulation model.
			(2) The Network Simulator shall have a “feedback” framework where the results from one model are used as inputs for other model to reach convergence.
			(3) These individual models shall comprehensively capture the demand-supply interactions at all levels of analysis.
M10	Auto-correct or self-validate based on the latest data.	Data Generator	(1) The Data Generator shall support algorithms to detect and flag erroneous or missing values in the real-time data and plug the data gaps with the help of imputation techniques.
M.11	Process should be able to capture uncertainty in data used to monitor the system.	Network Simulator	(1) The models in the Network Simulator shall add a randomness component or assign some inherent uncertainty to the input variables received from the Data Generator to account for the uncertainties that trickle through all the steps from data gathering to data processing.
			(2) The simulation models in the Network Simulator shall also add uncertainty to the network supply side in terms of operational up-/downtime of roadway sensors and probability of failure of traffic signals/DMS.

Table 8-2: Assessing the System Performance–Modeling Requirements versus AMS Needs

AMS Needs	Needs Description	ATDM AMS Component	Modeling Requirement
A.1	Use both real-time and historical data to assess and predict future performance.	Network Simulator	(1) The models in the Network Simulator shall use the archived data in conjunction with the historical data to forecast the trend of performance measures reflecting the anticipated traffic conditions in the next time window.
A.2	Continuously predict network conditions in a moving window.	Network Simulator	(1) The travel demand model in the Network Simulator shall use historical and real-time data to forecast time-dependent travel demand for the next time window.
			(2) The DTA-based mesoscopic simulation model in the Network Simulator shall use the travel demand forecasts for the next time period (e.g. next 30 minutes), as generated by the travel demand model, as inputs to predict the traffic flow patterns in the forecast window.
			(3) The microscopic simulator in the Network Simulator shall be able to simulate traffic conditions for the forecast period in smaller regions at a detailed level.
			(4) The “feedback” structure of data flow within the Network Simulator shall support convergence of outputs from the different simulation models.
A.3	Generate performance measures and confirm that they meet agencies’ goals and objectives.	Network Simulator	(1) The Network Simulator shall include procedures and models that can use the simulation output for the next time period to compute performance measures such as traveler throughput, travel time reliability, and travel time delay, as defined by the agency goals.
A.4	Consider possible demand and supply changes in the forecast period and their net impact on system performance.	Network Simulator	(1) The travel demand model in the Network Simulator shall use historical and real-time data to forecast time-dependent travel demand for the next time window.
			(2) The Network Simulator shall be able to update the supply parameters in the models to incorporate the anticipated changes in the network supply (either controlled by the agency or impacted by network conditions).
A.5	Explicitly capture human factors and their impact on network demand.	Network Simulator	(1) The travel demand models in the Network Simulator shall include advanced traveler behavior models that can account for traveler decisions such as destination choice, time-of-day choice, and mode choice in response to the changes in network conditions or issued advisories with high fidelity.

AMS Needs	Needs Description	ATDM AMS Component	Modeling Requirement
			(2) The mesoscopic and microscopic simulation models in the Network Simulator shall include traveler behavior models that can replicate the effects such as user acceptance and user trust in the technology.
			(3) All models in the Network Simulator shall be able to account for heterogeneity of the traveler population in different stages of decisionmaking, such as likelihood of taking transit, elasticity towards congestion pricing.
			(4) The traveler behavior models for all parts of trip chain shall be sensitive to individual traveler's behavior characteristics.
A.6	Capture uncertainties in demand and supply.	Network Simulator	(1) The models in the Network Simulator shall add a randomness component or assign some inherent uncertainty to the input variables received from the Data Generator to account for the uncertainties that trickle through all the steps from data gathering to data processing.
			(2) The simulation models in the Network Simulator shall also add uncertainty to the network supply side in terms of operational up-/downtime of roadway sensors and probability of failure of traffic signals/DMS.
A.7	Support interactions between demand and supply for multimodal trip chain analysis.	Network Simulator	(1) The Network Simulator shall support multi-mal analysis including auto (SOV, HOV2, HOV3+) and transit.
			(2) The models in the Network Simulator shall be able to access the characteristics of different modes and their interactions (e.g., proximity, competitive modes).
A.8	Explicitly model transit operations impacts on system performance.	Network Simulator	(1) The Network Simulator shall use quantify the impact of transit operations on network performance.
			(2) The models in the Network Simulator shall include the interactions between the transit and automobile options while capturing the modal split of travel demand. These mode choice models shall be sensitive to the transit operations factors such as fares and frequency.
A.9	Include visualization capabilities to display forecasted network conditions.	Network Simulator	The Network Simulator shall include tools to visualize the simulation of individual vehicles, and aggregate measures such as person throughput and speeds as thematic network renderers. These visualization tools shall assist in identifying and tracking problem locations visually.

AMS Needs	Needs Description	ATDM AMS Component	Modeling Requirement
A.10	Calibrate/validate the tools to estimate the impact of different strategies.	Network Simulator	The Network Simulator shall include tools to calibrate and validate data. These tools' functionality will include iterative proportional fitting, curve fitting techniques, and regression.

Table 8-3: Evaluating Impact of Strategies–Modeling Requirements versus AMS Needs

AMS Needs	Needs Description	Modeling Requirement	Strategy
E.1	Identify a range of strategies or group of strategies to evaluate.	(1) The simulation framework in the Network Simulator module shall support parallel computing of multiple strategies at once.	All
E.2	Model the impact of the ATDM strategy on different elements of the trip chain.	(1) The route choice models in the Network Simulator shall parking space availability in the route and mode choice.	Dynamic Wayfinding
		(2) The traveler behavior models in the Network Simulator shall include the sensitivity of traveler to dynamic pricing with respect to mode choice, time-of-day choice, and lane/facility choice. The models shall make use of the demographics data to determine the price sensitivity of the population.	Dynamic Pricing
		(3) The mode choice models in the Network Simulator shall model dynamic ridesharing as a carpool mode option. The availability and the timeframe of the availability of suitable matching ride shall be included as the driving factors for choosing carpool mode.	Dynamic Ridesharing
		(4) The algorithms for matching the “ride-requesting” demand to the “ride-offering” supply within the geographically and temporally practical context shall be used in the mode choice model to generate the mode splits of traveler population.	Dynamic Ridesharing
		(5) The traveler behavior models in the Network Simulator, especially the route choice and lane choice models, shall capture the impact of dynamic speed limits in terms of attractiveness of a route or lane based on the speed limit.	Dynamic Speed Limits
		(6) The availability of the transit service (as a function of the dynamic scheduling and dynamic routing) shall be linked to the utility of the dynamic transit service mode option in the mode choice model.	Dynamic Transit Service
		(7) The sensitivity of travelers to parking fees shall be included in the mode choice and route choice models in the Network Simulator.	Dynamically Priced Parking
		(8) The dynamic pricing algorithm/model in the Network Simulator shall include a tradeoff analysis of the updated inventory of available parking spaces hosted by the Data Generator and the most recent for the parking demand as determined from the simulation results. The tradeoff analysis shall be supported by the elasticity of the drivers to pay the parking fees.	Dynamically Priced Parking
		(9) The changes in the dynamic pricing structure for the parking facilities shall be conveyed to the supply side of the virtual world, from where it would be incorporated into the traveler behavior models.	

AMS Needs	Needs Description	Modeling Requirement	Strategy
		(10) The Network Simulator shall include utility-based discrete choice models for destination choice, mode choice, time-of-day choice, and route choice that are sensitive to the traveler information.	Predictive Traveler Information
E.3	Model microscopic driver behavior changes resulting from dynamic actions, as applicable in the subarea of interest (e.g., for variable speed limit).	(1) The car following and lane changing models in the Network Simulators shall be responsive to the traffic signals within visibility distance of the driver.	Adaptive Traffic Signal Control
		(2) The Network Simulator module of the AMS framework shall have a distinct microscopic simulation component with advanced driving behavior models to represent car following, lane changing, merging, and tailgating maneuvers.	All
		(3) The sensitivity of travelers to pricing of lane or corridor facility shall be incorporated in the mode choice, route choice, and lane choice models in the Network Simulator.	Dynamic Pricing
		(4) The added capacity of the lane shall be incorporated as an additional option in the lane choice models. The route choice models shall also include the preference/aversion of travelers to select routes with shoulder lane facilities.	Dynamic Shoulder Lanes
		(5) The route choice models in the Network Simulator shall include the changes in speed limits of the facility as a driving factor.	Dynamic Speed Limits
		(6) The traveler behavior models in the Network Simulator shall consider the changed free-flow speed of links based on the road weather conditions, which in turn shall affect the outputs of traveler behavior models.	Dynamic Speed Limits
		(7) The reduced visibility of DMS under unfavorable weather conditions shall be captured in the models in the Network Simulator.	Dynamic Speed Limits
		(8) The risk-avert behavior of travelers under blizzard conditions shall be captured in the car following and lane changing models.	Dynamic Speed Limits
		(9) The route choice and lane choice model shall be able to capture the "urgency" of the traveler to make a decision on the route choice and the lane choice as a response to the queue warning. These models shall consider every individual traveler's driving behavior characteristics such as aggressiveness and compliance to advisories.	Queue Warning
		(10) The models shall use queue warning information in conjunction with the dynamic speed limits to capture the compound effect of these strategies on travelers.	Queue Warning
		(11) The models shall capture the on- and off-ramp driving behavior of the travelers in terms of maneuvers such as merging—courtesy, normal, or forced.	Queue Warning

AMS Needs	Needs Description	Modeling Requirement	Strategy
E.4	Model the demand-supply interactions resulting from implementation of ATDM strategies.	(1) The Data Generator shall maintain an updated inventory of available parking spaces and shall communicate it to the Network Simulator periodically.	Dynamic Wayfinding
		(2) The ATSC algorithms shall be embedded in the supply side of the virtual world in the Network Simulator, and it shall be sensitive to the most recent sensor data received from the Data Generator.	Adaptive Traffic Signal Control
		(3) The models in the Network Simulator shall be able to account for limited data availability from the roadway sensors during blizzard conditions.	Adaptive Traffic Signal Control
		(4) The information channel to disseminate dynamic parking information to travelers using mobile devices or DMS shall be modeled in the supply side of the Network Simulator along with the dynamics of these dissemination methods.	Dynamic Wayfinding
		(5) The models in the AMS framework shall use the price sensitivity of the traveler population to determine the demand elasticity and subsequent impact of pricing on the travel demand.	Dynamic Pricing
		(6) The algorithms to compute dynamic speed limits shall account for the reduction in safe free-flow speeds under severe weather conditions.	Dynamic Speed Limits
		(7) The dynamic scheduling algorithms for the regional transit operations shall be incorporated in the supply control component of the Network Simulator.	On-Demand Transit
		(8) The simulation framework shall have a feedback loop to the dynamic scheduling and dynamic routing algorithms of transit operations to fine-tune them according to the recent transit demand.	On-Demand Transit
		(9) The destination choice model of the Network Simulator shall be able to model travelers' propensity to cancel the trip or switch modes to transit under severe weather conditions and shall be explicitly modeled in the activity-based models.	Predictive Traveler Information
E.5	Consider anticipated behavior changes to predict future performance.	(1) The ATSC algorithms in the Network Simulator shall include the anticipated traveler response to changes in signal timings in designing the traffic signal cycles.	Adaptive Traffic Signal Control
		(2) The mode-choice and route-choice models in the Network Simulator shall include the anticipated traveler response to the pricing strategy.	Dynamic Pricing
		(3) The design of dynamic speed limits shall consider the anticipated user response to the advisories based on traveler behavior factors such as user acceptance and user reliability in travel advisories.	Dynamic Speed Limits

AMS Needs	Needs Description	Modeling Requirement	Strategy
		(4) The models in the AMS framework shall anticipate user reactions to the information conveyed to the traveler in the analysis done for determining the traveler information to be disseminated.	Predictive Traveler Information
E.6	Support multiple spatial and temporal extents of analysis (e.g., region, corridor, peak period, peak hour).	(1) The algorithms for matching the ride-request demand to the ride-offering supply within the geographically and temporally practical context shall be used in the mode choice model to generate the mode splits of traveler population.	Dynamic Ridesharing
E.7	Validate the network performance conditions	(1) The procedures within the Network Simulator shall be able to ensure that the anticipated network conditions are validated using historical data.	All
E.8	Include visualization capabilities to display forecasted network conditions.	The Network Simulator shall include tools to visualize the simulation of individual vehicles, and aggregate measures such as person throughput and speeds as thematic network renderers. These visualization tools shall assist in identifying impacts of strategies	All

Chapter 9: References

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Appendix A: List of Acronyms

Acronym	Definition
AASHTO	American association of state highway and transportation officials
AMS	Analysis, simulation, and modeling
API	Application programming interface
ATDM	Active transportation and demand management
ATSC	Adaptive traffic signal control
BPR	Bureau of public roads
CCTV	Closed-circuit television
CONOPS	Concept of operations
DMS	Dynamic message sign
DSS	Decision support system
DTA	Dynamic traffic assignment
GPS	Global positioning system
HOT	High-occupancy toll
HOV-2	High-occupancy vehicle with two or more people
HOV-3	High-occupancy vehicle with three or more people
HSR	Hard shoulder running
HSR	Hard shoulder running
ITS	Intelligent transportation system
JDOT	Jeffersonia department of transportation
LOS	Level of service
MOE	Measure of excellence
MOVES	Motor vehicle emissions simulator
NCNJ	New Camden And Northern Jeffersonia
NCTA	New Camden Transit Authority
NJMPO	NCNJ metropolitan planning organization
O-D	Origin-destination
SCADA	Supervisory control and data acquisition
SOV	Single-occupancy vehicle
SR	State route
SSAM	Surrogate safety assessment model
STMC	Super-regional transportation management center
TOF	Transit operations facility
VOT	Value of time
WAF	Weather adjustment factor
WTP	Willingness to pay

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