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ATMS Functional Requirements and Specifications

Task C Final Working Paper for Design of Support Systems for Advanced Traffic Management Systems
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SECTION 1
INTRODUCTION

This document is third in a series describing the results of a five-year research program, entitled the ***Design of Support Systems for Advanced Traffic Management Systems.*** The purpose of this work is to define, design, prototype, and evaluate the baseline support systems for the implementation of Advanced Traffic Management Systems (ATMS).

1.1 Approach

This document describes the Functional Requirements and Specifications for ATMS Support Systems, and builds on previous work in Tasks A and B. Our approach for developing these requirements is described in the following paragraphs.

State-of-the-Practice

The first step in developing the requirements was to survey the state-of-the-practice to develop a thorough understanding of how traffic networks are currently managed. This review was conducted through interviews with Traffic Management Center (TMC) managers, TMC inspection visits, and a literature search and review. The results of this review are documented in another report entitled, ‘Traffic Management Centers - The State-of-the-Practice.”

Concept of Operations and Generic System Requirements

Using the results from the state-of-the-practice review as a foundation, the second step was to develop a vision and a comprehensive list of ATMS functions u~at would meet the objectives of the Intelligent Vehicle Highway System (IVHS). This list was then used to derive ATMS functional requirements (i.e., generic system requirements). The functional requirements served as the baseline for a top-down analysis (the third step), in which each function was analyzed to determine input requirements, necessary processing, and output information to be produced. Using this list, more detailed analyses were performed to identify ATMS boundaries, the role and assets of ATMS itself, identification of external entities, data and information exchange between ATMS and external entities, and the decomposition of functions within ATMS, A byproduct of these analyses was the identification of ATMS subsystems from which logical Support Systems were later derived. Each of the identified functions in the subsystems was exercised using operational scenarios. The results of these steps are documented in a previous report entitled, “ATMS Concept of Operations and Generic System Requirements.”

Functional Requirements and Specifications for Support Systems

Using ‘the results from the state-of-the-practice review, the generic system requirements, and the top-down structured analysis as a foundation, the logical Support Systems were transformed into physical Support Systems. For each physical Support System, there are associated Support Subsystems. In the sixth and fmal step, functional requirements and specifications for Support Subsystems were derived. The results of this work are documented in this report.

The results of these analyses provide a framework for upcoming work — the design of ATMS support systems.

1.2 Requirements Control and Configuration Management

As was the case with the analysis and generic system requirements identified in earlier work, the requirements and specifications identified in this document are under strict configuration control. The requirements and specifications presented in this document represent the baseline version. Any additions, changes, or deletions are tracked (for an example reference Appendix B’s change log for the changes to generic system requirements) through the use of Requirements Discrepancy Reports (RDR).

The requirements and specifications presented in this document (see Appendix A), have already been independently reviewed by our Advisory Committee and by internal Loral Consortium team members. Their inputs have been considered and have helped establish this baseline version.

Finally, through the use of Computer-Aided Software Engineering (CASE) environments, the requirements identified in this report are automatically tracked throughout all phases of the software development lifecycle (i.e., analysis, design, prototyping, implementation, testing). When requirements are changed or deleted, for instance, a CASE tool can automatically identify potential impacts on various components of the system.

1.3 Design Highlights

This section summarizes some of the significant design features incorporated in the proposed architecture.

a. Subsystem de-coupling accomplished through a Database Management System (DBMS) to better facilitate “plug-in” subsystems and modularity.

b. All external data managed by the Communications Support System.

c. All DBMS writes managed by the Data Validation subsystem.

d. Common Graphical User Interface (GUI) facilitates a consistent, user-friendly Human-Machine Interface (HMI) with all Support System applications.

e. All traffic control managed by the Traffic Control System. Wide-Area Traffic Management and Incident Management interface with the Traffic Control System to request direct Traffic Control action.

f. Integrated Modeling Manager handles all input/output with models and simulations -- used for both online and offline purposes.

1.4 Document Organization

Section 1 of this report provides introductory information concerning the project, current and past tasks, methodologies used, goals and objectives. Section 2 is a discussion of the proposed ATMS Support Systems and associated subsystems. In this section, descriptions are given for each Support System that detail, the major functions for each of the contained subsystems. The actual baseline version of the functional requirements and specifications are provided in Appendix A. In Section 3, system level requirements are addressed. The system-level requirements are those requirements that are applicable to the system as a whole, to which each Support Subsystem shall be compliant. The system-level requirements address hardware, software, operator interface, facility, system architecture, fault tolerance, and system-level performance requirements. In Section 4, deployment considerations are addressed. Finally, Section 5 describes future directions.

1.5 Applicable Documents

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f. Federal Highway Administration (FHWA), ***Programming Style Guidelines for*** C ***Language,*** Draft March 1993.

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SECTION 2

DESCRIPTION OF SUPPORT SYSTEMS

This section describes the functionality of the proposed ATMS Support Systems. Each of the proposed Support Systems contains three or more Support Subsystems. Altogether there are 26 Support Subsystems. These Support Systems, as illustrated in Figure 2- 1, are the following:

a. Communications. The capabilities needed for interfacing with external ATMS entities are provided by this Support System.

   1. I/O Manager.

   2. Input Stream Processing.

   3. Output Stream Processing.

b. Monitoring. This Support System performs data processing and provides the necessary controls and interfaces to the operator for monitoring the traffic network.

   1. Surveillance Image Processing.

   2. Traffic and Environmental Monitoring.

   3. Vehicle Tracking.

c. Data Management. This Support System provides the capabilities for archiving, storing, sorting, and retrieving data that ATMS requires.

   1. Data Validation.

   2. Inter-TMC Data Exchange.

   3. Document and File Management.

   4. TMC Database.

d. Traffic Management. Control and management capabilities required for managing the traffic network are provided by this Support System.

   1. Wide-Area Traffic Management.

   2. Traffic Control (for Freeways and Surface Streets).

   3. Incident Management.

   4. Individual Vehicle Routing.

e. ATMS System Management. This Support System monitors, configures, and manages ATMS assets.

1. Maintenance and Repair Scheduling.
2. Configuration and Inventory Management.
3. TMC Hardware and Software Monitoring.
4. Automated Control Software Downloading.
5. Event Planning and Scheduling.

f. Analysis and Modeling. The capabilities for analyzing and modeling all aspects of the traffic network are provided by this Support System.

1. ATMS Component Simulation Models.
2. Traffic Simulation Models.
3. Signal and Control Optimization Models.
4. Dynamic Traffic Assignment Models.
5. Integrated Modeling Manager.
6. Historical Data Analysis.
7. Origin-Destination (O-D) Processing.

g. Common Services. These are capabilities required by all of the ATMS Support Systems. Included in this Support System are the User Interface, security, inter-process communication, and operating systems. These subsystems will be primarily Commercial-Off-the-Shelf (COTS) products.

1. Inter-Process Communications.
2. Operating System.
3. Network Backbone.
4. Operator Training.
5. GUI.
6. Security.

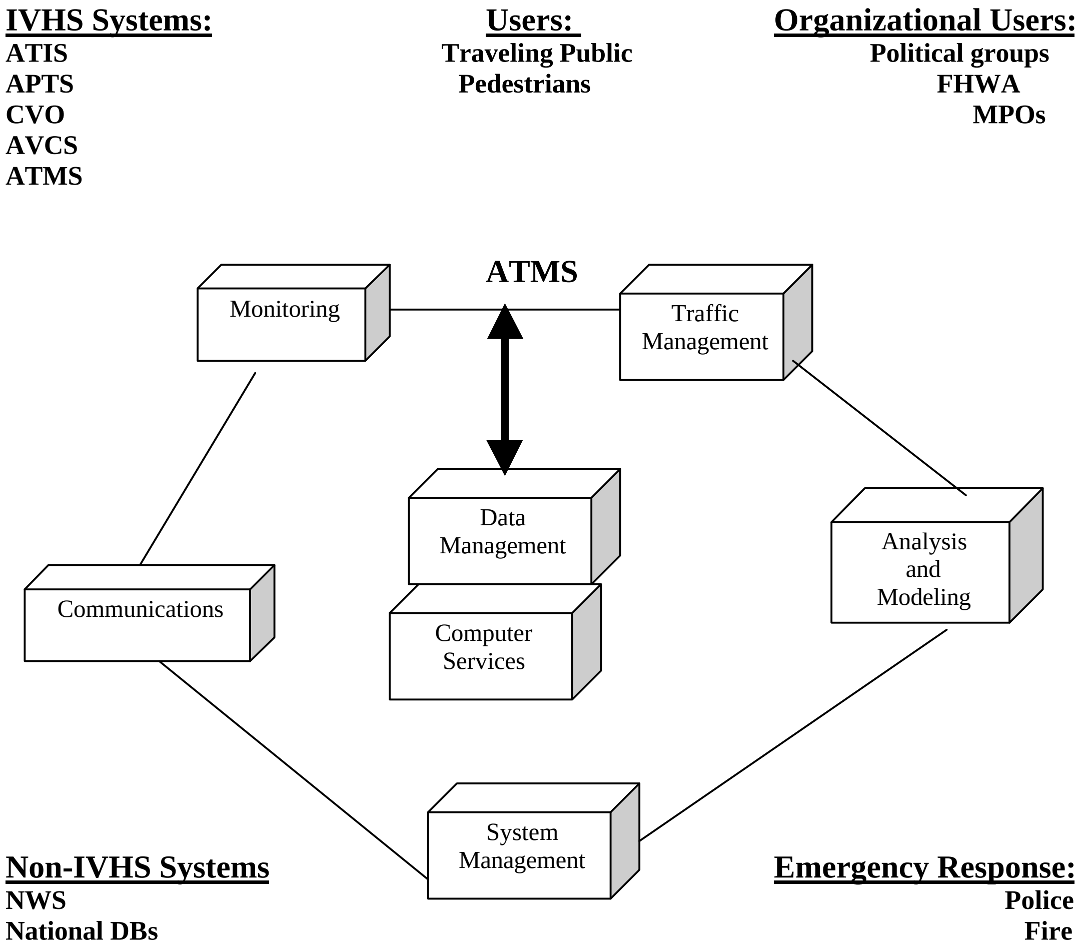


Figure 2-1. Support System Overview

In this section, illustrations will be provided that show the Support Systems and their associated subsystems. The functionality of each Support Subsystem will be discussed. Functional requirements, operator interaction, and interfaces to other Support Subsystems will be addressed. The mechanisms for conveying the functionality of each subsystem will be text descriptions and Input Process Output (IPO) charts.

Each IPO graphic summarizes the major functional requirements for the subsystem. Top Level Data flows are indicated for each subsystem-to-subsystem interface.

For the actual functional, interface, data, and performance requirements reference Appendix A, which contains the full set of requirements and specifications for each Support Subsytem.

For simplification purposes, Support Subsystem abbreviations are used commonly throughout this document. The algorithm for abbreviations is as follows: the first letter of the abbreviation indicates the Support System, and the last 3 indicate the first letter in the title of the Support System. For example the Support Subsystem Input Stream Processing that is encompassed in the Communications subsystem has an abbreviation CISP. Table 2-1 provides a mapping of letter assignments to Support Systems. Table 2-2 provides a complete list of support Subsystem acronyms.

Table 2-1. Support System/Identifier Mapping

First Letter	Support System
M	Monitoring
D	Data Management
T	Traffic Management
S	System Management
A	Analysis and Modeling
C	External Communications

Table 2-2. Support Subsystem Acronyms

Acronym	Support Subsystem	Support System
AACS	ATMS Component Simulation Models	Analysis and Modeling
ADTA	Dynamic Traffic Assignment	Analysis and Modeling
AHDA	Historical Data Analysis	Analysis and Modeling
AIMM	Integrated Modeling Manager	Analysis and Modeling
AODP	Origin-Destination Processing	Analysis and Modeling
ASCO	Signal and Control Optimization Models	Analysis and Modeling
ATSM	Traffic Simulation Models	Analysis and Modeling
CIOM	I/O Manager	External Communications
CISP	Input Stream Processing	External Communications
COSP	Output Stream Processing	External Communications
DDFM	Document and File Management	Data Management
DDVA	Data Validation	Data Management
DIDE	Inter-TMC Data Exchange	Data Management
DTDB	TMC Database	Data Management
MSIP	Surveillance Image Processing	Monitoring
MTEM	Traffic and Environmental Monitoring	Monitoring
MVTR	Vehicle Tracking	Monitoring
SACS	Automated Control Software Downloading	System Management
SCIM	Configuration and Inventory Management	Traffic Management
SEPS	Event Planning and Scheduling	System Management
SMMS	Maintenance Management	Traffic Management
STHS	TMC Hardware and Software Monitoring	System Management
TIMS	Incident Management	Traffic Management
TIVR	Individual Vehicle Routing	Traffic Management
TTCS	Traffic Control System (Frwys, SS)	Traffic Management
TWTM	Wide-Area Traffic Management	Traffic Management

2.1 Communications

The External Communications Support System receives data from external electronic systems and agencies. This system, depicted in Figure 2-2, is composed of the following three subsystems:

a. I/O Manager.
b. Input Stream Processing.
c. Output Stream Processing.

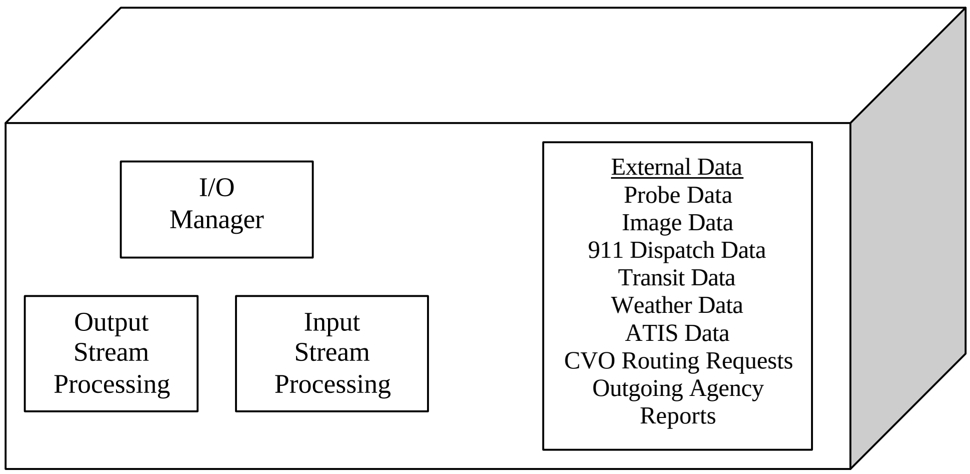


Figure 2-2. The External Communications Support System

Basically, this system receives and transmits all types of data that are not inherently bundled with the Traffic Control Subsystem. The Traffic Control Subsystem is responsible, for instance, for receiving loop detector data from the controllers that it manages. This sets the foundation so that existing and new Traffic Control Systems can fit into the ATMS architecture with minimal design modifications.

2.1.1 I/O Manager Subsystem Description

The I/O Manager (CIOM) Subsystem (see Figure 2-3) handles the scheduling of data that needs to be transmitted to other systems. This subsystem receives electronic requests to schedule output data. A request consists of an event identification and a time. Each new incoming request is inserted into a time-sorted schedule or queue. This subsystem processes the sorted queue and at the appropriate time activates the appropriate system, providing an Event ID as a key. The Event ID is referenced in the TMC DBMS to inform the individual applications of the specific type of activity that needs to be performed. In most cases, the Event ID will correspond to a set of data that needs to be transmitted to other systems. In other cases, the Event ID will be used to activate some specific processing.

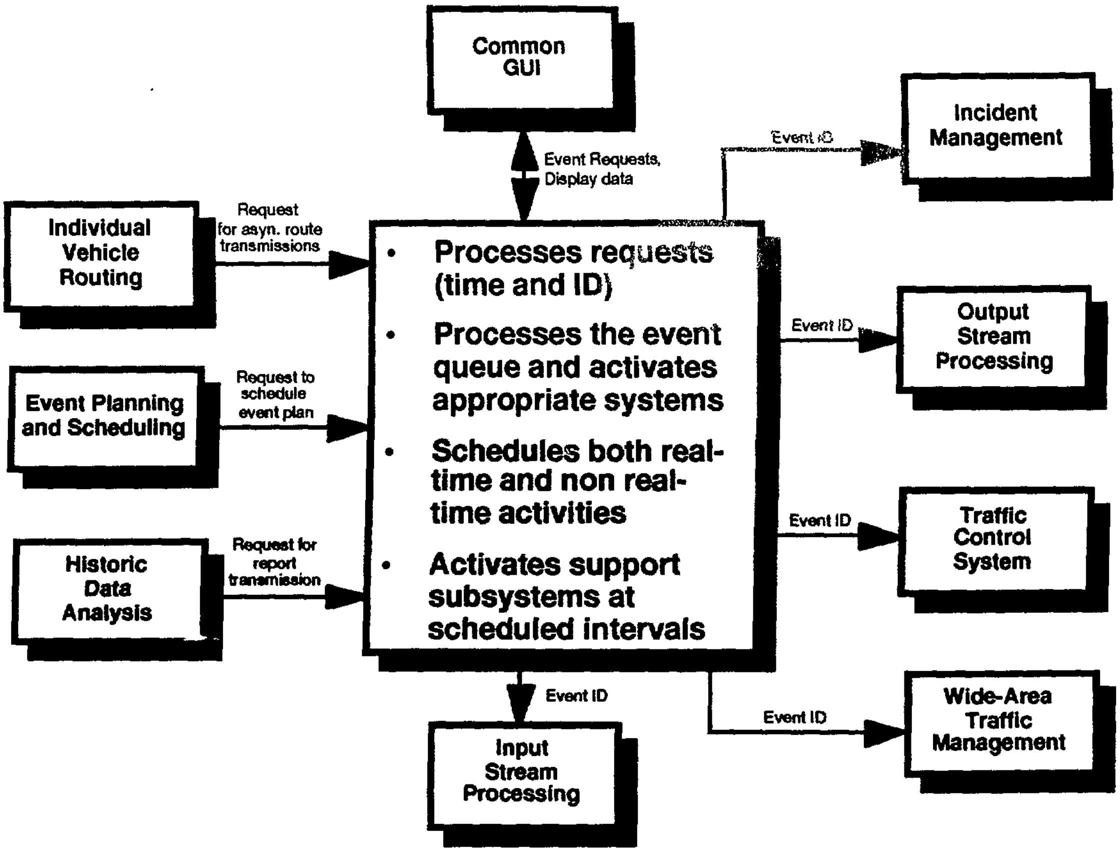


Figure 2-3. The I/O Manager Subsystem

This subsystem outputs scheduled data both to external systems and to internal systems. Requests to transmit data to external systems originate from the following sources:

a. Individual Vehicle Routing. Transmitting a computed route back to an emergency, HAZMAT or CVO vehicle.

b. Historical Data Analysis. Transmitting a regular (weekly or monthly) report to external systems or agencies.

c. Local to the CIOM Subsystem or the TMC DBMS. Transmitting subsets of the TMC DBMS to ATIS and regional ATMS. This is an co-requirement with another subsystem, reference the TMC Data Exchange subsystem requirements and issues.

Requests to transmit data to internal systems originate from the following subsystems:

a. Wide-Area Traffic Management. Transmitting notifications to a Traffic Control Subsystem that a strategy (located in the TMC DBMS) is scheduled for implementation. Note that the strategy itself is not transmitted, just the notification. The strategy will be obtained from the TMC DBMS by the appropriate control system.

b. Traffic Control. Scheduling its own implementation of tactics, or plans.

c. Event Planning and Scheduling. Scheduling strategies, tactics, or plans that will need to be implemented by Wide-Area Traffic Management and Traffic Control for planned events.

The CIOM Subsystem provides notifications of scheduled events to either the Output Stream Processing Subsystem or directly to the appropriate internal subsystem (i.e., Wide-Area Traffic Management, Traffic Control, or Historical Data Analysis). In both cases, the Event ID is transmitted. The Event ID maps to a specific activity that is configurable in the TMC DBMS. For example, when the Output Stream Processing Subsystem receives Event ID 25, it will use this ID to obtain the appropriate data from the TMC DBMS (real-time traffic surveillance or network state data, incident locations, etc.) and to transmit this data to ATIS.

Finally, this subsystem provides a user interface to display and update the contents of the event schedule.

2.1.2 Input Stream Processing Subsystem Description

The Input Stream Processing (CISP) Subsystem (see Figure 2-4) is responsible for collecting data from sources external to ATMS, this includes:

a. IVHS Systems - ATIS, CVO, APTS, AVCS, other ATMS.

b. Non-IVHS Systems (e.g., National Weather Service).

c. Organizational Users [e.g., Metropolitan Planning Organizations (MPO)] .

d. Users (e.g., the travelling public).

e. Emergency Services (e.g., police).

The role that each of these sources plays in IVHS is largely in the formative stage. Because of this the exact format, data content, and frequency of transmission are being defined. Evolving data formats constitute a risk to the CIOM Subsystem development because they could impact software design. To mitigate this risk, commercially available communications protocols and media will be used, and a modular approach will be taken to isolate evolving components.

The CISP Subsystem will receive analog, digital, and video data. It performs the following processing on these data streams:

a. Communications protocol handling.

b. Data formatting and database loading.

c. Alert generation and data routing to other ATMS subsystems.

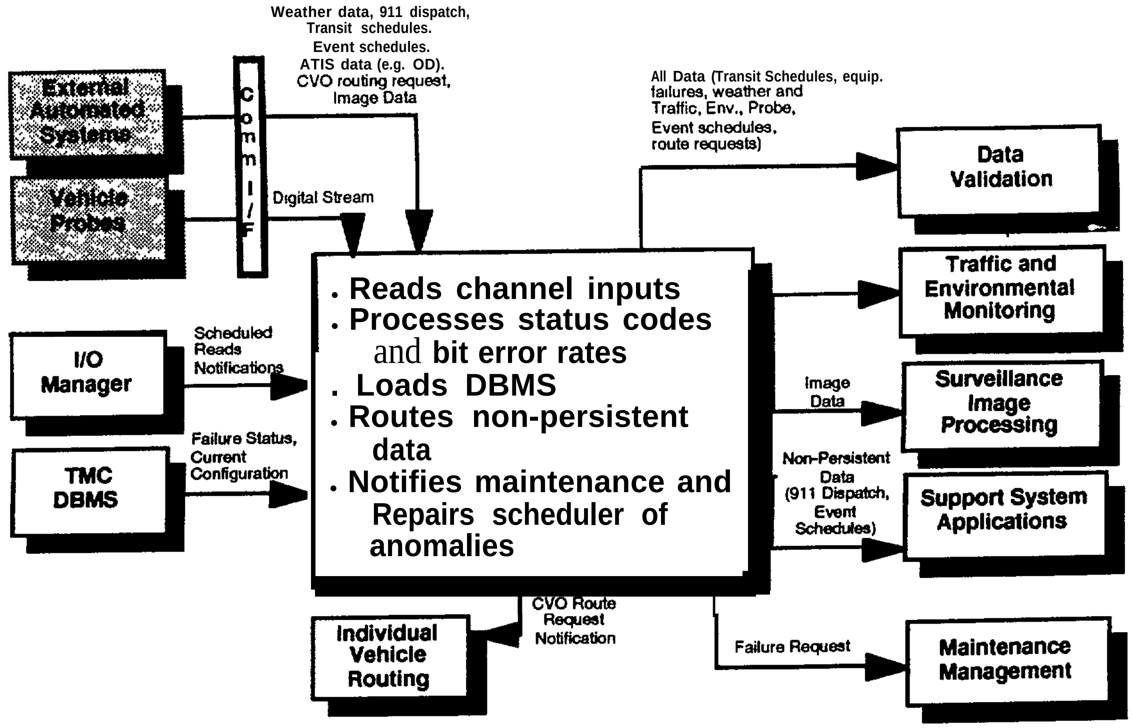


Figure 2-4. The Input Stream Processing Subsystem

The communications protocol handling that this subsystem performs includes:

a. Reading the appropriate communications channel.

b. Capturing and buffering the input data.

c. Performing communications integrity checks, such as sequence checking, CRC error checking, and acknowledgements.

d. Removing communication artifacts (e.g., packet headers and trailers).

In the event that errors are detected while performing this process, appropriate messages will be generated. These error messages will be stored for the purpose of performing analysis of the communications system performance.

The CISP Subsystem is also responsible for formatting and loading the data it receives into the ATMS database. This will be done by:

a. Extracting data from the communications packet.

b. Translating that data into the database-defined format (e.g., an integer is 32 bits).

c. Tagging the data value with a database-supplied identifier.

d. Generating the Structured Query Language (SQL) call for loading the data into the database.

e. Generating error messages in the event of a database load error.

The CISP Subsystem also generates messages that alert other ATMS subsystems that the data the other subsystem requires has been received. An example of this type of message is an alert to to the Incident Management subsystem that a request for generating a route for an emergency vehicle has been received.

2.1.3 Output Stream Processing Subsystem Description

The Output Stream Processing (COSP) Subsystem (see Figure 2-5) is responsible for transmitting data to the following sources external to ATMS:

a. IVHS Systems - ATIS, CVO, APTS, AVCS, other ATMS.

b. Non-IVHS Systems (e.g., National Weather Service).

c. Organizational Users (e.g., MPOs).

d. Users (e.g., the travelling public).

e. Emergency Services (e.g., police).

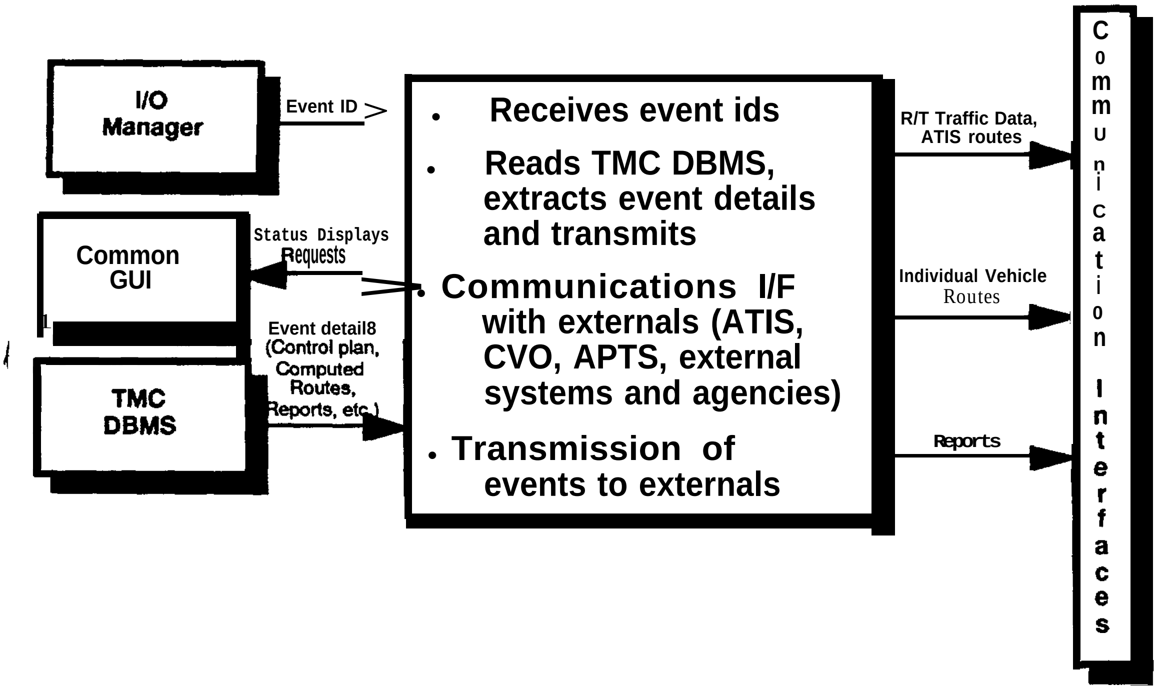


Figure 2-5. The Output Stream Processing Subsystem

As in the case of Input Stream Processing, exact format, data content, and frequency of transmission are being defined. The use of commercially available communications protocols and media will mitigate this risk.

The COSP Subsystem will transmit analog, digital, and video data. It performs the following processing on these data streams:

a. Communications protocol handling.

b. Data formatting and transmission.

The communications protocol handling that this subsystem performs includes:

a. Writing to the appropriate communications channel.

b. Performing communications integrity checks, such as sequence checking, CRC error checking, and acknowledgements.

If errors are detected while performing this process, appropriate messages will be generated. These error messages will be stored for performing analysis of the communications system performance.

2.2 Monitoring

The Monitoring Support System is responsible for data processing and traffic network monitoring. This system, depicted in Figure 2-6, is composed of the following three subsystems:

a. Surveillance Image Processing.

b. Traffic and Environmental Monitoring.

c. Vehicle Tracking.

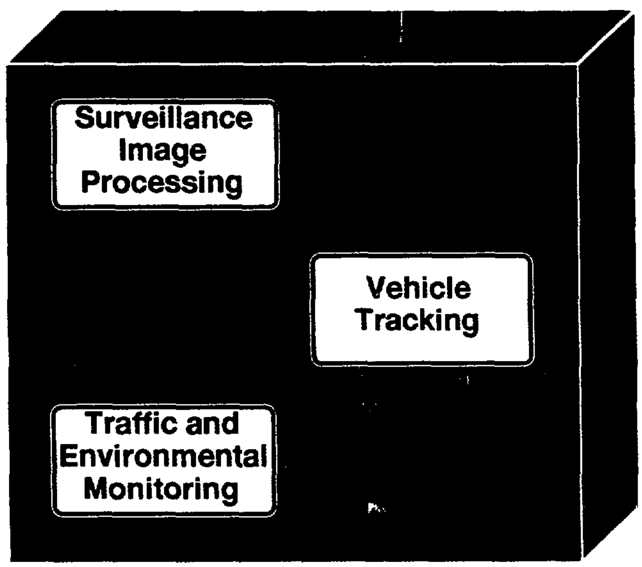


Figure 2-6. The Monitoring Support System

2.2.1 Surveillance Image Processing Subsystem Description

The Surveillance Image Processing (MSIP) Subsystem (see Figure 2-7) receives raw image data for processing from Closed-Circuit Television (CCTV) cameras in the field through the Input Stream Processing Subsystem. The primary functionality of the MSIP Subsystem includes processing the raw image from the CCTV system to perform the following:

a. Compute the traffic data (volume, density, speed, queue-length, delay, traffic classifications).

b. Detect incidents.

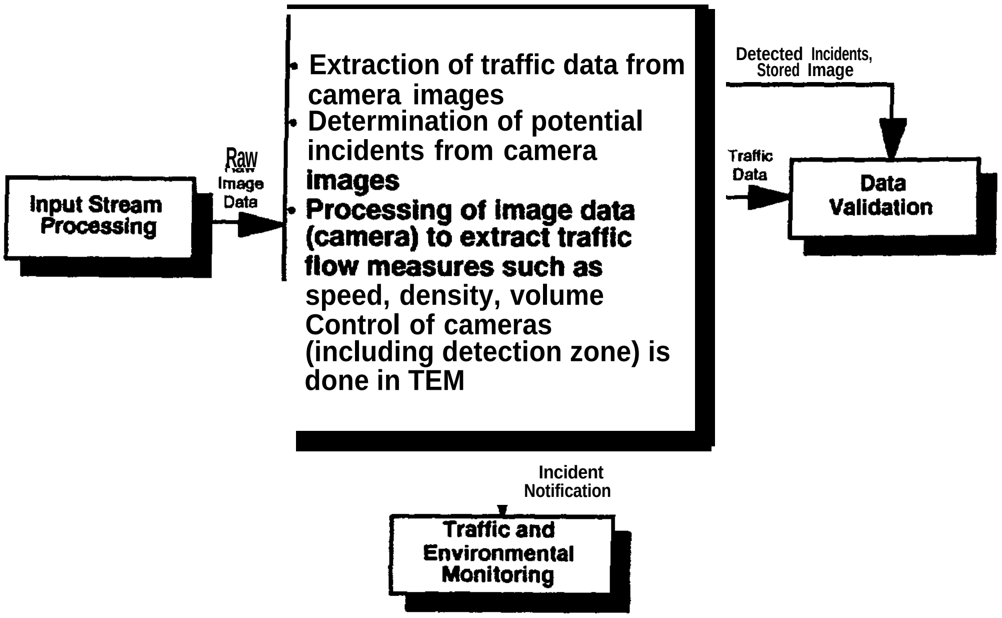


Figure 2-7. The Surveillance Image Processing Subsystem

Unlike the Traffic and Environmental Monitoring Subsystem which is used for monitoring, the MSIP Subsystem uses the raw image data only to detect incidents and calculate traffic data.

To calculate the traffic data, the MSIP Subsystem performs image analysis to emulate the inductive loop detector outputs. A detection zone for each camera is established by the Traffic and Environmental Monitoring System. This detection zone is used by the MSIP Subsystem to emulate a detector loop. The MSIP Subsystem will surpass the loop detector functions for determining the queue-length, by determining queue-length beyond the detection zone (which is missing in the loop detector outputs) as well as vehicle delays. Vehicle classification will also be provided. The MSIP Subsystem will extract the traffic data at the necessary level of details such as by lane, approach, vehicle etc. This subsystem will store the extracted data in the TMC DBMS through the Data Validation Subsystem.

The MSIP Subsystem provides a suite of Artificial intelligence (AI) techniques that will be used to detect an incident and classify it from the raw image data and the numerical data from the TMC DBMS. When an incident has been detected, the MSIP Subsystem will be able to store the raw images in the TMC database. The stored raw image will provide a base for future retrieval, and comparison for future detection and classification of accidents. The incident detection techniques will result from processing the images on a wide-area basis. The term "wide-area" implies full camera view. This is within and beyond the defmed detection zones. In case of a detected incident, the MSIP Subsystem shall support an interface with the Traffic and Environmental Monitoring Subsystem to provide notification. The Surveillance Image Processing Subsystem shall have the capability to interface with the Data Validation Subsystem to provide it with the detected incident data.

The MSIP Subsystem will perform under variable conditions. It will provide satisfactory performance under restricted visibility conditions such as low-light or adverse weather. The MSIP Subsystem will also perform under traffic conditions ranging from under-saturated to over-saturated. It will be able to distinguish individual vehicles when they closely follow each other during over-saturated conditions.

The MSIP Subsystem shall have the capability to process any digitized video image, and the flexibility for using this subsystem within the existing CCTV systems. The same camera could be used for automated image processing and occasional manual incident verification and monitoring.

The MSIP Subsystem shall have the capability to detect vehicles with 95 percent accuracy under normal conditions, and 90 percent accuracy under adverse conditions.

2.2.2 Traffic and Environmental Monitoring Subsystem Description

The primary processing functions of the Traffic and Environmental Monitoring (MTEM) Subsystem (see Figure 2-8) are:

a. Process multiple traffic and environmental sensor measurements to generate link-based estimates of traffic and environmental variables for use by all TMC Support Systems.

b. Generate network-wide estimates of traffic and environmental conditions.

C. Detect and verify incidents on both freeways and surface streets.

d. Fuse additional sources of information on incident occurrences.

e. Detect and verify surveillance equipment failures.

f. Provide operator control of CCTV cameras (pan, tilt, zoom).

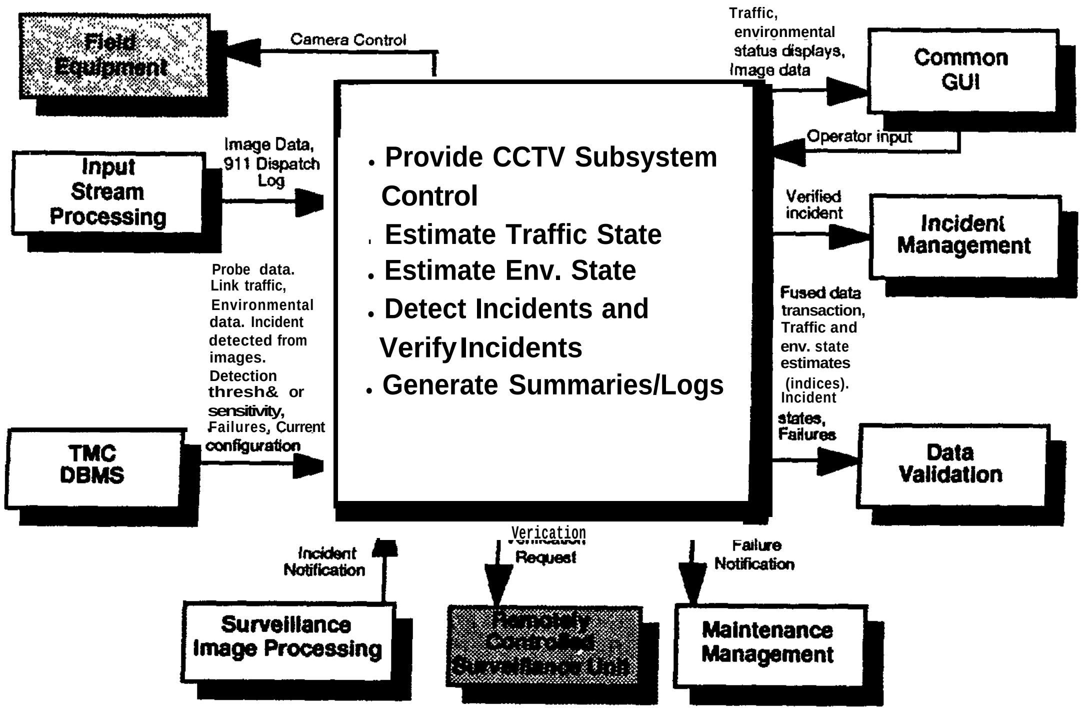


Figure 2-8. The Traffic and Environmental Monitoring Subsystem

2.2.2.1 Processing Traffic and Environmental Sensor Measurements

The MTEM Subsystem will process traffic measurements provided by traditional traffic sensors (e.g., inductive loops), and by emerging sensor technologies (sonar, image-based sensors, and vehicle probes) to produce estimates of traffic states variables such as link densities, speeds, queues, and volumes. In the course of this processing, data is fused and abnormalites in the measurements may be detected by comparisons to expected values based on the local traffic state. These abnormal measurements are flagged and eventually logged, and removed irom further processing.

Incident detection algorithms process the traffic state measurements to produce indications of the presence of incidents and estimates of the location, severity, and duration. Where incidents are not detected, estimates of the likelihood of future incidents (e.g., in the next hour) are computed based on current traffic and environmental conditions.

Reports of incidents, received via cellular phone calls, police Computer-Aided-Dispatch systems, imaging sensors, or “May Day” requests from an ATIS-equipped vehicle, are converted and stored in a common format for later retrieval.

MTEM also processes the raw environmental data to produce a current estimate of the temperature, precipitation, and roadway surface condition of each link. The link-based environmental estimates are processed to produce a single, common environmental network estimate. This data is used to set the context in which further validation of traffic data can be performed.

Finally, MTEM processes the raw air-quality data to produce current estimates of levels of selected pollutants.

2.2.2.2 Preparing Summaries Which Characterize the Current State of the Network, and Highlight Abnormalities

The traffic state estimates are processed to produce current summary measures of traffic densities, queues, speeds, and volumes of each link, and to identify areas of severe congestion. Likewise, the current environmental and air quality state estimates are processed to produce current summaries of the environmental parameters, and to highlight areas with non-normal conditions.

This common user interface shall also support the operator by providing appropriate displays of current traffic, environmental or air-quality variables, in textual and/or graphical form (i.e., shown on a network map). Abnormal values of any of these current state variables may be suitably highlighted, for example, by the use of color text or icons superimposed on the map.

CCTV equipment and associated software shall provide for remote control and local display. The CCTV equipment consists of field equipment, high bandwidth communications, and video switching and display equipment in the TMC. Functions provided through the Common GUI provide remote control of the field cameras (i.e., pan, zoom, tilt), selection of field cameras to display inside the Traffic Management Center, and specification of detection zones (to be utilized by the Surveillance and Image Processing Subsystem). A default detection zone for the camera view will be provided; however, the operator will be able to create/modify a detection zone. The MTEM Subsystem will provide self-calibration and self-referencing capabilities whenever the camera setting is changed.

Control of displays requires video switching hardware and software providing user-friendly assignment of images to multiple displays (e.g., monitors, workstations), including one or more large screen displays.

2.2.3 Vehicle Tracking Subsystem Description

The Vehicle Tracking (MVTR) Subsystem (see Figure 2-9) tracks the location of vehicles equipped with Automatic Vehicle Identification/Automatic Vehicle Location (AVI/AVL) by displaying them on a GUI superimposed on a map grid. Registered vehicles equipped with AVI/AVL will send probe data (e.g., location, speed data, and environmental data) to the ATMS system via the Input Stream Processing subsystem (which will load the DBMS with the data). The MVTR Subsystem is used for the following:

a. Tracking individual vehicles.

b. Tracking groups (or classes) of vehicles.

c. Emergency vehicle response coordination.

The user may request the display of AVI/AVL vehicles in the following ways:

a. Providing the vehicle identification.

b. Selecting a vehicle from a system-provided list.

c. Providing a vehicle class.

d. Selecting a vehicle class from a system-provided list.

e. Selecting an accident from a system-provided list of current incidents to track vehicles assigned to that incident.

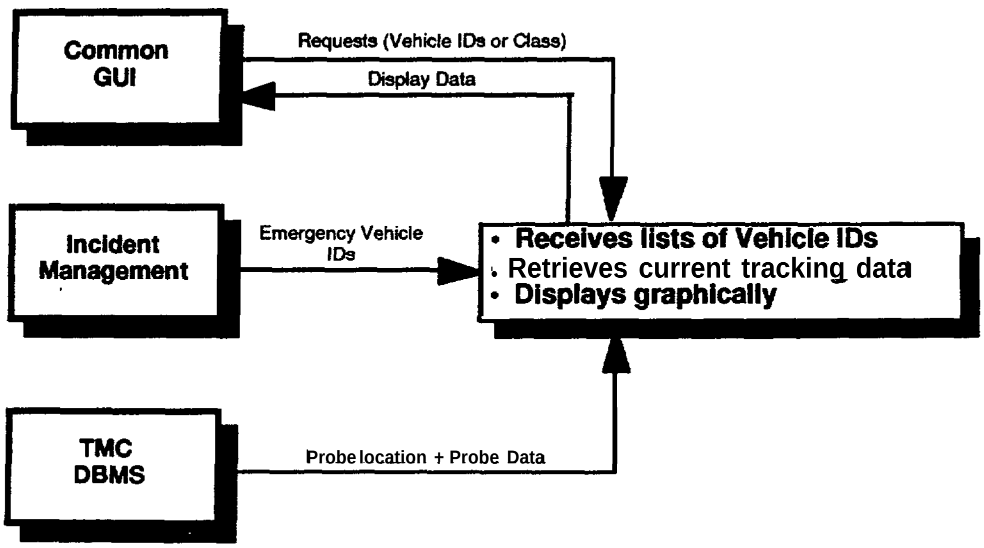


Figure 2-9 The Vehicle Tracking Subsystem

The tracking system retrieves current probe data from the TMC DBMS and displays an appropriate symbol (based on its class or vehicle type) on the correct location on the map display. The position is updated in real time. Tbe user may, at his/her discretion, select new vehicles to be tracked simultaneously or obtain additional probe data for selected vehicles. Finally, this subsystem supports an interface with the Incident Management Subsystem to receive updates to vehicles that have been assigned to an accident scene.

2.3 Data Management

The Data Management Support System is responsible for the management of data used by ATMS. This includes not only alphanumeric data that is stored in a DBMS, but also files and documents. This system, depicted in Figure 2-10, is composed of the following four subsystems:

a. Data Validation.

b. Inter-TMC Data Exchange.

c. Document and File Management.

d. TMC Database.

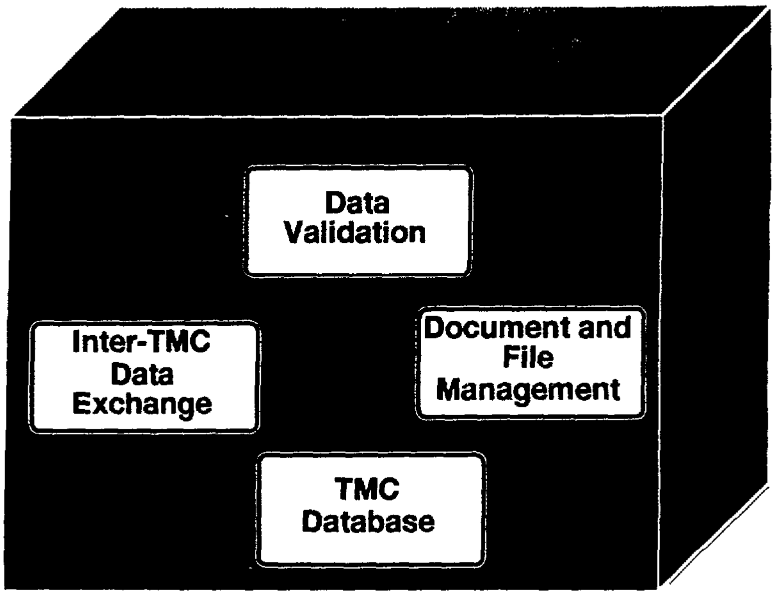


Figure 2-10. The Data Management Support System

2.3.1 Data Validation Subsystem Description

The Data Validation (DDVA) Subsystem (see Figure 2- 11) provides an interface layer between all application software and the TMC database for update transactions. It is a library of data validation routines that are automatically exercised prior to the data being stored in the database, and can be called by applications for optional validation. The subsystem contains functions and procedures used to automatically derive the limits that determine data element validity from context-based parameters.

Specific capabilities for the user interface and support for defining the parameters used in validation routines are expressed in the requirements specified in Appendix A. The key features of the subsystem are the following:

a. Various validation levels ranging from format checks to context-determined limits.

b. Detection of equipment failures (this requirement is co-allocated to the Traffic and Environmental Monitoring Subsystem).

c. Restricted user access control and Application Program Interface (API).

d. Automatic derivation of context-based limits on data values using functional evaluations and rule-based procedures with the capability to process user/application input parameters.

e. User input value deactivation after a user-specified time limit.

f. ANSI standard SQL DBMS interface.

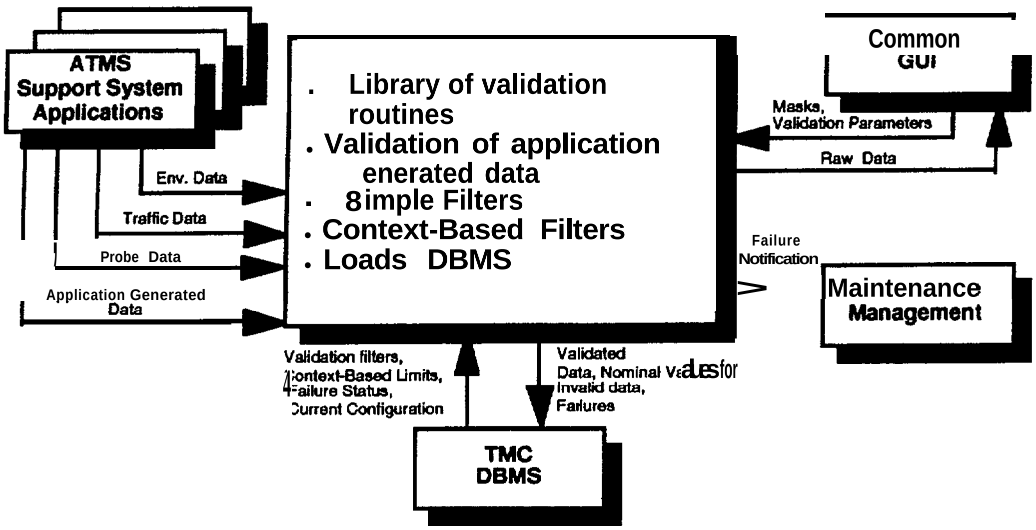


Figure 2-11. The Data Validation Subsystem

2.3.2 Document and File Management Subsystem Description

The Document and File Management (DDFM) Subsystem (see Figure 2-12) is responsible for providing online access to all files and documents used in the ATMS. Although any file may be part of the DDFM library, it is intended to provide storage for the following types of files and documents:

a. Manuals for local and regional policies.

b. Jurisdictional polices and objectives.

c. ATMS budgets.

d. ATMS plans.

e. Traffic control contingency plans.

f. Executable object code, source Code for ATMS subsystems.

g. Diagnostic procedures.

h. Field maintenance and repair manuals.

i. Configuration procedures.

j. Other text documents.

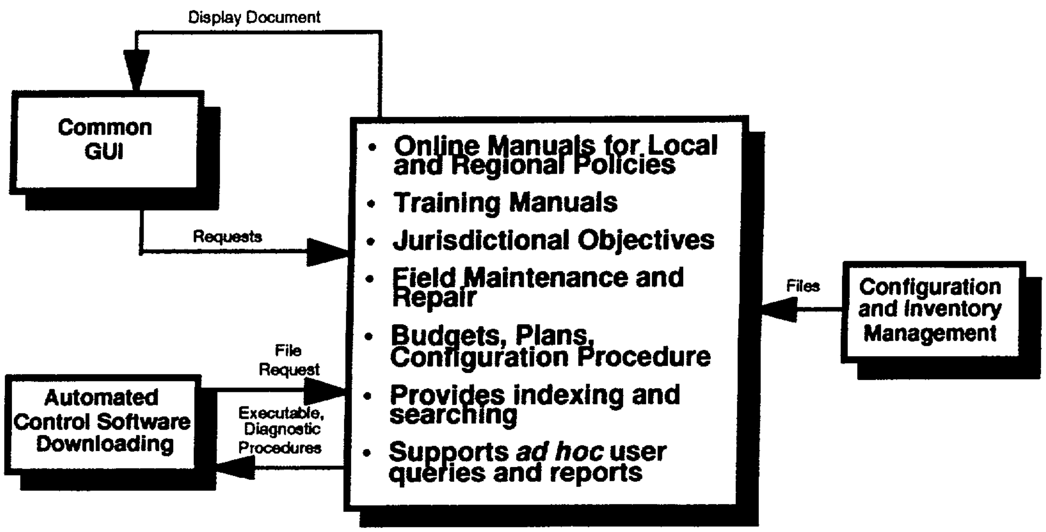


Figure 2-12. The Document and File Management Subsystem

This subsystem is responsible for locating various documents and for retrieving them so that they may be displayed by the user. There are several ways to locate a document, including:

a. Viewing a list of Document Titles and selecting the appropriate one.

b. Searching document titles for keywords.

c. Searching selected documents (text search) for keywords.

Once a document is located and displayed, this system provides the user with browse, search, and report options. Support for grouping documents together under a "Bookshelf" name is also provided. For instance, all maintenance and repair related documents can be grouped together under a common name.

2.3.3 Inter-TMC Data Exchange Subsystem Description

The requirements for the Inter-TMC Data Exchange (DIDE) Subsystem (see Figure 2-13), stem from the support needed for the operation of the TMC in a distributed ATMS environment. In this environment, multiple TMCs cooperate to manage traffic on a wide-area basis, with each TMC maintaining control of its hardware and data resources. In such an environment, data must be shared in a timely fashion by the cooperating agents to effect control.

The DIDE Subsystem resides at both ends of the two-way exchange: at the sending end, it captures the data to be exchanged, reformats, and sends; at the receiving end, the DIDE Subsystem pulls the data, reformats, and loads the DBMS. This type of exchange assumes a “replication architecture.” Replication architectures work well in a homogeneous distributed database configuration. However, due to the unlikelihood of homogeneous environments, this architecture can accommodate heterogeneous environments as well.

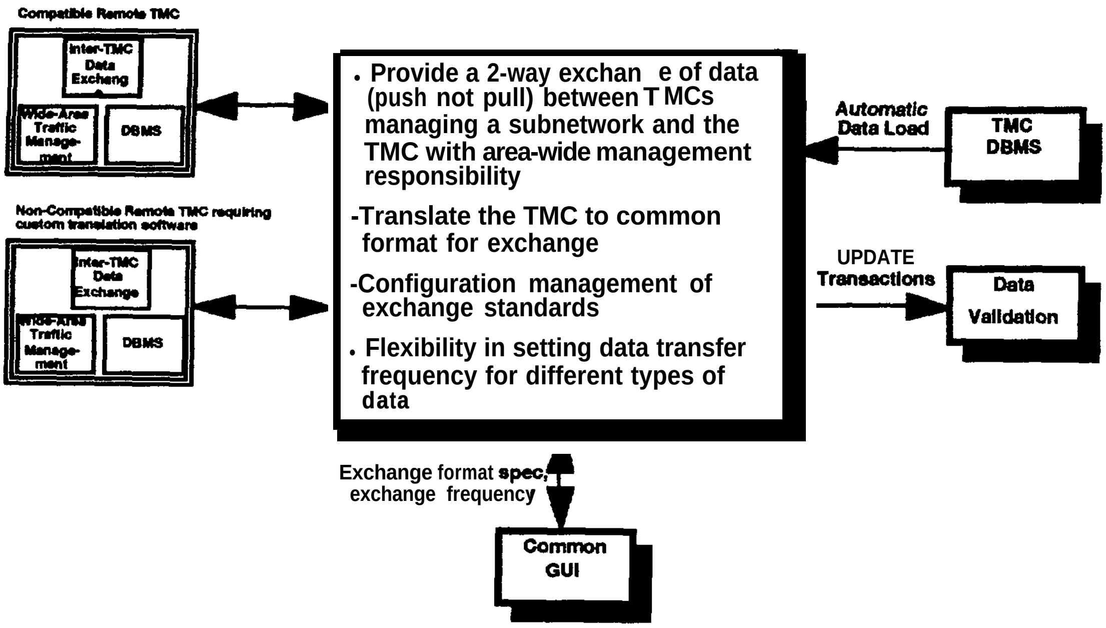


Figure 2-13. The Inter-TMC Data Exchange Subsystem

The DIDE Subsystem will support the translation of data from non-standard databases in cases where local TMCs have non-SQL databases and file structures. This situation is likely to arise as ATMS is deployed; it will definitely arise during the testing phase of this project, since not all state-of-the-practice TMCs use relational DBMS with ANSI Standard SQL. To meet this requirement, the DIDE Subsystem will provide custom interfaces to such databases.

2.3.4 TMC Database Management Subsystem Description

The TMC Database Management (DTDB) Subsystem (see Figure 2- 14) manages the storage and retrieval of all data needed by the TMC to perform its primary control and internal support functions. Three primary classes of data are considered the responsibility of the DBMS: alphanumeric structured data (including text fields), map data, and geo-referenced data. Presently, TMC documents and knowledge bases are contained within separate support systems.

The configuration of the database is a design consideration which is subject to the data and performance requirements imposed on the DBMS. These requirements reflect the various processing needs of applications, ranging from real-time to offline, and the data needs. Key operational requirements of the DBMS are the following:

a. Access to all data needed by the TMC for its operation within an integrated IVHS environment.

b. Transparent interface to the Inter-TMC Data Exchange Subsystem for receiving and sending data needed for area-wide management of traffic.

c. Flexibility of the DBMS in supporting online modifications to the data structures.

d. Quick response.

e. Integrity and security maintenance.

f. Procedures for backup, archiving, recovering, and other offline data management support.

g. Support for minimizing the effects on application source code for evolving data structures.

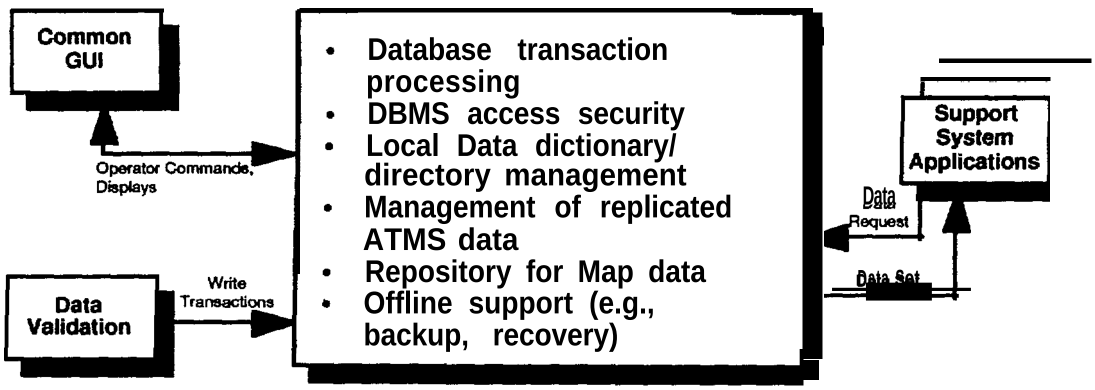


Figure 2-14. The TMC Database Management Subsystem

These features of the DTDB Subsystem reflect an overall data-centered approach to TMC support system design and are essential to accomplish the goal of modularity and openness. The benefits resulting from this approach include:

a. All subsystems have straight-forward, uniform access to any portion (or all, if appropriate) of the data maintained by ATMS.

b. A "data sharing" environment is encouraged, thus reducing data redundancy. Data is not duplicated by many subsystems. The advantages to reducing data redundancy are:

1. Physical storage requirements are minimized.

2. Data integrity is increased. Data modifications will require updating a single copy of the data. The risk of data corruption resulting from multiple copies of data not being updated is eliminated.

3. System resources are conserved since duplicate data is not processed and maintained.

c. The use of a commercial relational database provides a proven facility for maintaining data. Each individual subsystem will not be required to create its own “custom data management facility” to maintain and retrieve data.

d. Performance tuning issues (such as indexes and memory management) are addressed using the COTS relational database rather than relying on each individual subsystem to properly structure, maintain, and optimize its data. As a result, performance issues are addressed at a system-wide level to balance the overall operation of the ATMS environment.

e. *Ad hoc/new* queries and reports that access data utilized by any subsystem can be easily created using the facilities provided by the COTS relational database. Each individual TMC is able to create these queries and reports to meet their individual needs and requirements without impact to the existing subsystems.

Since the DTDB Subsystem provides a data-centered approach to data management, special attention to hardware and software configurations is necessary to optimize performance and minimize the risk of a major system failure. Reliability of the DTDB Subsystem is dependent on the following items:

a. The COTS relational database will be configured in a client-server architecture within a network of UNIX workstations. The subsystems utilized by ATMS users working on individual workstations will function as clients to the database server. A specific machine will be designated as the database server machine, but operational control will be provided so that the database server may reside on alternate machines within the network. In the event of a database server machine failure, the database server may be started on another machine.

b. To minimize the impact of disk failures, ATMS will mirror critical database data on secondary disks. In the event of a single disk failure, the database server will continue to operate without interruption. When the failed disk is replaced and brought online, the data will be restored without the need to stop processes. The DTDB Subsystem will not experience a system failure due to disk failure unless a primary and its corresponding secondary disk fail.

   Data mirroring may be implemented using facilities provided by the COTS database or by the operating system. These two alternatives implement the functionality in different ways:

1. The COTS database alternative will mirror the data by writing sequentially to the two disks. The time required to complete database updates is essentially equivalent to twice the time required in a non-mirrored environment.

2. Provided the primary and mirrored data is configured on separate disks and disk controllers, the operating system alternative will write the data to both disks nearly simultaneously. In addition, data will be read from the disk that has the shortest "seek time" (time required to move disk head to proper disk location).

Using the operating system to mirror the data is the preferred mechanism since it is more efficient than the COTS database alternative.

c. The COTS relational database maintains a log of all transactions. In the event of a system failure, such as power loss, the COTS relational database will utilize the transaction log to restore the database to a consistent state. Committed transactions are maintained and uncommitted transactions are rolled back (deleted) to bring the system back online without data loss. This transaction log is also used to perform routine backups and recoveries of the data.

As a described above, the data management facilities of the DTDB Subsystem allow uniform data access, performance optimization, and data consistency. Fault tolerance requirements are satisfied through the client-server architecture and disk mirroring. With these capabilities, the risk of a single point of failure is dramatically minimized. The reliability of such an arrangement is essentially 100 percent.

2.4 Traffic Management

The Traffic Management Support System is responsible for the traffic control and management of the traffic network. All traffic control is performed by the Traffic Control System. Wide-Area Traffic Management is proactive and coordinates with the various Traffic Control Systems at each TMC for network-wide optimization, not necessarily subnetwork optimization. Wide-area Traffic control notifies the Traffic Control System of optimizations to be implemented. The Traffic Control system is responsible for implementing the optimization by directly communicating with signal and control equipment. The Traffic Management Support System, depicted in Figure 2-15, is composed of the following four subsystems:

a. Wide-Area Traffic Management.

b. Traffic Control (for Freeways and Surface Streets).

c. Incident Management.

d. Individual Vehicle Routing.

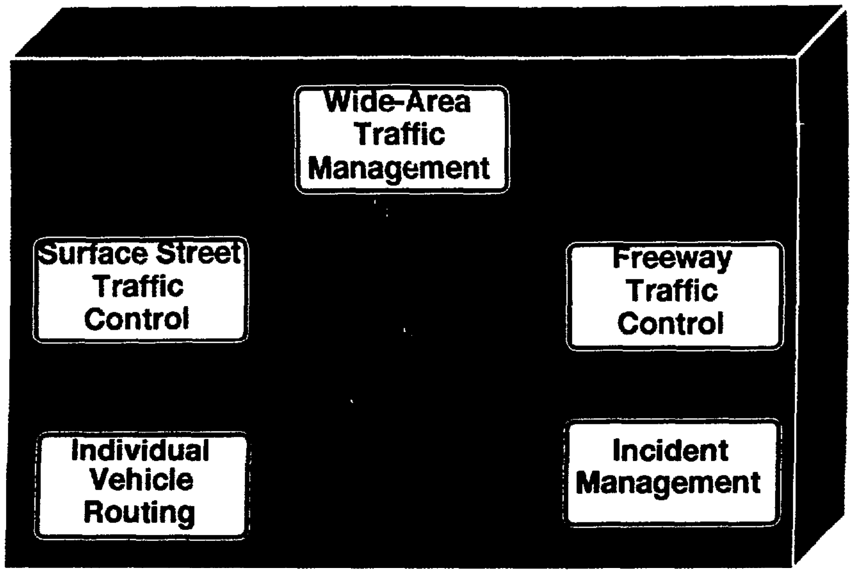


Figure 2-15. The Traffic Management Support System

2.4.1 Incident Management Subsystem Description

The Incident Management (TIMS) Subsystem (see Figure 2-16) provides assistance in the management of major incidents by supporting the following functions:

a. Classification of incidents.

b. Determination of severity and expected duration.

c. Monitoring the status of incidents until they are cleared.

d. Identification of appropriate agencies and resources to handle the incident site.

e. Provision of detailed procedures for coordination with these agencies.

f. Notification to the Traffic Control subsystem that an incident requires management.

g. Notification to the Individual Vehicle Routing Subsystem that emergency vehicles have been assigned to an incident.

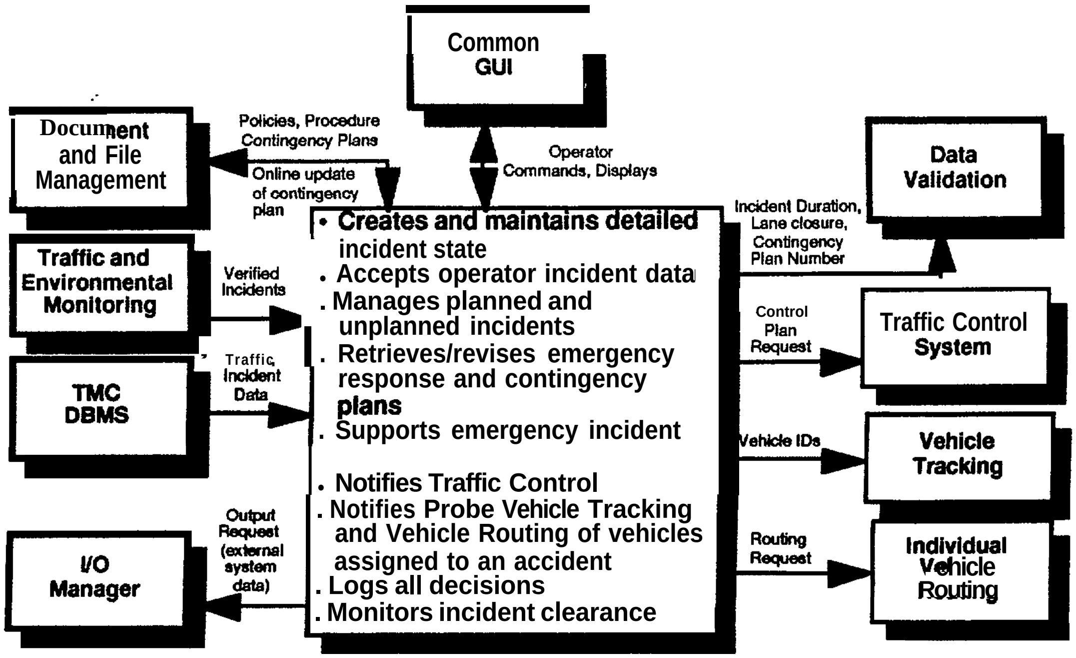


Figure 2-16. The Incident Management Subsvstem

The Incident Management Subsystem is supported by the Event Planning and Scheduling Subsystem through which contingency plans are developed for response to indicents of various types. The contingency plans developed offline are stored in the TMC database where they are available for retrieval when responding to incidents. They reflect the policy and procedures of the various emergency response agencies and the agreements between the TMCs and those agencies. The initial response and the real-time monitoring of the incident clearance is the responsibility of TIMS, which cooperates with the Traffic Control Subsystem through data interchange to manage the traffic conditions resulting from the incident.

Execution of incident site management plans also entails routing of emergency vehicles. The Incident Management Subsystem provides information to the Individual Vehicle Routing Subsystem to initiate a coordinated response (signal preemption on surface streets and metering or closure of freeways). These vehicles are also identified to the Individual Vehicle Routing Subsystem.

2.4.2 Traffic Control Subsystem Description

The Traffic Control (TTCS) Subsystem (see Figure 2- 17) supports the traffic control function for a single intersection, a sub-network, or a control region. It performs real-time, traffic adaptive signal control. It also supports the use of other control modes, such as those used in the traditional Urban Traffic Control System (UTCS) and those that will be developed within the emerging IVHS information rich environment.

The primary functions of the TICS Subsystem are: to effect the control of traffic flow within its jurisdiction, to manage the equipment resources including surveillance sensors, the controllers, other access control equipment, and the communication system, and to participate in region-level coordination with other Traffic Control Systems (TTCS) through interaction with the Wide-Area Traffic Management (TWTM) Subsystem.

The primary physical subsystems of a traffic control system are: surveillance, including all detectors and sensors which are considered to be organic to the control system; the internal communication system to manage communication within all elements of the control architecture; the controllers and associated signal equipment, traffic signs and associated equipment; access control equipment such as gates and moveable lane markers; and control and equipment monitoring software within and outside the TMC. Other support software such as section or network level traffic monitoring, database, user interface, and support for offline analysis of timing plans, (which would normally constitute additional 'ITCS subsystems) are considered for the purpose of this specification to be ATMS Support Systems which will serve the TTCS.

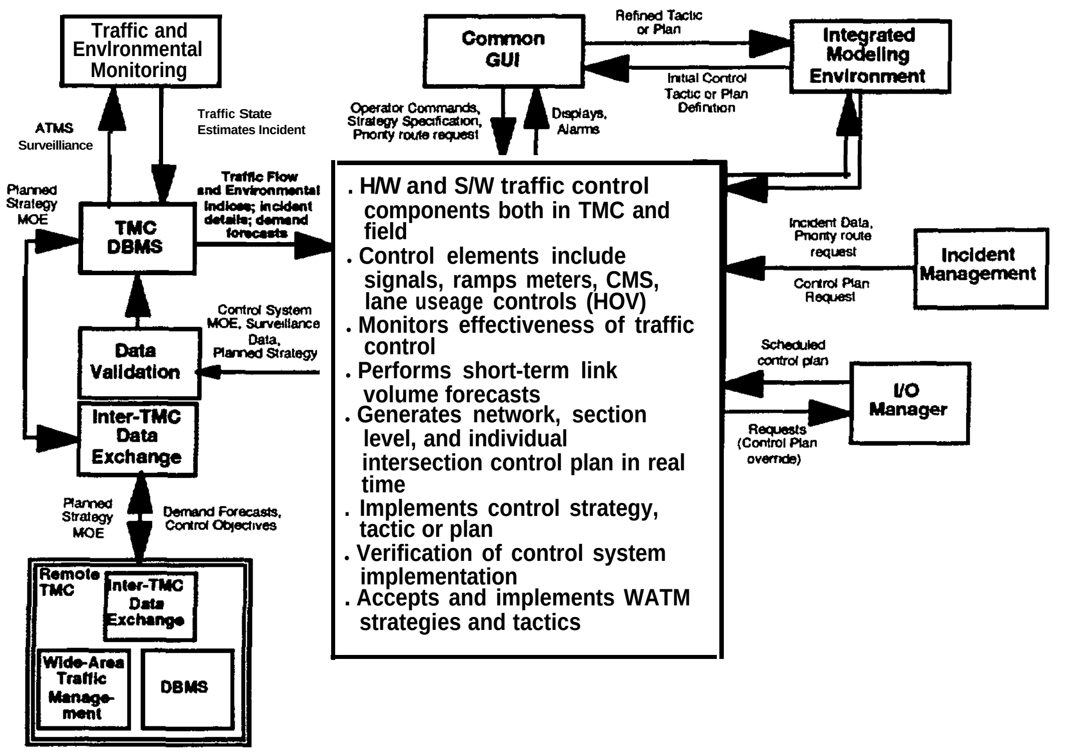


Figure 2-17. The Traffic Control Subsystem

It is assumed that the TTCS Subsystem can control freeways, surface streets, and/or a combination of both in a corridor. As shown in Figure 2-18, the coordination between two or more traffic control subsystems is achieved through the regional strategy selection performed by the Wide-Area Traffic Management Subsystem. This is implemented by the effected TCSs through the exchange of data with the Wide-Area Traffic Management Subsystem node via the Inter-TMC Data Exchange Subsystem and the ATMS Communication Network. If a communication link is down, then the data will be routed via another TMC.

In optimizing traffic flow, the TTCS Subsystem shall use its organic surveillance data supplemented by additional information received from the Wide-Area Traffic Management Subsystem to select an appropriate control strategy/tactic and to produce the signal timing parameters (e.g., cycle length, split, offset, phase sequence) that are "optimal" for the selected strategy. The definition of "optimality" is in part determined by the strategy selection and in part by the overall control configuration of the system. For example, a congestion strategy will define optimality in terms of queue lengths rather than vehicular delay. Optimality in a centralized configuration consists of network delays; in a distributed configuration, optimality conditions are determined at the local level.

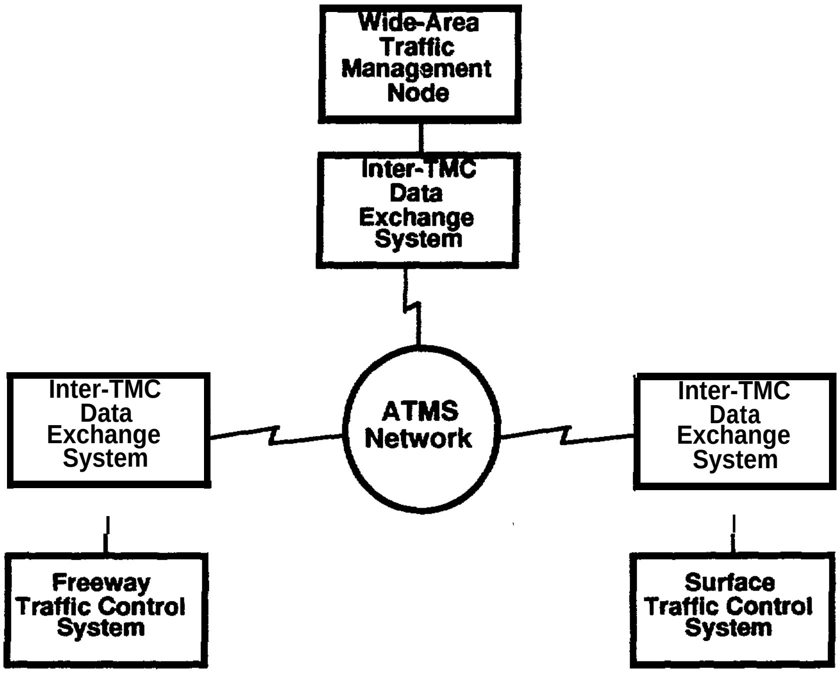


Figure 2-18. Traffic Control Subsystem Interfaces

The control architecture also has a significant impact on other requirements, foremost among which are the communication system requirements and the data processing requirements at the TMC. With multi-level architectures and non-central plan generation, data loading requirements at the TMC are minimized at the expense of system optimal solutions. For the purpose of this specification, the TTCS control architecture is not salient because the communication with other TCSs and TMCs is assumed to occur between top-level controllers only. Furthermore, the communication between traffic control and individual vehicles for the purpose of route selection and probe data exchange has been assumed to occur outside the immediate scope of the TTCS and has been allocated to other support systems within the TMC.

2.4.3 Wide-Area Traffic Management Subsystem Description

The Wide-Area Traffic Management (TWTM) Subsystem (see Figure 2-19) is responsible for providing support for the following:

a. Proactive traffic management over a large traffic network consisting of one or more traffic control subsystems, either surface street, freeway and/or corridor.

b. Implementing demand management policies and strategies that include the control of High Occupancy Vehicle (HOV) facilities, reversible lanes, and coordination with public transportation systems.

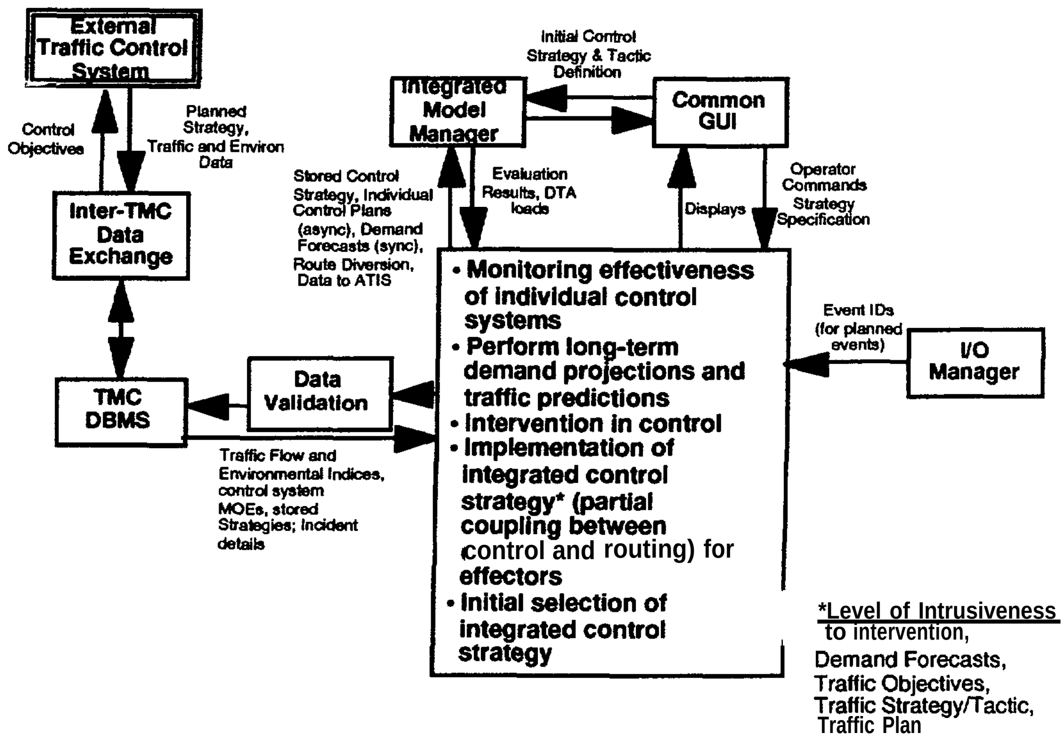


Figure 2-19. The Wide-Area Traffic Management Subsystem

It is assumed that a single TWTM Subsystem exists within an ATMS region. This TWTM Subsystem may be implemented in any of the Traffic Management Centers within the ATMS region, and will be accessible from each of the Traffic Management Centers within the ATMS region. The TWTM Subsystem will communicate with TWTM Subsystems in other ATMS regions.

Coordination between individual traffic control systems can be accomplished through:

a. The formulation of individual control objectives and control constraints that will support coordinated operation.

b. The development of demand forecasts that anticipate traffic conditions in one control area based on observed demand and control strategies in other control areas and information from dynamic assignment and vehicle routing systems.

c. The prediction of local and area wide congestion and congestion propagation in response to detected incidents and incident management plans.

The formulation of control objectives and control constraints to support coordinated operation are strategic traffic management functions and must include consideration for individual jurisdictional policies and practices, demand management considerations, incident management strategies, and current traffic conditions and demand. The current traffic conditions and demand includes routing considerations for individual vehicles, through the Dynamic Traffic Assignment Subsystem or through travel demand information. Strategic control objectives may include minimization of delay, stops and/or queue length, or maximization of throughput, or a weighted combination of these. During periods of congestion in one control area, signal control may be used for metering the flow of traffic into the congested area. Control constraints may consist of maximum fixed cycle lengths, limiting ramp meter rates to improve freeway flow (upper metering rate limit) or reduce queue spillback (lower metering rate limit) as well as constraining the signal timing associated with the interchange approaches that are feeding the congested freeway off ramp.

The TWTM Subsystem will generate specific tactics (ramp metering rates, signal timings, etc.) in the case of incidents or when the Traffic Control Subsystems fail or are not capable of generating the necessary tactics. Although the TWTM is responsible for the generation of the tactic, the traffic control subsystem is responsible for its implementation. The traffic control subsystem is responsible for communicating directly with signal and control equipment to implement the tactic.

Demand forecasting provides the proactive responsiveness of the TWTM Subsystem. Demand forecasts are based on historical travel patterns, observed origin-destination pairs from probe vehicles, assigned vehicle routes from the Dynamic Traffic Assignment Subsystem, and current traffic conditions and controls. It is important to recognize that TWTM does not depend on the use of probe data, however, the TWTM algorithm needs to be able to receive probe data, when available.

The prediction of local and wide area congestion, and congestion propagation in response to detected incidents and incident management plans, provides the reactive responsiveness of the TWTM Subsystem as well as information essential to the responsive coordination across several individual traffic control systems. The evolution of congestion after an incident begins with increased congestion in the area immediately surrounding the incident. The level of congestion depends on traffic conditions and how much roadway capacity is restricted by the incident. The local area effected by the incident may include local side streets, frontage roads, and adjacent arterials. Local area traffic control considerations, such as phase skipping, movement blocking and preemption for emergency vehicles may be required to improve traffic flow as well as increase the safety considerations of the on-site incident management team. The geographic size of this local area will increase for a period following the incident. As travelers observe increased traffic congestion and are advised of the incident and impending delays, they will begin to select alternative routes. This route diversion will effect traffic demand in a wider area and hence the need for management and coordination considerations.

Another important function of the TWTM Subsystem is to provide monitoring, prediction, and control consideration as a result of environmental conditions such as rain, snow, and ice. Anticipation of increased risk associated with environmental conditions can be translated into control objective and constraints formulations to increase safety through traffic control.

Support for the implementation of demand management policies and strategies includes the control of HOV facilities, reversible lanes, and coordination with public transportation systems. As part of a demand management policy, an HOV lane may be allocated to encourage ride sharing. In the event of an incident or special event, the HOV lane could be reallocated for general use to relieve congestion. Similar considerations can be made for reversible lanes and HOV priority ramp metering. Signal control priority and coordination for public transportation vehicles (buses, light rail, etc.) and allocation of lanes and facilities for exclusive use are other possible demand management strategy implementation methods.

The TWTM Subsystem will support operator decision making through the GUI where the processed surveillance and detection information, as well as the strategic and tactical controls, are presented to the operator in a format that is consistent with their view of the network operating conditions. The GUI will be used to allow operators to implement management decisions.

2.4.4 Individual Vehicle Routing Description

The Individual Vehicle Routing (TIVR) Subsystem (see Figure 2-20) develops optimal routes for specific trips upon requests received by the TMC from a variety of sources. Since the trip can extend over a significant period of time, it will be necessary to “roll” the optimal trip path determination as conditions change during the course of the vehicle’s travel. Each of these requests for special routing guidance should be analyzed either by the software or by the operator to determine its urgency and validity.

Assuming that the request is accepted, the trip is assigned a priority classification as a basis for determining the kinds of response that the TMC should provide. This response may be limited to information given to the vehicle (e.g., the next segment of path) or may involve a control and wide area guidance response to provide an extremely favored treatment for the vehicle of interest. If a control response is to be provided, then the vehicle’s position, projected path segment over the coming time period, and the vehicle’s desired speed will be provided to the traffic control policy so that action can be taken to provide expedited service for the vehicle. If, in addition, it is desired to divert other traffic from the path of this vehicle, then the wide area control support system must be alerted to that requirement to take the appropriate action.

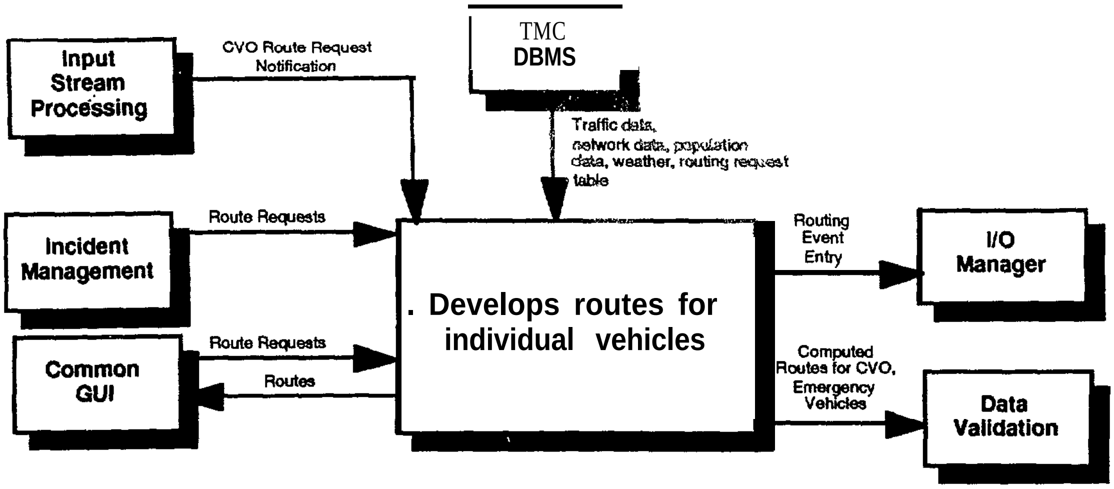


Figure 2-20 The Individual Vehicle Routing Subsystem

In any case, the status of the vehicle will be updated at rather short intervals (e.g., every minute or two) with a new path segment computed based upon the changing conditions defining the traffic environment. Furthermore, if an incident should develop which would impact the path of this vehicle over the current segment, then this support system will be activated to perform an immediate recalculation of the optimal path to contend with the sudden change in the traffic environment.

The TIVR Subsystem will interact with the operator through the GUI keeping him/her informed of the current state of the trip and accepting any instructions from the operator that will influence the path determination.

2.5 System Management

The System Management Support System monitors, configures, and manages ATMS assets. Support for planning and scheduling of construction and special events is also provided in this system, This system, depicted in Figure 2-2 1, is composed of the following five subsystems:

a. Maintenance Management.

b. Configuration and Inventory Management.

c. TMC Hardware and Software Monitoring.

d. Automated Control Software Downloading.

e. Event Planning and Scheduling.

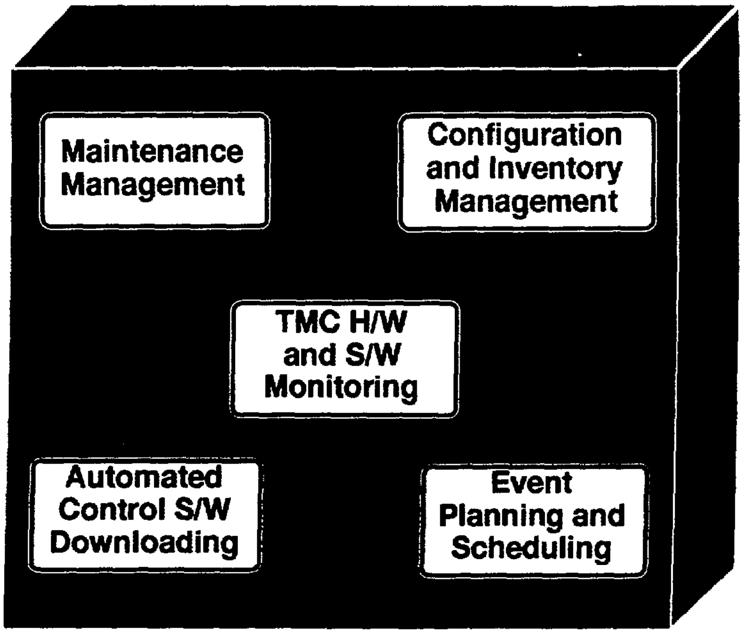


Figure 2-21. The System Management Support System

2.5.1 Automated Control Software Downloading Subsystem Description

The Automated Control Software Downloading (SACS) Subsystem (see Figure 2-22) is a support tool that allows electronic transmission of software to selected field equipment in a remote site. The types of software transmitted to controllers or processors in the field includes the following:

a. Executable.

b. Data Files.

c. Diagnostic Procedures.

This subsystem will display the current configuration of controllers and processors in the field from data obtained in the TMC DBMS. Included in the display are details to reveal the version of software executing, the executable name, the date revised, etc. Also included is the communication network for each controller selected (an assumption is being made that controllers have a dynamic communication wireless network that is reconfigurable). Support will then be provided to allow the user to select various controllers (all for a particular subnetwork, by kind, or individual ones) that are to be sent software.

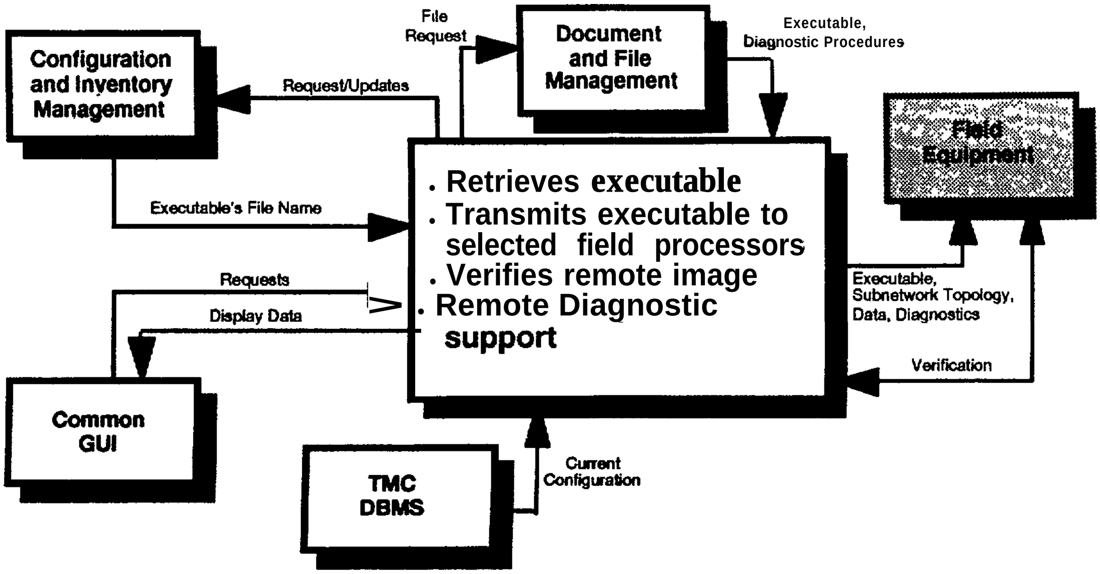


Figure 2-22. The Automated Control Software Downloading Subsystem

The user, through the user interface, will be able to do the following:

a. See displays of the current configuration.

b. See details for a particular component in the configuration.

c. Select components (controllers, processors) to receive software (executables, data files, diagnostics) by individually selecting components by subnetwork, network, or type.

d. Trigger the retrieval the appropriate software from the Document and File Management subsystem.

e. Transmit the software to the field.

f. Start or restart software in the field.

g. See verification from the field that the software was instituted.

When executables are sent, they are to replace existing control software executables. When data files are sent they are to replace existing data files that provide data to the system at initialization or run-time. The data files can include any type of data file the control software uses (e.g., data to reconfigure the dynamic communication network). In either of the two previous cases, support will be provided to remotely restart the control software. When diagnostic procedures are sent, they will be executed and results will be electronically sent back to the TMC.

After verification is received from the field equipment that the new control software is successfully in place, the Configuration and Inventory Management Subsystem will be electronically invoked and supplied with the updated configuration.

2.5.2 Configuration and Inventory Management Subsystem Description

The Configuration and Inventory Management (SCIM) Subsystem (see Figure 2-23) supports both configuration management and inventory management.

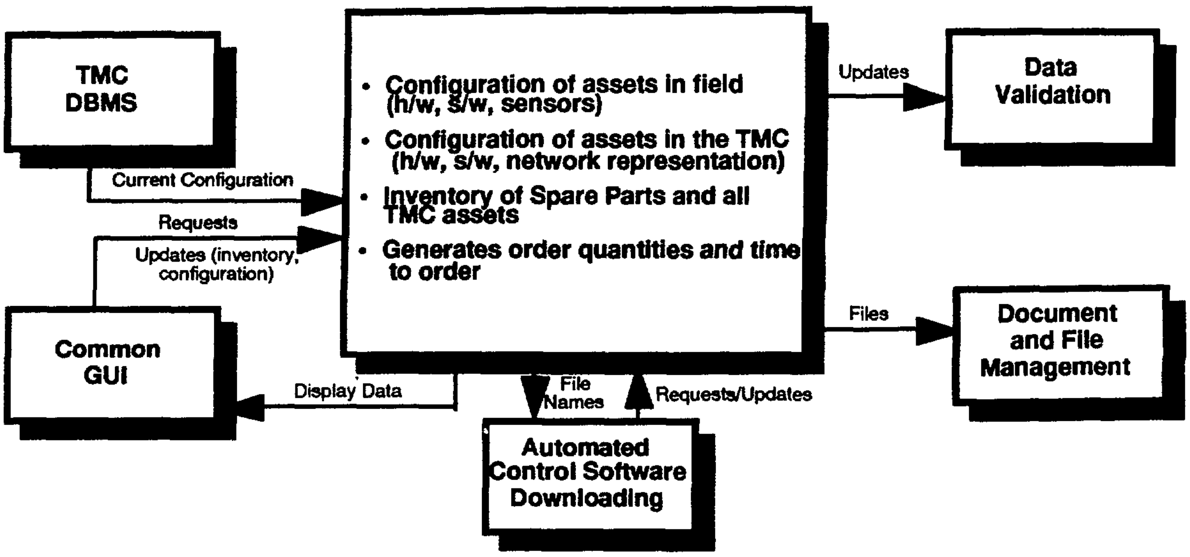


Figure 2-23. The Configuration and Inventory Management Subsystem

This subsystem supports configuration management by tracking configuration changes to hardware and software assets that reside in either the field or inside the TMC. For hardware assets, this system interacts with the TMC DBMS to maintain and track hardware component locations, installation dates, servicing dates and history, manufacturer name, manufacture number, dates purchased, and other technical details associated with the specific hardware component. For hardware components in the field, this system also maintains records from the TMC DBMS that define a common network representation. The common network representation defines the communication network between controllers, detectors, signals, and the TMC. It also defines the state of each component in the network (e.g., working, requires servicing, abnormal). For software assets this system interacts with the TMC DBMS to maintain and track creation dates, functions performed, authors, modification dates and history, and other technical details associated with the particular software component.

This subsystem supports inventory management by:

a. Maintaining inventories, obtained from the TMC DBMS, of spare parts and all TMC assets.

b. Generating order quantities and time-to-order estimates.

The subsystem accommodates a GUI that will: accept requests for configuration or inventory updates; provide display capabilities for current configuration and inventory data from the TMC DBMS; and facilitate report capabilities.

2.5.3 Event Planning and Scheduling Subsystem Description

The Event Planning and Scheduling (SEPS) Subsystem (see Figure 2-24) is responsible for the offline planning and scheduling of three types of activities:

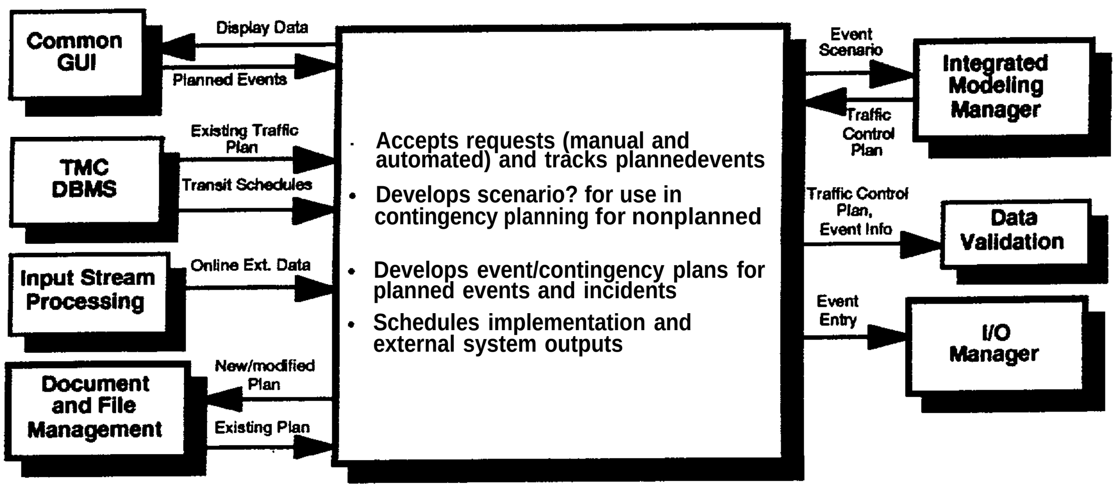


Figure 2-24. The Event Planning & Scheduling Subsystem

a. Planned Construction Events.

b. Planned Special Events.

c. Incidents (contingency planning only).

For planned events the SEPS Subsystem assists the operator by providing support for the following:

a. Manually entering requests.

b. Automatically accepting requests through an external communication system interface.

c. Placement of requests on the event calendar (schedule) or the identification and resolution of conflicts.

d. Generation of the planned event scenario (e.g., for a special event, such as a football game, scenario generation entails determining event attendance and spectator profiles, and emergency service needs, such as police, fire, rescue, etc.).

e. Retrieval of event plans (traffic and logistic) for past similar events.

f. Generation of traffic control plans through interaction with the Integrated Modeling Environment.

g. Storing of new event plans.

h. Scheduling of control plan implementation with the I/O Manager Subsystem.

i. Scheduling of outputs to external systems and agencies with the I/O Manager Subsystem.

The SEPS Subsystem also supports contingency planning for unplanned events (e.g., incidents such as an overturned HAZMAT on freeway 495). Contingency planning for unplanned events is supported in the same way as planned events. However, requests for resources are not automatically received, and the activities of the plan are not scheduled until the time of the emergency.

2.5.4 Maintenance Management Subsystem Description

The Maintenance Management (SMMS) Subsystem (see Figure 2-25) is responsible for the logging and scheduling of reported failures or preventive maintenance requests. These requests will consist of various types, including:

a. Field Surveillance Equipment.

1. Loop Detector Malfunction or Service Request.
2. Controller Malfunction or Service Request.
3. CCTV Malfunction or Service Request.

b. Failures of Field Control and Signal Equipment.

1. Traffic Light Malfunction or Service Request.
2. 170 Controller Malfunction or Service Request.
3. CMS Malfunction or Service Request.
4. Ramp Meter Malfunction or Service Request.

c. Failures of Communications Interfaces between the Field and TMC.

1. Cable Connectivity Malfunction.
2. Noisy Line Malfunction Plan.

d. Roadway Problems.

1. Potholes.

2. Road Resurfacing Request.

3. Preventive Maintenance Request.

e. Failures of TMC Hardware and Software.

1. Front-End Communication Interface Malfunction.

2. Hardware Node Malfunction.

3. Software Process Malfunction.

4. DBMS Malfunction.

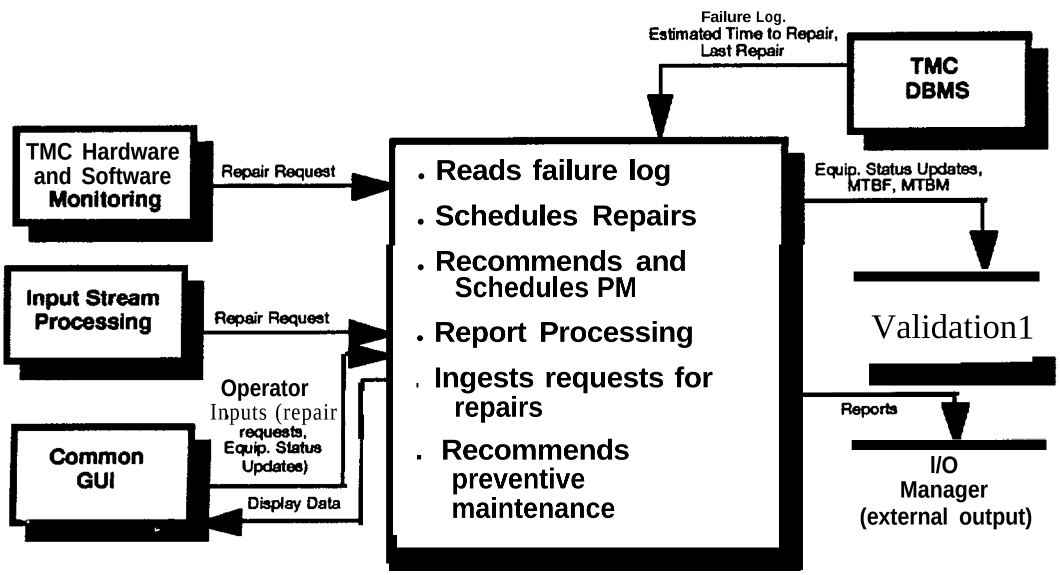


Figure 2-25. The Maintenance Management Subsystem

Requests received by this subsystem will be either a failure or a request for preventive maintenance. As identified above, failures will include all assets of the ATMS, those within the TMC and those in the field.

Reported failures and preventive maintenance requests will come electronically or from human-entered events. Electronically reported requests will come mainly from other subsystems in the System Management Support System performing monitoring functions; although, subsystems in other Support Systems who perform ancillary monitoring functions as a side-effect may report failures (e.g., the Input Stream Processing Subsystem). Human-entered events will come from the operator who has received a failure report or maintenance request from an external source.

The logging process will consist of taking all reported failures and requests and writing them to a disk file sorted by time and type, The logging process will support the overall system management process in providing information to operators that will allow them to quickly identify and resolve anomalies in the ATMS.

The automated scheduling process will take a particular type of failure, assign a priority, and generate a new schedule for that type of request. This subsystem will provide support for high-level and detailed-level automatic and manual scheduling. Additional support will be provided for conflict resolution, resource management, temporal constraint management, and graphical and hard copy representations of scheduled activities, resource allocations, and availability. It is envisioned that daily schedules will be used both internal to the TMC as well as for input for other agencies. For instance, the daily output of the schedule might be electronically transmitted to the local Public Works Department.

An important part of the scheduler is a specification for a standard request notation that allows various entities to electronically request a maintenance or repair activity. The request is then parsed by the scheduler and incorporated into either a new or existing schedule. The scheduler will manage any constraints expressed and resources required in the request. If the request can be successfully placed on the schedule, the scheduler will do so; otherwise, the scheduler will report conflicts both to a log tile and to the operator interface.

2.5.5 TMC Hardware and Software Monitoring Description

The TMC Hardware and Software Monitoring (STHS) Subsystem (see Figure 2-26) is responsible for monitoring the assets within the TMC to detect failures. Once a failure is detected, it is reported to the TMC DBMS, Configuration and Inventory Management Subsystem, and depending on the level of priority associated with the failure to the user interface and Maintenance Management Subsystem. For the most critical failures a pager will be automatically invoked.

The assets monitored (and detectable failures) within the TMC include:

a. Hardware. Down nodes, CPU, memory, disk, peripheral.

b. Software. O/S problems, swapped out process and down process.

c. Communication. Links between hardware nodes and interfaces to external systems.

d. DBMS. Database usage (table access counts, number of joins, etc.) and database sizing (database size, table size, etc.).

The monitoring of assets is done to essentially verify that the system is healthy and behaving correctly. It also is proactive in that it could potentially prevent additional malfunctions from occurring by identifying them early.

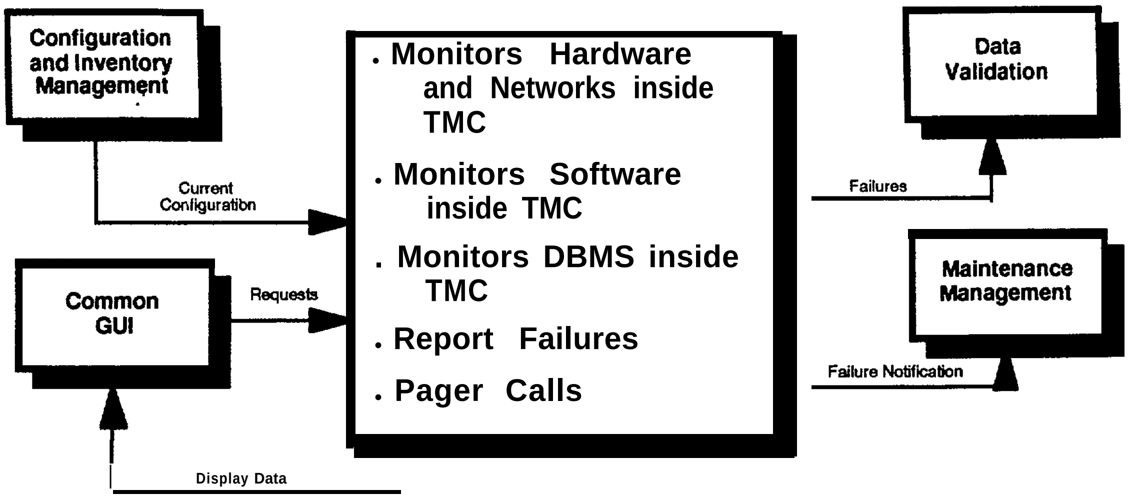


Figure 2-26. The TMC Hardware and Software Monitoring Subsystem

2.6 Analysis and Modeling

The Analysis and Modeling Support System is responsible for providing the capabilities for analyzing and modeling all aspects of the traffic network. This Support System, depicted in Figure 2-27, is composed of the following seven subsystems:

a. ATMS Component Simulation Models.

b. Traffic Simulation Models.

c. Signal and Control Optimization Models.

d. Dynamic Traffic Assignment Models.

e. Integrated Modeling Manager.

f. Historical Data Analysis.

g. Origin-Destination (O-D) Processing.

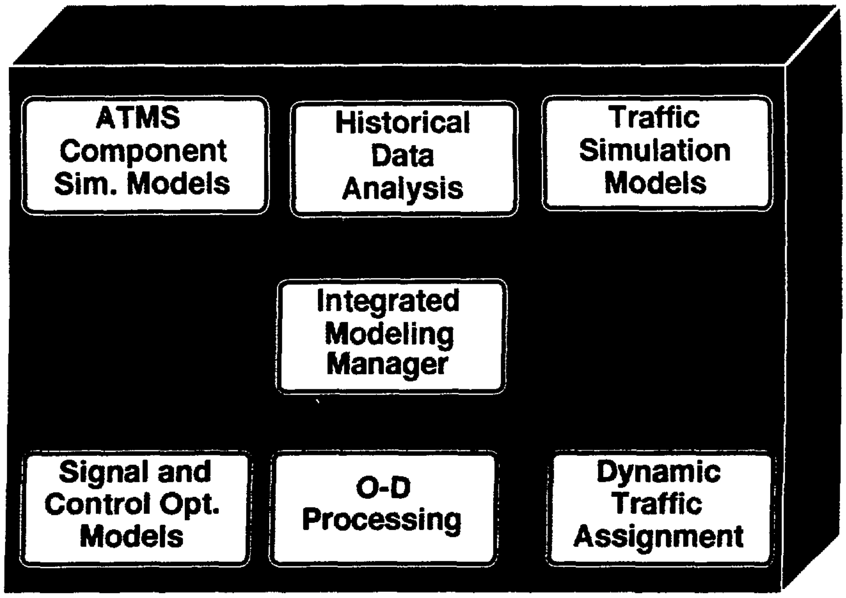


Figure 2-27. The Analysis and Modeling Support System

2.6.1 ATMS Component Simulation Models Description

The ATMS Component Simulation Models Subsystem (AACS) (see Figure 2-28) is a repository of models that simulate data streams for all of the various ATMS inputs. This includes all external data to the TMC [data from surveillance equipment, Organizational Users (MPOs), Individual Users (the traveling public), Online External Systems, Emergency Response, and IVHS external systems]. Specific data types include:

a. Video Data.

b. Traffic Surveillance Data. Loop detectors, area-wide detectors, queue length detectors, acoustic detectors, optical/infra-red (image processing) detectors, bus detector, sonic, radar, light emission, etc.

c. Weather and Environmental Surveillance Data. Visibility detectors, fog detectors, ice detectors, precipitation (sleet, snow, rain) detectors, temperature detectors (road and air), pollution detectors.

d. Trip planning data or O-D data.

e. Parking Surveillance Data.

f. Ground vehicle probe data.

g. AVI priority data.

h. Inter-regional traffic information from other ATMS.

i. HAZMAT and emergency vehicle routing requests.

j. MAYDAY messages.

k. Requests for historical information.

l. The operational status of external systems.

m. Environmental data including weather and pollution levels.

n. Data from external systems or databases (e.g., HAZMAT).

o. Signal preemption data such as vehicle location and speed.

p. Incident status reports.

q. Special event plans and requests for support.

r. Transit data (e.g., bus schedules: routes, headways, stops).

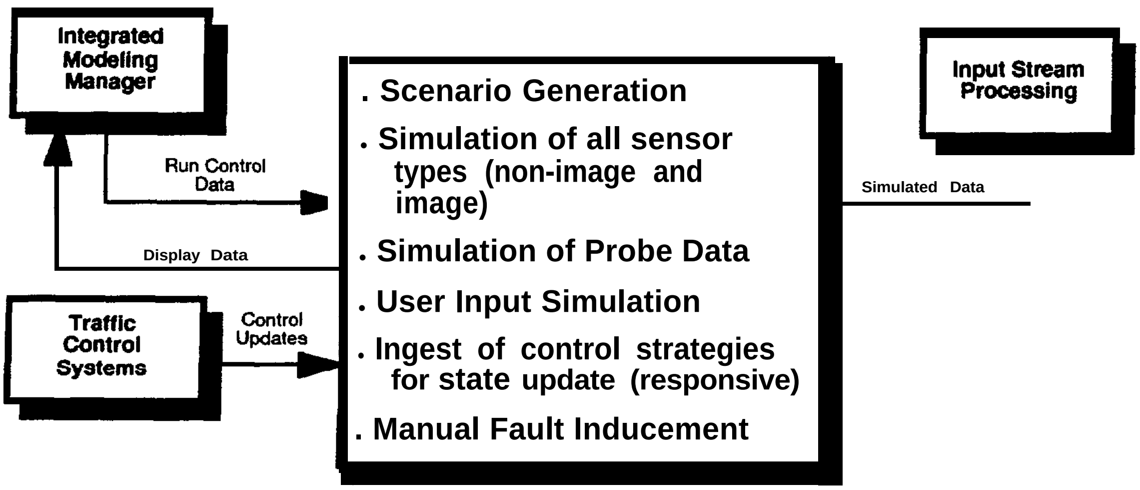


Figure 2-28. The ATMS Component Simulation Models Subsystem

As noted simulated data encompasses synchronous and asynchronous data. In addition to providing models that simulate the outputs of each of the above data types, this support subsystem will provide mechanisms to control the behavior of the simulation, such as variable simulation speed control and the capability to manually introduce changes in the simulated data.

The simulation of each of the above input types will be accomplished through separate simulation models for each type of data stream. The component simulation models will microscopically replicate, to the same level of detail as the devices themselves, their output data, structure, and protocol information. Some of the less sophisticated models function more like data generators than models (e.g., the simulation of a routing request), while other more sophisticated models are active and responsive. The more sophisticated models are similar to Finite

State Automata (FSA); they model 1 or more states; in each state a different behavior is modeled; the models receive information that transition them to a new state.

The accuracy and meaningfulness of the simulated data is a function of the level of sophistication for each model. For instance, the speed output from a loop detector might be generated a number of ways.

a. Data Generation. Based on historic data under similar conditions.

b. Nominal Model. Simulated based on a flow model given set link input volumes.

c. Sophistication Model. Simulated using a fully capable microscopic simulation, which can simulate the vehicle flows as well as the control system.

2.6.2 Dynamic Traffic Assignment Subsystem Description

The Dynamic Traffic Assignment (ADTA) Subsystem (see Figure 2-29) performs several key functions within the context of wide-area proactive traffic control. These functions include:

a. Developing 15-minute forecasts of network loads at interface points between Traffic Control Systems, based on a time-dependent regional O-D. The required assignment interval is a function of the size of the network. For small networks, a 15-minute interval is probably sufficient; for large networks, 30 minutes or longer may be required.

b. Developing 5-minute forecasts of network link volumes using the network loads previously developed and specific control strategies being employed by the Traffic Control System.

c. In cooperation with a detailed traffic simulation program, generating Measures of Effectiveness (MOE) for evaluating regional and local control strategies being considered by the Wide-Area Traffic Management Subsystem and the Traffic Control Systems.

d. Developing optimized routes in support of Wide-Area Traffic Management Subsystem's route diversion strategies and ATIS route determinations.

As shown in Figure 2-29, the primary interfaces of the ADTA Subsystem are with the Integrated Modeling Manager (AIMM) Subsystem. The Integrated Modeling Manager Subsystem serves as the data manager for ADTA Subsystem, providing both DBMS and GUI interfaces, as well as managing the API with other models/simulations.

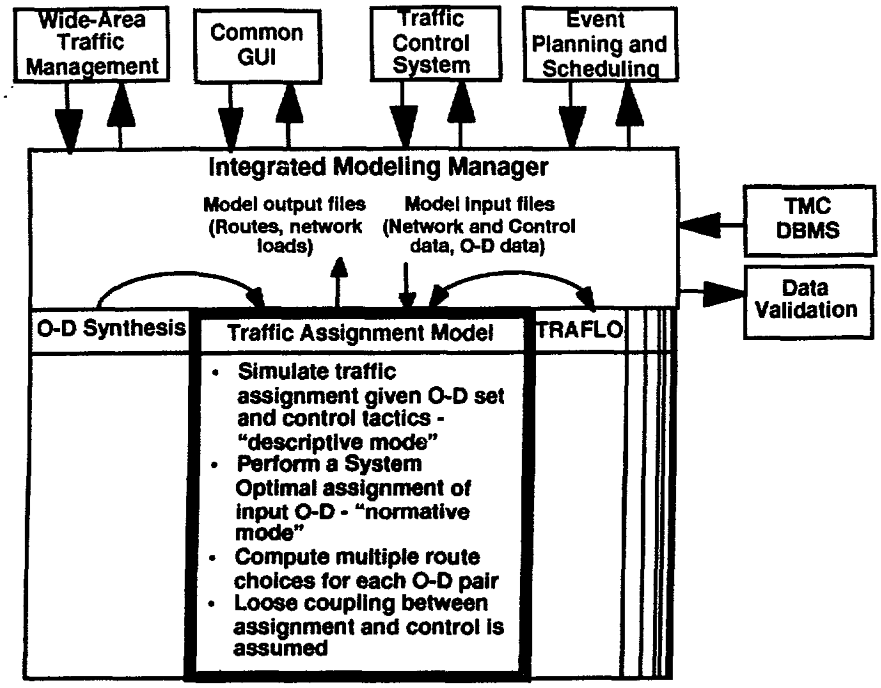


Figure 2-29. The Dynamic Traffic Assignment Subsystem

The algorithm(s) of the ADTA Subsystem must support various capabilities for representing the behavior of travelers [including various traffic signal control modes, ramp meters, CMS, reversible lanes, HOV lanes, and broadcast information to vehicles via ATIS, Highway Advisory Radio (HAR), etc.]. In addition, the ADTA Subsystem must be capable of representing the regional network and control functions so as to meet both the requirement for internal consistency of travel time and the requirement for providing evaluation support for TWTM-developed strategies and tactics.

The timing requirements for ADTA are crucial to its use within the ATMS/ATIS real-time environment and pose performance problems which have to date not been resolved. Current research in dynamic assignment involves the use of large parallel computing machines to solve the resulting mathematical programming problem. For TMC implementation, this is not a realistic solution for the near-term, although, with the projected advances in computational power on workstations, it may be feasible within 5-10 years.

At the regional level, it determines network loads using path-based assignment with the network and provides control and driver behavior representations sufficient to compute with reasonable accuracy the projected volumes at key entry and exit points to each of the TCSs within the regional ATMS. Figure 2-30 illustrates the overall ATMS link volume forcasting architecture, which employs ADTA regionally at the TWTM node and locally at each of the TTCS nodes. At the 'local' level, the ADTA Subsystem determines projected link loads for use by the respective Traffic Control Systems in computing 5-minute link volume predictions using statistical methods. Again, by interfacing with a detailed simulation program, the ADTA Subsystem supports evaluation requirements.

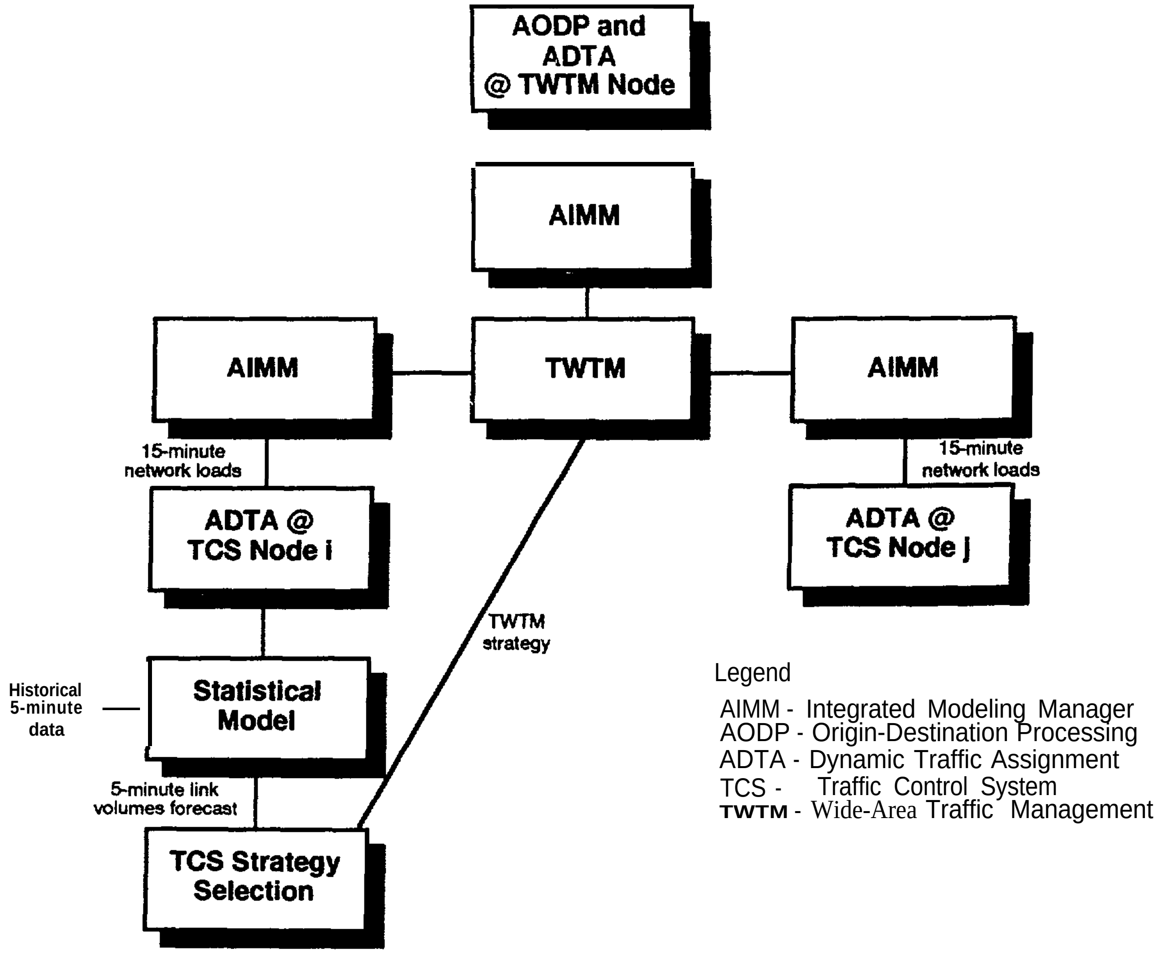


Figure 230. Dynamic Traffic Assignment Subsystem Interfaces

The meeting of the last objective (item d in the preceeding list) has additional and more global implications in terms of the overall ATMS and IVHS architectures since it potentially involves individual vehicle route selection. For the purpose of the ATMS Support System Contract, it has been assumed that ATMS ~~is not~~ responsible for individual vehicle route calculations; rather, ATMS will provide ATIS with suggested routes. Thus, the ADTA Subsystem computes "best" routes between "zonal pairs" which can be disseminated to ATIS for its use in selecting the vehicle route. If vehicles, in turn, communicate the route decision to the ATMS, that data can be used during the next time period to develop the new assignments. This is a partial coupling mode that is one of the architectural alternatives for coupling traffic control and route selection.

2.6.3 Historical Data Analysis Subsystem Description

The Historical Data Analysis (AHDA) Subsystem (see Figure 2-3 1) is responsible for providing the operator with a transparent interface to the TMC DBMS and will primarily generate necessary reports, calculate growth trends and project future data. The reports include both routine and ad ***hoc*** requests. The routine reports are the reports such as weekly summary traffic volume data for specific locations that undergo routine review. The ***ad hoc*** request for reports may originate whenever a need for summary data arises, especially for offline planning purposes. The AHDA Subsystem will schedule the routine reports automatically. The ***ad hoc*** requests for reports will be entered manually by an operator through an interactive GUI. The subsystem will translate the manual information request into a script file readable by the system to generate reports. The operator should be able to save the information query in a file for future retrieval and use. The subsystem will also store the reports in the TMC DBMS for future retrieval and use.

The AHDA Subsystem retrieves the data from the TMC DBMS and generates the report in a specified format. The report may be reviewed electronically and/or on a hardcopy printout. The subsystem will have a library of various predefined report formats for the routine reports. In addition, the operator may create or modify a report format through the GUI.

It is anticipated that the AHDA-provided reports will vary in complexity. Simple reports will just involve providing report format of the necessary data from the TMC DBMS without performing any kind of mathematical/statistical operation. The operator will have access to this statistical toolset through the interface.

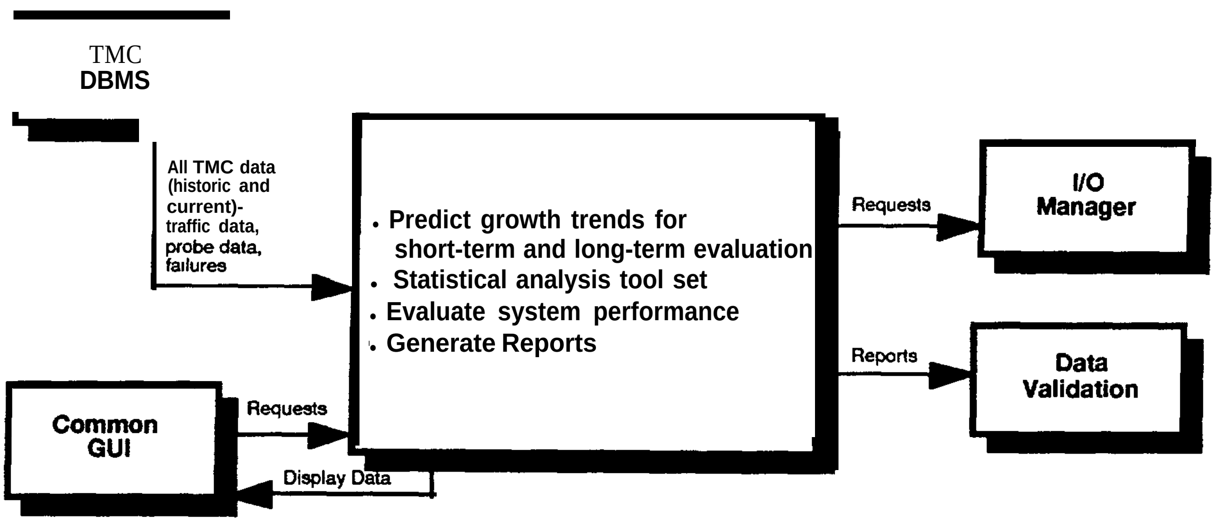


Figure 2-31. The Historical Data Analysis Subsystem

The AHDA Subsystem will provide a system interface to the I/O Manager Subsystem for scheduling dissemination of the report to the appropriate entity. An event entity and a time will be provided to the I/O Manager Subsystem. The event ID will later be used to recall the corresponding report to be generated and transmitted to the appropriate locations at the requested time.

The AHDA Subsystem will also have a system interface to the I/O Manager Subsystem for scheduling regular reports that need to be generated by the AHDA Subsystem. These reports may require statistical analysis and user control and/or input.

The AHDA Subsystem will prioritize requests for historical data processing based on the request classification.

2.6.4 Integrated Modeling Manager Subsystem Description

The Integrated Modeling Manager (AIMM) Subsystem (see Figure 2-32) is the subsystem that manages all of the models available for use in the ATMS. The essential function of the AIMM Subsystem is two-fold:

a. To provide a layer of software on top of all existing models that will allow them to be accessed from anywhere within the ATMS -- for both online (real-time and hyper real-time) and offline purposes. This includes providing an electronic system interface so that the Traffic Control or Wide-Area Traffic Management Subsystems can evaluate a specific control strategy/tactic/plan in real time or so that an operator can configure a scenario to evaluate/create an optimum strategy/tactic/plan. More than one model may be accessed and executed at the same time.

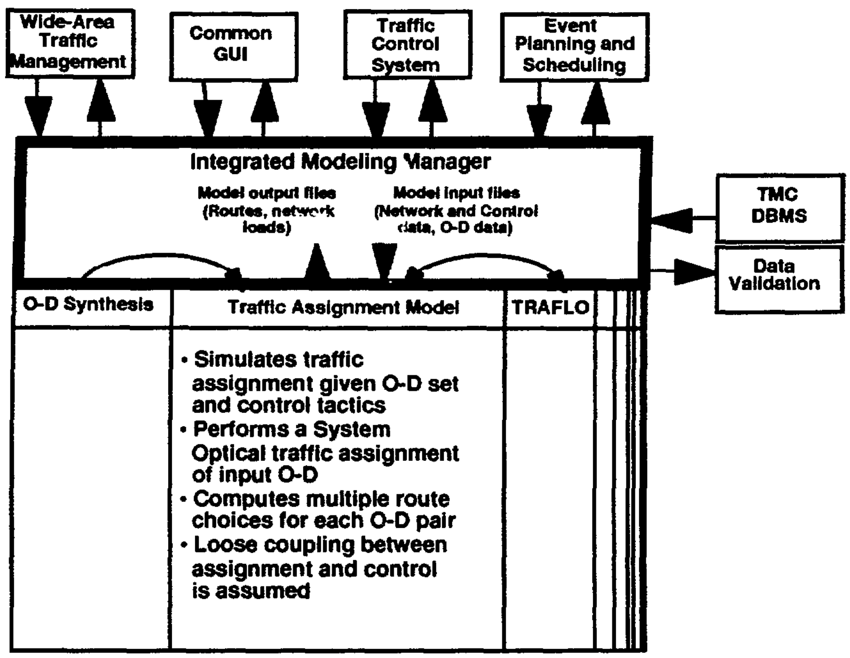


Figure 2-32. The Integrated Modeling Manager Subsystem

b. To provide a standardized, common entry into the analysis and modeling repository. The repository includes all of the various microscopic and macroscopic traffic simulation models, signal and control optimization models, and the ATMS component simulation models (which simulate ATMS inputs and functions).

To accomplish these functions, the AIMM Subsystem must collect and format the inputs obtained from the TMC DBMS and from the operator (via the GUI) so that they are ingestible by the various models. The opposite is likewise true. The AIMM Subsystem must collect and format the outputs obtained from the various models so that they are displayable and storable to the operator and the TMC DBMS, respectively. To do this, this system must obtain interface control documents and specifications that will describe the connectivity of the various models to the AIMM Subsytem and potentially with each other.

2.6.5 Origin-Destination Processing Subsystem Description

The Origin-Destination Processing (AODP) Subsystem (see Figure 2-33) performs a key function, along with the Dynamic Traffic Assignment Subsystem in meeting the essential ATMS requirement for proactive traffic management and control. The AODP Subsystem's function is to synthesize and forecast an origin-destination matrix from observed traffic information including: real-time link volumes computed by the Traffic and Environmental Monitoring Subsystem, origin-destination information (current and forecasted) collected from ATIS sources such as ATIS equipped vehicles, historical origin-destination data, and traffic information. The AODP Subsystem will have the capability to develop a partial origin-destination matrix.

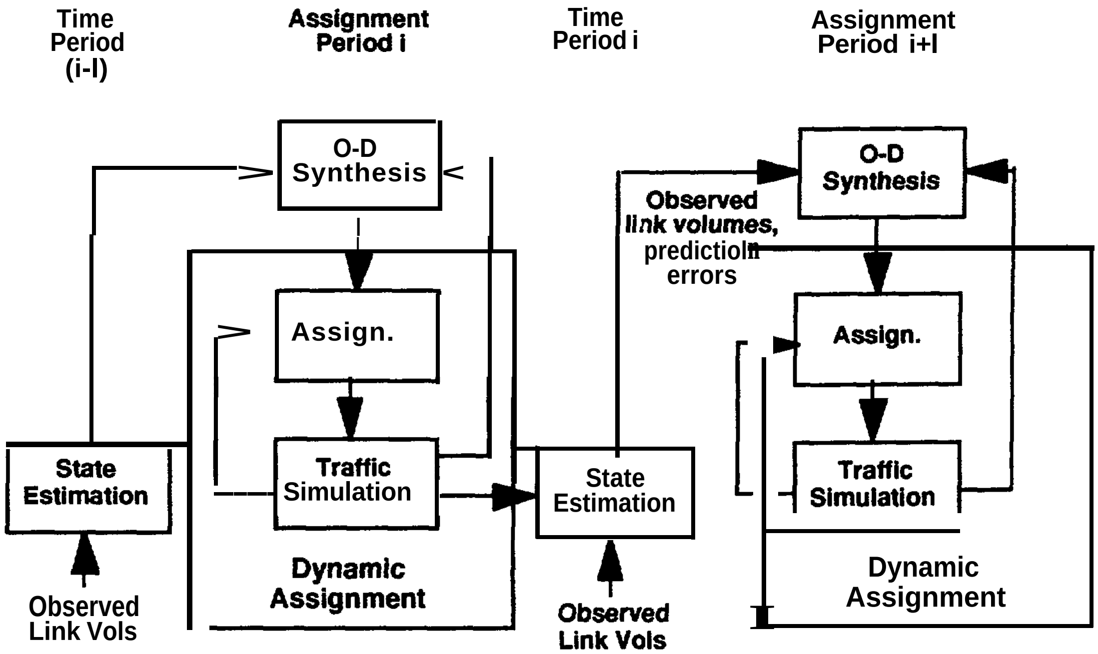


Figure 2-33. The Origin-Destination Processing Subsystem

The AODP Subsystem will interface with the Integrated Modeling Manager to transfer data to other TMC support systems. The interface shall support both the standalone use of this subsystem, as well as the transfer of data to and from other subsystems.

This subsystem will have the capability to forecast the synthesized origin-destination matrix over the assignment period required by the Dynamic Traffic Assignment and Wide-Area Traffic Management Subsystems (currently assumed to be 15 minutes). Real-time and offline evaluation support will be provided.

The origin-destination synthesis process will be self-calibrating. Short-term calibration, if it is possible, will be a real-time activity; long-term calibration can be performed offline. The AODP Subsystem will evaluate the accuracy of the forecasts developed by the Dynamic Traffic Assignment Subsystem and use these results to modify (calibrate) the origin-destination model behavior through parameter adjustment.

2.6.6 Signal and Control Optimization Models Subsystem Description

The Signal and Control Optimization Models (ASCO) Subsystem (see Figure 2-34) contains a repository of all Signal and Control Optimization Models available for use in the ATMS. This subsystem is a library of traffic simulation programs under the control of the Integrated Modeling Manager. This includes both microscopic and macroscopic level models such as TRANSYT, PASSER II, SIGOP III, SOAP, MAXBAND, etc. This also includes second-generation models that will be available through the “Models to Simulate IVHS Operations” Contract.

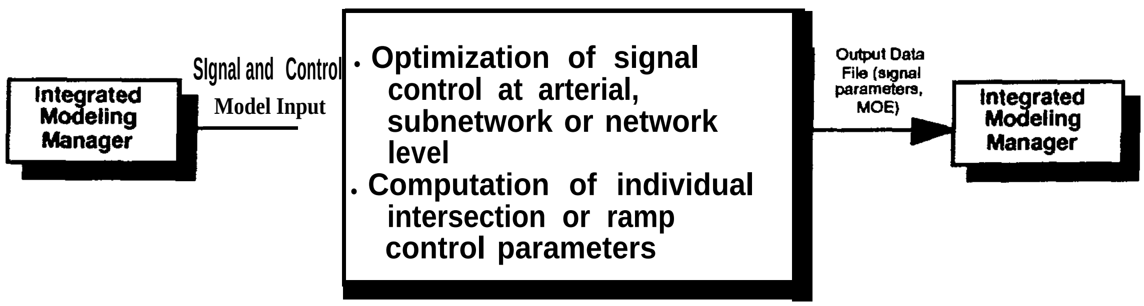


Figure 2-34. The Signal & Control Optimization Models Subsystem

This Support Subsystem shall be used to evaluate the efficacy of candidate ATMS control strategies online prior to the deployment of the “best” candidate strategy. It will also be used “offline” to evaluate new strategies to determine whether they should be introduced into the ATMS library of candidate control strategies.

It is important to understand that each of the models available for simulation and analysis is accessible only through the Integrated Modeling Manager Subsystem. The Integrated Modeling Manager Subsystem manages all inputs and outputs to each of the respective models; it is a “server” that interacts with the various models. It provides a common interface to both the operator and other support subsystems that wish to use the models available.

The inputs that are made available to the ASCO Subsystem through the Integrated Modeling Manager Subsystem include the following:

a. Data directly from the TMC DBMS Static network data (i.e., geometries), incident data, real-time surveillance or traffic state data (link speeds/volumes, link turning volumes, parking capacities by location, etc.), suggested routing information, O-D data or tables, transit schedules and data, environmental data (rain, snow, fog, icy pavements, temperature, pollution varying both spatially and temporally), vehicle classes and composition.

b. Data from the User Interface. Scenario definition data (size and scope of the analysis network, the surveillance input data, traffic flow input data, traffic composition, etc.), run control data, events (modify traffic demand on any entry link, modify turning movements on internal links, failure inputs for any specified component such as a detector, a controller or communication line, change control tactics/plans), etc. This data may come initially at startup (scenario configuration) or dynamically during run-time.

The main functions of the models available in this subsystem are the following:

a. Determine optimal control strategies/tactics/plans.

b. Rank order of control strategies/tactics/plans based on MOE.

The outputs that are made available to the Integrated Modeling Manager Subsystem(and ultimately to the operator or other support subsystems) include:

a. Optimal control strategies/tactics/plans.

b. MOE (statistics describing traffic operations at a high level of detail) on each network link and for each network node.

c. Summary statistics and aggregates of these statistics, in accordance with user specifications, over subnetworks and network-wide.

It is also important to realize that the models that are available in this subsystem are used in real time, online and offline.

<u>Real-time mode operation</u>: In this mode, information is received in real time from the real world. That is, the simulation models are “plugged in” to the real-time system accessing the data that is received from the field via the surveillance and communication system. For instance, Traffic Control will request in real time (or hyper real time) for the evaluation of a strategy. The simulation analysis will be executed many times faster than for online purposes to fulfill the real-time performance requirements. In most cases, a user is left outside of the loop.

<u>Online mode operation</u>: This mode is similar to the real-time mode in that the simulation models are “plugged in” to the real-time system accessing the data that is received from the field via the surveillance and communication; and the simulation analysis may be executing in hyper real time. The major difference in the online mode is that there is human intervention. The human may perform

"what-if" analysis to be used in contingency planning or strategy evaluation/determination.

Offline mode: In this mode, the component simulation models operate in a manner which is separate and distinct from the online or real-time system. Here, the patterns of traffic demand have been archived in one of two ways:

a. From a prior application of these models in the real-time mode.

b. By specifying data from the Integrated Modeling Manager subsystem to create a traffic environment for study. This may involve local, historic data available through the TMC DBMS.

2.6.7 Traffic Simulation Models Subsystem Description

The Traffic Simulation Models (ATSM) Subsystem (see Figure 2-35) contains a repository of all traffic simulation models available for use in the ATMS. This subsystem is a library of traffic simulation programs under the control of the Integrated Modeling Manager Subsystem. This includes both microscopic and macroscopic level models such as NETSIM, NETFLO, FREFLO, FRESIM, CORFLO, TRAF, LINKOD, etc. These models also include second-generation models that will be becoming available through the "Models to Simulate IVHS Operations" Contract.

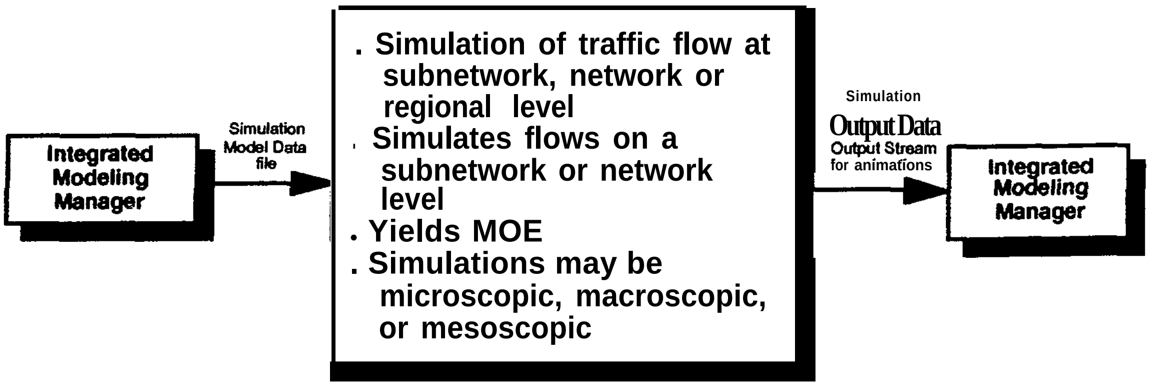


Figure 2-35. The Traffic Simulation Models Subsystem

It is important to understand that each of the models available for simulation and analysis is accessible only through the Integrated Modeling Manager Subsystem. The Integrated Modeling Manager Subsystem manages all inputs and outputs to each of the respective models; it is a "server" that interacts with the various models. It provides a common interface to both the operator and other support subsystems that wish to use the models available.

As is the case for the Signal and Control Optimization Models Subsystem, all interfaces to the models are via the Integrated Modeling Manager. Also, the data available to and used by ATSM is similar to that used by ASLO.

The main functions of the models available in this subsystem are the following:

a. Optionally macroscopically simulate the traffic flow at the subnetwork, network, or regional level in accordance with the run control options and the selected model.

b. Optionally microscopically simulate the traffic flow at the subnetwork, network, or regional level in accordance with the run control options and the selected model.

The outputs that are made available to the Integrated Modeling Manager Subsystem (and ultimately to the operator or other support subsystems) include the following:

a. MOE (statistics describing traffic operations at a high level of detail) on each network link and for each network node.

b. Vehicle trajectory data at one-second intervals for animation displays.

c. History of control actions (e.g., phase durations and sequences, cycle length, offset) over time.

d. Summary statistics and aggregates of these statistics, in accordance with user specifications, over subnetworks and network-wide.

It is also important to realize that the models that are available in this subsystem are used in real time, online and offline.

Real-time mode operation: In this mode, the simulation models are "plugged in" to the real-time system accessing the data that is received from the field via the surveillance and communication system. For instance, Traffic Control will request in real time (or hyper real time) or the evaluation of a strategy. The simulation analysis will be executed many times faster than for online purposes to fulfill the real-time performance requirements. In most cases, a user is left outside of the loop.

Online mode operation: In this mode, the operator may perform interactive "what-if" analysis to be used in contingency planning or strategy evaluation/determination.

Following an operator intervention, the simulated state of the traffic environment will depart from the real-world state as a consequence of the action taken by the operator. The simulation analysis can still proceed in real time by accessing information from the surveillance system which describes the movement of traffic into the analysis section. Furthermore, the simulation models themselves will continue operating in simulated real time; that is, the information presented to the operator would be in the same format as though it were provided in the real-time system and at the same rate.

The internal network links of the analysis network will, of/course be experiencing traffic conditions which reflect the action taken by the user. (It is the responsibility of the user to identify the "entry links" of the analysis network which would not be effected by the action taken.) The operator can also request the simulation model to continue to archive surveillance information in real time, in addition to performing the simulation activities. This feature will allow the user to compare the MOE generated by the simulation model reflecting the action taken by the operator, with the MOE generated at a later time in the absence of the such action by the operator, or in response to another action taken by the operator.

This process can be repeated with different operator actions taken at different times in accordance with the operator's judgment. For each such action, simulation components will provide MOE which assess the outcome of the actions taken by the operator. An analysis of these alternative actions can be made offline (see below) so as to compile a list of actions which are known to be effective under conditions reflective of the simulated real-world conditions.

<u>Offline mode</u>: In this mode, the component simulation models operate in a manner separate and distinct from the online or real-time system. Here, the patterns of traffic demand have been archived in one of two ways:

a. From a prior application of these models in the real-time mode.

b. By specifying data from the Integrated Modeling Manager Subsystem to create a traffic environment for study. This may involve local, historic data that is available through the TMC DBMS.

Even in the offline mode, the simulation model should execute at a speed which is commensurate with real-time operation. This is necessary for the displays produced by the simulation model to be presented at a real-time rate. Once again, the operator can intervene by incorporating some change to the traffic environment and the system will respond to that change in the offline mode at a level of responsiveness which represents the real-time system. Finally, under a more controlled environment, the user can rerun the same scenarios, incorporating different actions at different times based upon his/her judgment, to generate the information needed to evaluate these actions. From this evaluation, the engineer can establish a hierarchy of strategies which have a high prospect of being effective at future times.

2.7 Common Services

The Common Services Support System provides capabilities required by all of the ATMS Support Systems, most notably the Graphical User Interface (GUI). With the exception of the GUI and Operator Training, all of the other subsystems in this Support System are development by-products and are available through COTS products. The Common Services Support System, depicted in Figure 2-36, consists of the following six subsystems:

a. Inter-Process Communications.

b. Operating System.

c. Network Backbone.

d. Operator Training.

e. GUI.

f. Security.

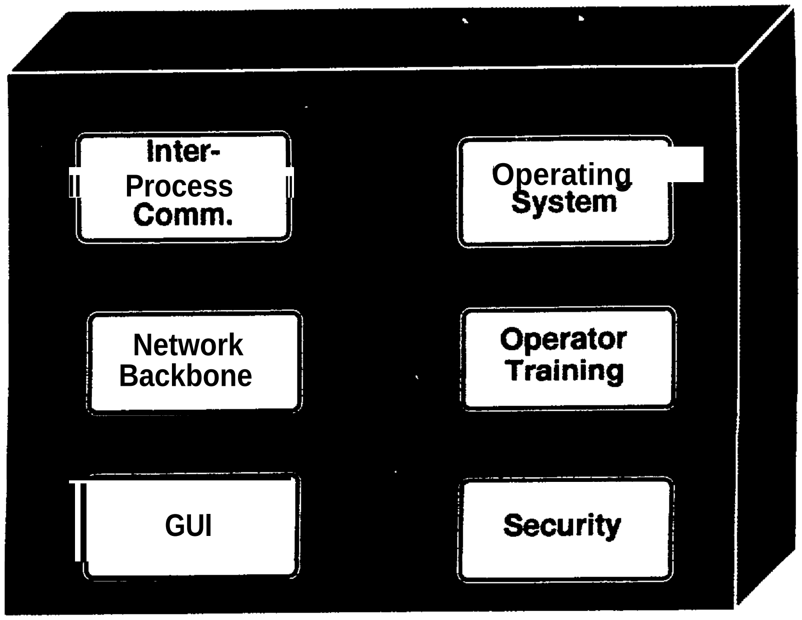


Figure 2-36. The Common Services Support System

The Operator Training function within the Common Services Support System is important for maximizing the performance and effectiveness of operator actions. It is currently envisioned that operator training will take the following forms:

a. Development of User Guides for each Support System.

b. Classroom Instruction/Training for each major activity (Incident Management, Traffic Management, Analysis and Modeling, Event Planning, etc.).

c. Simulation and On-the-Job Training (OJT).

Additional Operator Training functions are provided in other subsystems:

a. Document and File Management subsystem (online documentation, electronic versions or user guides, tutorials) with hyper-text.

b. All Support System applications that have a user interface will provide context sensitive help (provided via the Common GUI).

Finally, operator performance assistance and monitoring may be required in key subsystems (e.g., Real-Time Traffic Control).

SECTION 3

SYSTEM-LEVEL REQUIREMENTS

This section describes the system-level requirements for the ATMS Support Systems. The system-level requirements are those requirements that are applicable to the system as a whole, to which each support system shall be compliant.

System-level requirements are defined for the following categories:

a. Hardware.

b. Software.

c. Operator Interface.

d. Facility.

e. System Architecture.

f. Fault Tolerance.

g. Performance.

Each of these requirement categories will be discussed in detail in succeeding paragraphs.

3.1 System-Level Hardware Requirements

The system-level requirements for the hardware to be used for the development of ATMS Support Systems are presented in the following paragraphs. Fault Tolerance requirements are addressed in paragraph 3.6.

HW 1 The system shall use standard, commercially available hardware. This includes all computer-related hardware (CPUs, peripherals, large screen displays, CCTV monitors, CCTV video import cards, etc.).

HW 2 The hardware platform shall be capable of meeting the software, facility, operator interface, and fault tolerance requirements for the ATMS.

HW 3 The hardware for the operator workstations shall be capable of accommodating interfaces for video inputs.

HW 4 The hardware for the operator workstations shall be capable of allowing a configuration of multiple monitors, each controlled by a single keyboard.

HW 5 The hardware for video switching to TV monitors shall be capable of selecting any camera in the configuration and displaying its outputs.

HW 6 The hardware for the front-end communications system shall be capable of interfacing with various types of communication links to receive both digital and analog information.

It is important to recognize that the actual number of workstations, communication links, and the characteristics of the hardware in general are subject to change based on the following:

a. Size of the Traffic Network (surveillance and control scope).

b. System Performance Requirements.

c. Functional Specifications.

d. Customer/Site Requirements (external interfaces, type and quantity of incoming and outgoing data at each site -- e.g., AVI/AVL vehicles, required staffing profiles).

e. Size of the ATMS Region (e.g., number of participating nodes, communication load requirements).

f. Technological Advances (e.g., hardware performance).

g. Deployment Considerations.

   1. Characteristics/Configuration of Existing System.

   2. Upgrade/Migration Path.

   3. Policies and Procedures.

   4. Budgets.

   5. Available Space.

These issues will be addressed during the design considerations of Task D.

3.2 System-Level Software Requirements

The system-level requirements for the software used in the development of ATMS Support Systems are presented in the following paragraphs. The system-level requirements for the software are driven by the need to perform the following:

a. Execute applications on any vendor's platform (hardware independence).

b. Produce a maintainable and modular system.

To accomplish this, ATMS Support Systems shall be compliant with established and mature open system standards. Two of the biggest requirements enforced will be the following:

a. POSIX-compliant operating systems with ANSI- and POSIX-compliant source code.

b. SQL-compliant database and source code level APIs.

These requirements are levied so that the functionality needed to provide interoperability, portability, and scalability of software across hardware platforms and networks of heterogeneous types is achieved. These standards and others identified in formal requirements in the following paragraphs, will specify standard services, interfaces, data formats, and protocols that are available on a variety of hardware platforms and network configurations.

3.2.1 Operating System

SW1 The operating system shall be multi-tasking and multi-user.

SW2 The operating system shall support distributed file systems, directory services, and remote procedure calls.

SW3 The operating system used shall be a POSIX-compliant Unix (FIBS PUB 15 l-2). POSIX 1003.1 (a.k.a. POSIX.1 - System Application Program Interface [C Language]), POSIX 1003.2 (a.k.a. POSIX.2 - Shell and Utility Interface), and POSIX 1003.4 (a.k.a. POSIX.4 - Real-Time Services)' at minimum shall be met. No proprietary operating system shall be used.

SW 4 The operating system shall provide real-time extensions (reference POSIX.4) for process priorities and preemptive scheduling.

3.2.2 Programming Languages

SW 5 The programming language for all newly developed source code shall be ANSI-compliant C or C++[2]. Utilization of extensions to programming languages provided by specific vendors is to be avoided.

3.2.3 Communications

Communications includes the services necessary for reliable, transparent, end-to-end data transmission across communication networks.

1 As of this date 1003.4 is in draft 12, however, implementations with major API functionality are now available on most commercially available operating systems.

2 As of this date an ANSI C++ language definition does not exist., however, the Stroustrup's Second Edition of the C++ Programming Language manual is the base document for the ANSI C++ standardization effort.

SW 6 The inter-process communication standard for point-to-point and broadcast communication shall be either POSIX message queues (specified in POSlX.4) or TCP/lP sockets/datagrams.

SW 7 Access to the system shall be provided from a remote node via a Telnet or rlogin connection.

SW 8 File transfer from a remote node shall be available via the File Transfer Protocol (FTP). This will allow a file to be obtained anywhere in the network.

SW 9 The extension of local procedure calls to a distributed environment shall be achieved via the Remote Procedure Call specification.

3.2.4 Database

This section will address high-level database (including map database) and GIS requirements.

For a complete listing of Database (including map database) and GIS requirements, reference Appendix A, the DTDB Subsystem. In addition, map display requirements are addressed in paragraph 3.3.2.

SW 10 The system shall use a commercially available Structured Query Language (SQL)-compliant Relational Database Management System (RDBMS) for the storage and retrieval of all alphanumeric data. An SQL C preprocessor will also be necessary.

SW 11 The system shall use a commercial GlS/Map Database for the storage/retrieval of digitized maps and other forms of spatial data (subject to performance and design trade-off analysis). The GIS must provide native mode SQL calls to a relational database, other than the vendors database. The GIS/Map database requirements are extensive, however, there are several key areas that need to be addressed. These are addressed below:

a. The map database needs to have the capability to store in DXF standard format.

b. The GIS needs to support the editing and maintaining of spatial data. Additionally, the GIS needs to have a feature editor.

C. The GIS needs to support the import and export of the following data formats: ARC, DIME, TIGER, ETAK, ERDAS, LANDSAT, SPOT, DEM, and Digital Orthophotography.

d. The GIS needs to support a seemless spatial data model.

e. The GIS needs to support and maintain topological spatial data and relationships as defined in FIPS 173.

f. The map/GlS displays need to support the display of CAD, raster, and vector data.

g. The map/GlS database needs to support a network topology with connectivity so that streets have relationships with each other. Low-level support for maintaining links, nodes, and polygons will be supported.

h. The map database needs to contain current (updated within 6 months) and accurate (both geometric and positional, within 100 feet) data.

i. The map/GIS needs to have at least a 90 percent hit rate for geo-coding.

SW 12 The DBMS, GIS, and map display components shall be compliant with the OSF/Motif style guide.

3.2.5 Software Design Characteristics

The ATMS Support Systems must be designed to be modular, maintainable, and flexible so that they are adaptable to existing TMCs and flexible to accommodate new technologies as they become available. The following requirements are actually design goals, however, they are delivered as part of the formal requirements to ensure that they will be met in each Support System.

SW 13 ATMS Support Systems shall be modular, maintainable, and flexible.

SW 13.1 ATMS Support Systems shall be modular. Modularity is characterized by the ability to add, change, or replace modules without affecting other modules. To achieve modularity, the inter-dependencies (coupling) between the Support Systems will be minimized and the cohesion of functions within a Support System will be maximized. The extent to which Support Systems or subsystems within a Support System can function as standalone entities will be maximized.

SW 13.1.1 High module cohesion is achieved by the grouping of related functions into one complete package. A package, for instance, could be a file or a class. The module should not contain more than 60 lines of source code instructions (Page-Jones, 1988). Object-oriented design practices (e.g., data abstraction, encapsulation, and information hiding) shall be used where feasible and practical.

SW 13.1.2 Low coupling between modules is achieved by removing unnecessary relationships between modules and by reducing the number of necessary relationships between modules. Where coupling is necessary, the passing of parameters shall be maximized and the mapping to common data areas shall be minimized. The DBMS shall be used where possible to store persistent data (e.g., data that is required by other applications).

SW 13.2 ATMS Support Systems shall be maintainable. Maintainability will be Supported through well-defined system interfaces, modularity (reference SW 14.1), high-level programming languages (reference SW 4), software layering, up-to-date system documentation, and through the mandatory use of industry standards (reference SW I-9).

SW 13.2.1 Well-defined system interfaces are established by providing access to the services (functions, methods, etc.) provided by a given module or subsystem, specifying only the essential data that is to be input to the module and that which is to be output by the module. The passing of only essential data is emphasized to limit the dependencies between modules and to limit the exposure of unnecessary implementation details that are unique to the design of the module.

SW 13.2.2 Software layering is mandatory in cases where coupling to a non-standard component is required. Software layering is achieved by adding a separate Application Program Interface (API) to the system. It is the responsibility of the application program to call the API routine, not to directly call the non-standard component. Non-standard protocols, data formats and function calls are in the API only, not spread throughout application code. In this way, minimization of interaction with non-standard components is achieved.

SW 13.3 ATMS shall be flexible. Flexibility is the ability to adapt the software for different environments and domains, while minimizing code changes and recompilations. Flexibility shall be supported through parameterization and data-driven approaches. Parameterization shall to the extent possible, capture possible variations in the system as input parameters, compilation parameters/instantations (e.g., C++ templates or # DEFINEs), module parameters, and tables.

Flexibility is also achieved by designing for interoperability and portability. Interoperability will be supported to minimize changes to software systems communicating with each other in a heterogeneous environment (i.e., data communications). Portability shall be supported by mandatory compliance of software to ANSI and POSIX standards.

SW 14 All application software with access (both read and write) to a commercial DBMS shall contain ANSI-compliant SQL.

SW 15 The extent to which software interfaces directly to Map databases or GIS databases shall be limited. In cases where this is deemed necessary a separate API (not provided by the vendor) shall be used to minimize the impact of porting to a new map/GlS database (reference "software layering").

3.2.6 Software -Style

SW 16 ATMS Support Systems software shall be developed in accordance with the FHWA ***C Programming Language Style Guide.*** Any C++

Software shall be developed in accordance with the Loral **C++** ***Programming Language Style Guide.*** Of particular significance is the adherence to documentation guidelines, which are outlined in the style guide.

3.3 System-Level Operator Interface Requirements

The system-level Operator Interface Requirements for Support Subsystems are presented below. The requirements are driven by the need to:

a. Establish a common, consistent interface between users and applications to reduce training and increase operator productivity and performance.

b. Limit modifications to operator interface code when porting to a new hardware platform by adopting a common API that is stable for all or many platforms.

3.3.1 User Interface

The interface between the operator and applications is important since it provides the framework for interactions necessary for the effective and efficient operation of the system. To ensure that all user interfaces are well designed and easy to use, all user interface development will conform to ***the OSF/Motif Style Guide***[3]**.**

The OSF/Motif Style Guide strives to accomplish the following [OSF/Motif '91]:

a. Adopt the user's point of view.

b. Give control to the user.

c. Use real-world metaphors.

d. Keep interfaces natural (intuitive).

e. Keep interfaces consistent.

f. Communicate application actions to the user.

g. Avoid common design pitfalls.

OI 1 The User Interface to all Support Subsystems shall be a graphical, direct manipulation icon, menu, and windows-based user interface. The system will be mouse and keyboard driven.

3 The OSF/Motif Style Guide is closely consistent with Microsoft Windows, Presentation Manager, and Common User Access (CUA).

01 1.1 The GUI shall conform to OSF Motif and the X Window System Protocol standards.4

012 The development of the GUI shall conform to the ***OSF/Motif Style Guide.***

01 3 The GUI shall accommodate the input and display of all data, including system login, map displays, request for services (reports, application invocations/terminations, etc.), and all data obtained from the DBMS (real-time and historical traffic, failures, incidents, etc.). Reference the individual Support Subsystems in the Appendix A for GUI requirements relevant to each support subsystem).

3.3.2 Map Displays

This section will address the user-interface portion of the map-based display. For detailed requirements for the map database, reference Appendix A, the DTDB Subsystem.

A salient feature of a well-designed ATMS is to provide the tools necessary to effectively monitor traffic conditions. A key ingredient to fulfilling this requirement is the implementation of an effective Geographic Information System (GIS) and Map-based user-interface for the monitoring activities. The GIS and Map-based user-interface shall be capable of fulfilling the following requirements.

O14 The base map display shall provide zoom and pan capabilities for the traffic network of interest; display of coordinates; and display of user selected features/attributes; This could include a surface street/arterial network, or a freeway network, or some combination thereof (city maps with superimposed freeway maps).

015 The map display shall provide tool-kit level APIs or interfaces for a commercial GIS product to facilitate geo-coding and referencing, map customization and color-coding, feature association, spatial queries, and the superimposing of images and icons on the display.

016 The map display shall provide the capability of displaying street maps for cities and freeways at the highest level and network geometries (e.g., number of lanes, intersection layouts) at the lowest level for the analysis network of interest. The lowest level is likely to require the use of imported CAD files.

017 The map display must be able to display CAD, raster, and vector data.

01 8 The map display must support the ability to annotate maps with transportation symbols and text.

01 9 The DBMS, GIS, and map display components shall be compliant with the OSF/Motif style guide.

4 Since OSFs Motif is built on top of the X Window System, Motif implementations by default comply with the X Window System de-facto standard. Motif is available on most RISC workstations and PCs.

3.3.3 Event Logging

The GUI shall facilitate the display of events that are generated from various applications of the system. Events by definition are any action conducted by either the system or tbe operator.

01 10 The GUI shall accept different event types simultaneously (e.g., application events, operator events). The design of this subsystem will manage concurrecy issues.

0111 Events shall include at minimum the following:

Operator Events. User logs in/out, user starts/quits application, user database updates, user changes traffic control strategy, tactic, plan, or associated parameters.

Application Events. Incident detected, user input required, application error, node down, database storage capacity, performance problem, or any other monitoring abnormality. Each application is responsible for generating events and depositing them into the DBMS.

0112 Each event shall contain data that describes the following:

a. Event source (e.g., a tag of the application that generated the event message).

b. Event type.

C. Time/date the event was generated.

d. Any length message describing the event.

e An event priority.

01 13 All events shall be logged to a separate system file.

01 14 The events display shall be capable, at user request, to filter and/or sort events being displayed.

01 14.1 Events can be sorted by time, priority, source, and type. The default setting, which shall also be user definable, will be to sort by time.

01 14.2 Events can be filtered by time, priority, source, and type. The default setting, which shall also be user definable, is to receive all events.

01 15 The event system shall provide the capability to display either real-time events or archived events.

0116 The event display shall be scrollable.

01 17 The event system shall permit the display of multiple event windows, each configured (sorts, filters) to tbe user's specification.

01 18 All events shall be displayable, at user request, to the GUI or to a printer.

0 1 1 9 Events can be printed from the log file (all events) or from the GUI (with current user settings for filters and type of sort).

01 20 Color-coded events shall be associated with the highest priority events. The priority of each event as well as the priority ranges associated with the color codes shall be user-definable. The colors associated with the events (for consistency purposes) are not user-definable.

01 21 For high priority events, the system shall be capable of requiring acknowledgements and/or providing audible queues. The user will have the capability to define and change the priority ranges that are to generate acknowledgements and/or audio queues. It is not required that the user utilize this function. Aside from the user being able to define the ranges for acknowledgements and audio queues, the user shall also be provided the option to enable/disable this activity for existing definitions.

3.3.4 Software Access and Security

01 22 The system shall prevent unauthorized users from logging into the system. The system will use a login name/password combination to track authorized users.

01 22.1 All attempts (either by a valid or invalid user) to login to the system will be logged.

0122.2 After three unsuccessful attempts by a user to login to the system, the login prompt will be deactivated for 30 seconds.

01 23 The system shall support security levels. Security levels prevent authorized users, without the correct security level, from using certain applications (e.g., Traffic Control, Database Updates).

01 23.1 A user with security level in shall be permitted to execute any support system application, such that the required security level of that application is $<$ n.

0123.2 The login name/password combinations and associated security levels for all users and applications shall be reconfigurable (add, delete, change). The configuration or reconfiguration of this data is permitted only by the System Administrator.

01 23.3 Special security levels shall be provided that allow certain users to have access to operating system-level commands and to direct SQL level interfaces provided by the DBMS.

01 24 The system shall not permit the user to start new applications on a node that will cause it to exceed peak utilization of available

resources (CPU, Disk, I/O). This requirement works in conjunction with the operating system requirements that establish high priorities for real-time or time critical software processes (reference SW 4).

Software configuration management and Quality Assurance measures will be addressed in a Programmers Maintenance Document.

3.4 System-Level Facility Requirements

The system-level facility requirements for the ATMS are presented in the following paragraphs. It is important to understand that more specific facility requirements will be necessary pending design outcomes determined in upcoming work (e.g., type and number of workstations, number of consoles/operators, number of monitors, etc.). In addition, many of these decisions will be driven by the following:

a. Selected Hardware to meet Functional Specifications and associated Hardware requirements impacting Facility requirements.

b. Size of the Traffic Network (surveillance and control scope).

c. Customer/Site Requirements (external interfaces, type and quantity of incoming and outgoing data at each site, e.g., AVI/AVL vehicles, required staffing profiles).

d. Size of the ATMS Region (e.g., number of participating nodes, communication load requirements).

e. Technological Advances (e.g., hardware performance).

f. Deployment Considerations.

1. Characteristics/configuration of existing system.
2. Upgrade/migration path.
3. Policies and procedures.
4. Budgets.
5. Available space.

In general, however, it is our belief that the facility should be designed in accordance with Human Factors guidelines to leverage efficiency and effectiveness of operations.

FAC 1 The facility to house the TMC hardware, software, and operations crew shall be an office environment. The use of raised floors shall not be required.

FAC 2 The facility shall be capable of maintaining a temperature of 68”. The use of special air conditioning systems is obviously dependent on the type and quantity of hardware components, but it is not currently envisioned that special a/c systems will be necessary.

FAC 3 There shall be sufficient power outlets and resources for the necessary and redundant hardware components (e.g., computers, peripherals, large screen displays, banks of monitors, etc.). The number of outlets is dependent on design and deployment considerations.

FAC 4 Power outlets should be Uninterruptible Power Supply (UPS) compliant.

FAC 5 Surge protectors shall be required for processors.

FAC 6 The facility shall provide the infrastructure for network backbones for a LAN/WAN installations and incoming/outing communication lines and connections.

FAC 7 The facility shall provide sufficient lighting controls to minimize glare and eye strain.

FAC 8 The facility shall provide ample space for the storage of online hardware components and redundant components. This includes computers, printers, backup devices, telex and facsimile machines, etc. Space should also be provided for the storage of printed materials, such as system manuals and operation procedures. The actual square footage requirement is dependent on many factors, including type and number of consoles, staffing profiles, monitors, size of network, etc.

FAC 9 The facility shall provide ample wall space for the wall monitors and overhead projections. The wall space shall be easily viewable in entirety by all operator consoles.

FAC 10 The operator consoles shall be designed to accommodate ergonomic and operational demands. Ergonomic features shall conform to Human Factors guidelines (e.g., adjustable chairs, footrests). Operational demands include access from the console to the telephone, workstation components, camera controls, video switching monitors, and radio communications.

FAC 11 The physical access of the facility will be controlled. Access shall only be provided to authorized employees only. The use of card keys, cipher **locks, or similar mechanisms will be required on all door** entrances.

Illustrated in Figure 3-l is a typical configuration for a TMC facility.

3.5 System Level Architecture Requirements

The System Level Architecture requirements address the candidate software architecture to be used for development of Support Systems. Not included here are ATMS Architectural Issues (e.g., coupling between routing and control, roadway beacon versus satellite). Current assumptions, however, for these types of architectural issues are summarized in Appendix D.

Candidate TMC Facility Layout

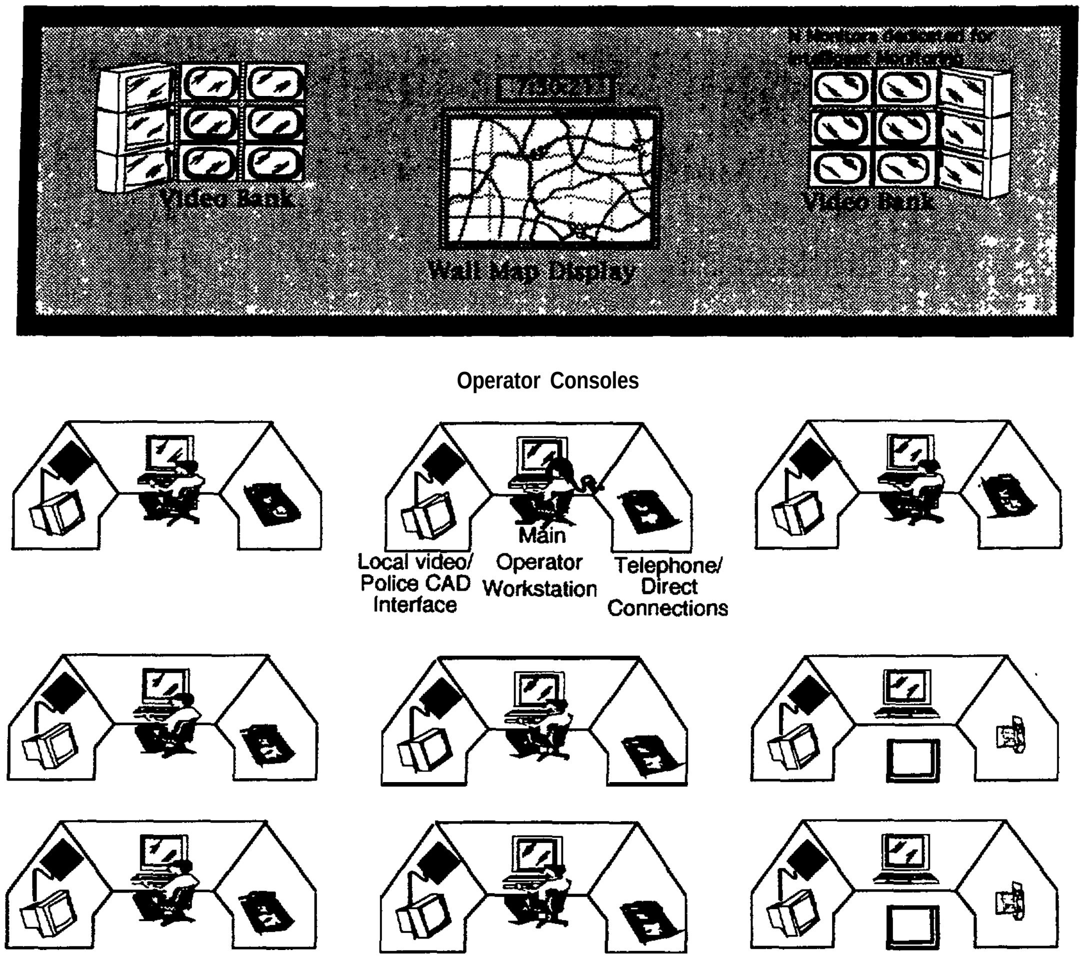


Figure 3-1. Candidate Facility Layout

The ATMS Support Systems will use client/server computing to distribute and share processing capabilities. The client/server model, an extension of shared device processing, offers several unique advantages well suited to the TMC software environment (Berson '92, see paragraph 1.6, item b) including the following:

a. Distribution/division of processing between clients and servers.

b. Server-based arbitration of multiple, simultaneous client requests.

c. Client/server cooperative interactions, that are initiated by a client.

d. Services or data provided to many clients by request.

e. Lower network traffic, response time, network bandwidth requirements, and costs.

f. Client/server model is scaleable in terms of hardware.

g. Lower lifecycle maintenance costs.

ARC 1 The implementation of Support Subsystems shall use a client-server technology where feasible (see Figure 3-2).

It is currently envisioned that there will be at least the following servers:

Svstem Servers

a. Database Server.

b. File Server.

c. Communications Server.

Application Servers

Most Support Subsystem applications will be application servers. However, there are application servers that may require special hardware requirements (parallel processing, extended memory, i/o) to meet the functional specifications. An example of this may be a parallel processor for image analysis.

3.6 System-Level Fault Tolerant Requirements

The system-level fault tolerance requirements are presented below.

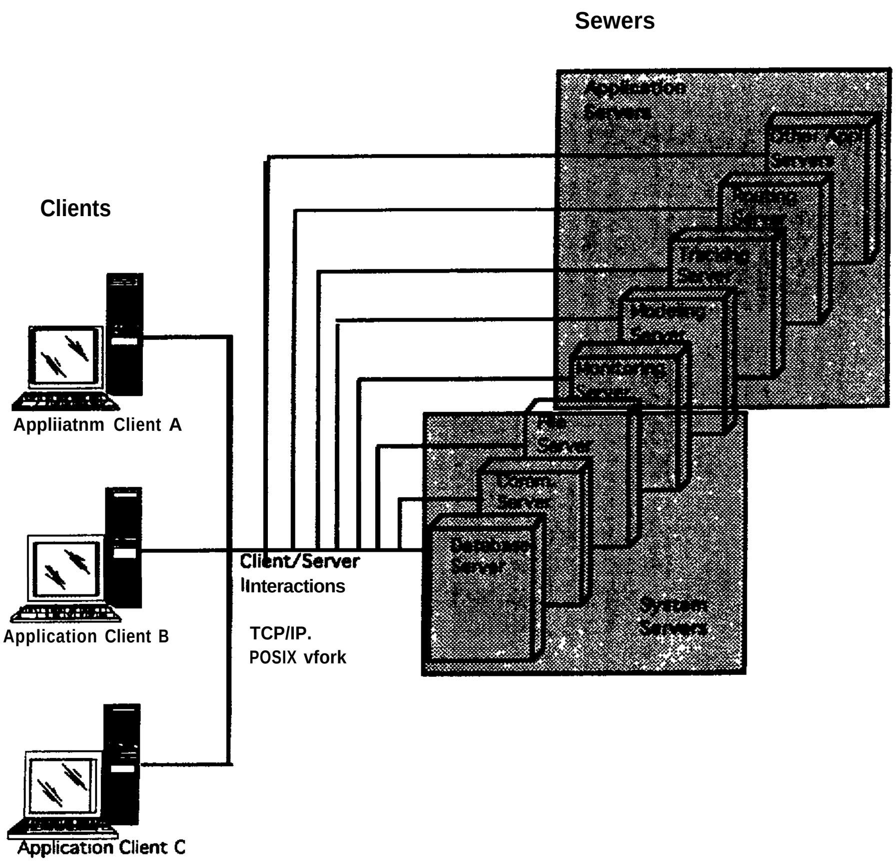
FT 1 The configuration of the software (including databases) shall not permit a single point of failure.

FT2 The configuration of the hardware (including networks) shall not permit a single point of failure to the system.

FT 3 The database shall support mirroring for online recovery of database failures (reference paragraph 2.3.4). Mirroring will be used only for the critical part of the database; it is not currently envisioned that mirroring of the whole database will be necessary.

FT4 The system shall not permit the user to start new applications on a node that will cause it to exceed peak utilization of available resources (CPU, Disk, I/O).

ATMS Support System Architecture
Utilizing Client/Server Technology



Preliminary Hardware/Communications/Software Specifications

IAN Backbone - 10 Base F "Fast Ethernet"
Client Platforms - X terminal or Low Power Unix RISC W/S, e.g. SPARCclassic
Sewer Platforms - Multi-CPU, scaleable Unix box, with configurations available for I/O intense servers (e.g. higher bandwidth, SPARCserver)
Protocols - TCP/IP and POSIX message queues and vfork
Windowing System - X Window System running OSF/Motif software
GIS/Map Database - Temporal and spatial relationships/queries, plugs to DBMS
Database - SQL compliant RDBMS

Figure 3-2. Client/Server Architecture

FT5 The design of the system (both hardware and software) shall permit the configuration of redundant components (e.g., dual rail ethernet, redundant platforms running critical applications, backup power sources etc.).

FT 6 In the event of a communication link failure between TMC nodes participating in the ATMS region, a rerouting capability shall be provided through other communication paths.

FT 7 The hardware platforms and associated software for time-critical and real-time applications shall have an availability rate of 99 percent. Provisions for recovery from failures will be provided through redundancy. The time to recovery from a hardware or software failure should take no longer than 5 minutes. This assumes redundant workstations already booted with. the necessary software loaded and configured.

3.7 System-Level Performance Requirements

This section identifies system-level performance-related requirements for ATMS. Specific subsystem-level performance requirements are contained in the requirements/specifications in Appendix A.

PERF 1 The system shall provide sufficient CPU, memory, disk, and network resources to simultaneously accomplish the following types of activities without severe degradation of system performance or response times:

a. Receive, validate, and load the DBMS for the real-time data (both synchronous and asynchronous) entering the system (vehicle probes, image-based, fixed location surveillance, ATIS O-D, Inter-Regional **ATMS,** etc.).

b. Retrieve from the DBMS and transmit real-time data (both synchronous and asynchronous) to external sources. This includes static network data, real-time traffic state data, incident data, routing information, traffic control, etc.

c. Satisfy the requests of Support Subsystem applications [including real-time (e.g., Traffic Control System), time-critical online (e.g., Traffic and Environmental Monitoring), online (e.g., Integrated Modeling Manager), and offline (e.g., Event Planning and Scheduling)] and their respective users (reference DTDB).

PERF 2 No system activity shall impair the performance of real-time or time-critical functions, such as real-time traffic control, surveillance input processing, or user display updates.

PERF 3 The system shall not use more than 75 percent of its primary resources (CPU, Disk, Memory, I/O Network) during normal operations; and not more than 90 percent during emergency situations. A subsequent analysis of primary function versus demand on primary system resources will be necessary on a subsystem-by-subsystem basis. This analysis will be conducted in Task D (design), and will serve as a driver for the number and type of workstations required.

PERF 4 User input via a keyboard or mouse should be accepted (not necessarily responded to) within .2 seconds.

PERF 5 The update of displays for real-time data shall occur at user-definable intervals with a minimum resolution of twice per second accurate to l/l0 of a second.

SECTION 4

DESIGN/DEPLOYMENT CONSIDERATIONS

This section addresses topics that are critical to the successful design, implementation, and eventual deployment of Support Systems. These topics are: a) issues with field integration, b) prototyping, c) coordination with the Georgia Tech Research Institute (GTRI) Human Factors contractor, and d) coordination with other relevant contracts.

4.1 Issues with Field Integration

This section addresses some of the significant deployment considerations prior to selecting the field site and prior to the prototyping and subsequent fielding of the Support Systems. Although most of the deployment considerations in this section are specific to the testing of prototypes to be developed under this contract, it is anticipated that many of the same types of issues need to be addressed when upgrading from state-of-the-practice technology.

In terms of desirable qualifications, candidate sites should have the capability to perform integrated freeway and surface street control. There should be instrumented (cameras, loop detectors, or acoustic detectors, etc.) roadways for a substantial portion of the traffic network, with some form of automated monitoring such as incident detection. Interfaces for probe data should be provided to accomodate the data when available. Roadways should be outfitted with with other types of control such as CMS and HAR. There should exist interfaces to external systems and agencies (e.g., Police CAD, MPOs, ATIS). The TMC itself should have ample facility space for the integration of selected Support Systems. Access to infrastructure services, such as communication lines, wall monitors, surveillance data, databases, policies, and procedures shall be provided.

The development and integration of Support Systems need to facilitate a migration path to accommodate all of the various types of existing TMCs with varying levels of sophistication. The migration path should provide the capability to deploy new Support Systems in phases, such that existing TMCs may retain current functionality (or at least major portions of the most critical components) initially and then in later phases slowly replace pieces as desired. The design of the Support Systems should be generic and modular enough to interface to many types of TMCs irrespective of the types of surveillance and control equipment. The Traffic and Environmental Monitoring subsystem, for instance, should work whether or not a particular TMC has CCTV capability. There are, however, several areas that have already been identified that will require in most cases custom interface and translation code. The most significant interfaces are identified in Table 4- 1.

Table 4-1. Interfaces

Interface	Function	Support Subsystem
Database	To interface to existing databases or memory (i.e., UTCS) to obtain surveillance data.	Inter-TMC Data Exchange
Database	To translate data from the current format to that of the ATMS DBMS.	Inter-TMC Data Exchange
Traffic Control System	To interface to the Incident Management subsystem for incident notification.	Traffic Control System/ Incident Management
Traffic Control System	To interface to the Wide Area Traffk Management subsystem for the purpose of proactive traffic control.	Traffic Control System/Wide-Area Traffic Control
Front-End Communications	To interface to the real-time system for the purpose of receiving certain types of data (e.g., image, probe).	Input Stream Processing
Front-End Communications	To interface to external systems for the purpose of information dissemination of both real-time and non-real-time data.	Output Stream Processing

A final issue with field integration involves interfaces to other systems, where the interface is either currently non-existent or evolving. The interface to ATIS and probe vehicles, for instance, is currently evolving. In these cases, risk mitigation techniques (modular design, adoption of appropriate standards, coordination with IVHS community) must be employed to limit impacts to other system components.

4.2 Prototyping

The use of prototyping prior or in parallel to upcoming design is an integral part of the approach to the design of the Support Systems. Upfront user and community involvement is critical to the acceptance and ultimately to the success of the system. To this end, our approach will be to prototype the GUI for key components of this system. The Traffic and Environmental Monitoring, Incident Management, Wide-Area Traffic Management, Event Planning and Scheduling and the Integrated Modeling Manager will require prototyping due to the importance and complexity of potential interactions between the user and the system. In addition, the overall framework (menus, pulldowns, event display system, map display system, database forms, etc.) will need to be prototyped.

4.3 Coordination with GTRI Human Factors Contract

Prior to the prototyping and design efforts, close coordination with the GTRI Human Factors contractor will be required to recommend/modify solutions for facility layout, console layout, wall maps, video banks, map displays, data presentation techniques, screen layouts, event notifications, levels of user control, and human versus automated functions. In addition, there are a few key issues that have been identified through the course of requirements analysis that will require human factors analysis to ensure an effective and efficient solution. Those issues are summarized in Table 4-2.

Table 4-2. Issues

Issue	Responsible Support System
Automated camera allocation to a selected subset of available monitors for the purposes of verifying a prioritized list of probable incidents. If the list is larger than the number of available monitors, then poll select cameras and display them for intervals of x seconds.	Traffic and Environmental Monitoring
Display of surveillance data from multiple TMCs on the ATMS network.	Wide Area Traffic Management
Optimum CMS message lengths and display durations.	Traffic Control System

4.4 Coordination with Other Relevant Contracts

In addition to coordination with the GTRI Human Factors team, there are several other ongoing contracts that will require coordination for successful implementation of a full-scale, IVHS-era ATMS. Those contracts that we art: aware of, and whose products could be (assuming coordination), and in some cases must be, integrated are identified in Table 4-3.

Table 4-3 Contract Products

ATMS Support Subsystem (prioritized)	ATMS Support System	FHWA Contract
Traffic Control System	Traffic Management	RT-TRACS, Farradyne
ATMS Component Simulation Models	Analysis and Modeling	TML-2
Dynamic Traffic Assignment	Analysis and Modeling	DTA Contract/Uoft, and new DTA contract
O-D Processing	Analysis and Modeling	DTA Contract/Uoft, and new DTA contract
Signal and Control Optimization Models	Analysis and Modeling	Network Opti. Contract
Traffic Simulation Models	Analysis and Modeling	TML-2, Models to Simulate IVHS Operations, Modifications to Traffic Models for Testing Real-Time Control Study
GUI (Map/GIS)	**Common** Services	Map Database and Link ID Systems/ORNL
Traffic and Environmental Aonitoring	Monitoring	Incident Detection Issues/Ball Systems

SECTION 5

FUTURE DIRECTIONS

This document identified candidate Support Systems and Support Subsystems. Requirements and specifications for the ATMS System and for the individual Support Subsystems were developed. The next step is to design and then implement those Support Subsystems which will be built under the scope of this contract. In the design, hardware and software alternatives and solutions will be presented for Support Subsystems to be built. The design will also entail coordination with those entities identified in paragraphs 4.3 and 4.4.

APPENDIX A

FUNCTIONAL REQUIREMENTS AND SPECIFICATIONS FOR SUPPORT SUBSYSTEMS

APPENDIX A

FUNCTIONAL REQUIREMENTS AND SPECIFICATIONS FOR SUPPORT SUBSYSTEMS

In this appendix, functional requirements and specifications for all support subsystems are identified. Requirements with an asterisk after the requirement identifier are long-term requirements (e.g., 2002).

For simplification purposes Support Subsystem abbreviations are used commonly throughout this document. The algorithm for abbreviations is as follows: the first letter of the abbreviation indicates the Support System, and the last three indicate the first letter of each word in the title of the subsystem (refer to Table A-l).

Table A-l. Abbreviations

First Letter	Support System
M	Monitoring
D	Data Management
T	Traffic Management
S	System Management
A	Analysis and Modeling
C	External Communications

For example, the Support Subsystem Input Stream Processing encompassed by the Communications Support System has an abbreviation CISP.

In Table A-2, a guide of the acronyms used for the Support Subsystems is provided. The requirements and specifications are listed in Table A-3.

Table A-2. Support Subsystem Acronyms

Acronym	Support Subsystem	Support System
AACS	ATMS Component Simulation Models	Analysis and Modeling
ADTA	Dynamic Traffic Assignment	Analysis and Modeling
AI-IDA	Historical Data Analysis	Analysis and Modeling
AIMM	Integrated Modeling Manager	Analysis and Modeling
AODP	Origin-Destination Processing	Analysis and Modeling
ASCO	Signal and Control Optimization Models	Analysis and Modeling
ATSM	Traffic Simulation Models	Analysis and Modeling
CIOM	I/O Manager	External Communications
CISP	Input Stream Processing	External Communications
COSP	Output Stream Processing	External Communications
DDFM	Document and File Management	Data Management
DDVA	Data Validation	Data Management
DIDE	Inter-TMC Data Exchange	Data Management
DTDB	TMC Database	Data Management
MSIP	Surveillance Image Processing	Monitoring
MTEM	Traffic and Environmental Monitoring	Monitoring
MVTR	Vehicle Tracking	Monitoring
SACS	Automated Control Software Downloading	System Management
SCIM	Configuration and Inventory Management	Traffic Management
SEPS	Event Planning and Scheduling	System Management
SMMS	Maintenance Management	Traffic Management
STHS	TMC Hardware and Software Monitoring	System Management
TIMS	Incident Management	Traffic Management
TIVR	Individual Vehicle Routing	Traffic Management
TTCS	Traffic Control System (Frwys, SS)	Traffic Management
TWTM	Wide-Area Traffic Management	Traffic Management

Table A-3. Requirements and Specifications

I/O MANAGER SUBSYSTEM (CIOM)

ID	REQUIREMENT AND FUNCTIONAL SPECIFICATION	IMPLEMENTATION SPECIFICATIONS
CIOM 100	**The CIOM subsystem shall ingest scheduling requests through an API with various TMC applications. Requests may be received from the following:** a. Historical Data Analysis. b. Traffic Control System. c. Wide-area Traffic Management. d. Individual Vehicle Routing. e. Event Planning and Scheduling.	Requests may be received for various functions: a. Input processing. b. Output dissemination to traffic control or to external systems. c. Execution of another non-I/O process. The API shall identify the process to be scheduled, the scheduled time and, in some cases, a pointer to the input data for the process.
CIOM 100.1	The CIOM shall support requests for both synchronous and asynchronous I/O events.	Synchronous requests will specify the interval at which the process is to be executed.
CIOM 101	**The CIOM subsystem shall schedule non-DBMS processes or functions (computer programs) to be executed within the TMC.**	DBMS process scheduling has been allocated to the DBMS (i.e. DIDE employs DBMS scheduling). Process scheduling in UNIX can be implemented using UNIX utilities. It is to be determined if the entire functionality can be made OS independent. Scheduling can be synchronous (e.g., output dissemination of real-time traffic data to ATIS) or asynchronous (special event). I/O Manager will internally maintain a next event log.
CIOM 101.1	The CIOM shall activate output application processes in the Output Stream Processing Subsystem.	Output stream programs comprise two general types: data retrieval and reporting application. In the first case, the only processing involved is the file access and dissemination. In the second case, an application is executed to generate the data which is then disseminated. Software implementation options include the storing of the program itself (e.g., SQL script) in the DBMS and compile at run time or store the object code as an OS file.
CIOM 101.2	The CIOM shall activate a software application at a scheduled time through an API, which passes the needed information to the scheduled process.	The API shall identify the process to be scheduled, the scheduled time and, in some cases, a pointer to the input data for the process.
CIOM 101.3	The CIOM shall activate a User Interface alarm if the scheduled process requires operator input.	
CIOM 101.3.1	The CIOM shall interface with the Event Scheduler of the Traffic Control system to implement a control strategy.	Depending on the architecture of the control system software, the interface may be with the Event Scheduler or directly with the control software.

CIOM 102	**The CIOM subsystem shall provide a User Interface through which one can schedule new events as well as change or delete already scheduled events.**	The event specification includes the same data as in CIOM 100. Various display options are included for viewing the event log (e.g., sorting by process and time, masking certain types of events).
CIOM 102.1	Tbe User Interface shall include the display of the event log including scrolling through the list.	
CIOM 102.2	The Event Log Display shall include the following data: a. Event ID- unique system identifier. b. Event Name - process name. c. Event Type. d. Scheduled time. e. Pointer to input data in the DBMS- optional. f. Originating application. g. User Name. h. Date/time event request received.	

Implementation Issues:

a. Programming Language Selection. Language choice will have an impact (Ada, C++ tasking versus C or FORTRAN interrupts) on whether CIOM can be made OS independent.

INPUT STREAM PROCESSING (CISP)

ID	REQUIREMENT AND FUNCTIONAL SPECIFICATION	IMPLEMENTATION SPECIFICATIONS'.
CISP 100	**CISP shall provide an interface for receiving digital and analog data from:** a. IVHS Systems - ATIS, CVO, APTS, AVCS, other ATMS. b. Non-IVHS Systems (e.g., National Weather Service). c. Organizational Users (e.g., MPOs). d. Users (e.g., the travelling public). e. Emergency Services (e.g., police). f. Internal interface to ATMS Component Simulations	Communication interface shall support multiple protocols (TCP/IP, CDPD, etc.). Utilizes IVHS standard protocols. Standard protocols for IVHS have not yet been developed and are pending the IVHS architecture study results.
CISP 100.1	CISP shall provide a digital (in some cases analog might be required) interface to receive the following types of data: a. Trip planning data (O-D). b. Ground vehicle probe data. c. Interregional traffic information from other ATMS. d. HAZMAT and Emergency vehicle routing requests. e. MAYDAY messages. f. Parking data. g. The operational status of external systems. h. Environmental data including weather and pollution levels. i. Data from TBD databases (e.g., HAZMAT). j. AVI data -- vehicle location and speed. k. Incident Status reports 1. Policy and budget data. m. Special event plans and requests for support.	Depending on the overall architecture: I) probe data might be concentrated prior to communicating with TMC, 2) Direct vehicle to TMC communications. Dedicated, multiple processors (scaleable) are likely to be required. Specific data rates will be determined during Task D.
CISP l00.2	CISP shall support receiving digital data using multiple transmission media including: a. Radio. b. Microwave. c. Twisted pair and coaxial cable. d. Fiber-optic cable.	
CISP 100.3	CISP shall support input data rates of TBD minimum rate and TBD maximum rate.	

CISP 101	**CISP shall provide an interface for receiving analog data from:** a. IVHS Systems - ATIS, CVO, APTS, AVCS, other ATMS. b. Non-IVHS Systems (e.g., National Weather Service). c. Organizational Users (e.g., MPOs). d. Users (e.g., the travelling public). e. Emergency Services (e.g., police).	
CISP 100.1	CISP shall provide a voice interface receiving the following types of data: a. HAZMAT and Emergency vehicle routing requests. b. MAYDAY messages. c. Requests for historical information. d. The operational status of external systems. e. Environmental data including weather and pollution levels. f. Signal preemption data such as vehicle location and speed. g. Incident Status reports h. Policy and budget data. i. Special event plans and requests for support.	
CISP 100.2	CISP shall support receiving analog data using multiple transmission media including: a. Radio. b. Telephone.	
CISP 101	**CISP shall provide an interface for receiving video surveillance data for as many as 1000 units.**	The interface depends on the communication links between the field units and the TMC. Various options are possible: 1) single line per unit 2) multiplexing several cameras onto a single fiber-optic line 3) selective transmission.
CISP 102	**CISP shall process received data to determine communication errors.**	Uses multiple commercially available protocols. Protocols can meet most of these requirements (e.g., TCP/IP).
CISP 102.1	CISP shall extract communications overhead bits from received data.	
CISP 102.2	CISP shall verify the integrity of received data through the use of commercially available algorithms such as sequence checking and Cyclic Redundancy Checking (CRC).	
CISP 102.3	CISP shall generate error statistics for all detected data receipt errors.	
CISP 102.4	CISP shall store generated error statistics.	
CISP 102.5	CISP shall provide thresholds for acceptable data receipt errors.	
CISP 102.6	CISP shall provide a method for modifying error thresholds at operator request.	
CISP 102.7	CISP shall provide methods for generating communications error reports.	

CISP 103	**CISP shall extract, format, and load the ATMS database with received digital and analog data.**	Required formats reflect the DBMS data schema. DBMS interface is provided via a SQL API.
CISP 103.1	CISP shall extract digital data from received data packets.	
CISP 103.2	CISP shall convert the digital data into the proscribed format.	
CISP 103.3	CISP shall generate a standard Structured Query Language (SQL) database for populating received data into the ATMS database.	SQL implementation is tentatively assumed. Non-relational databases will be evaluated during the design process.
CISP 103.4	CISP shall convert analog signal inputs to digital formats for further processing.	
CISP 104	**CISP shall generate messages alerting other ATMS processes that data they require has been received or route the data directly.**	ISP shall activate processes via client/server model (e.g., make a request to the routing server when a request is received) or send messages using TCP/IP sockets or POSIX message queues.
CISP 104.1	An interface shall be provided with the Individual Vehicle Routing subsystem for incoming route requests.	
CISP 104.2	An interface shall be provided with the Traffic and Environmental Monitoring subsystem for CCTV data.	
CISP 104.3	An interface shall be provided with the Surveillance Image Processing subsystem to receive forked image data for image analysis.	
CISP 104.4	An interface shall be provided with the Vehicle Tracking system for AVI incoming data.	

OUTPUT STREAM PROCESSING (COSP)

ID	REQUIREMENT & FUNCTIONAL SPECIFICATIONS	IMPLEMENTATION SPECIFICATIONS
COSP 100	**COSP shall provide an interface for transmitting digital and analog data to:** a. IVHS Systems - ATIS, CVO, APTS, AVCS, other ATMS. b. Non-IVHS Systems c. Organizational Users (e.g., MPOs). d. Users (e.g., the travelling public). e. Emergency Services (e.g., police).	Communication interface shall support multiple protocols (TCP/IP, PCM, etc.).
COSP 100.1	COSP shall provide a digital interface to transmit the following types of data: a. Real-time traffic data (ATIS traffic information). b. Interregional traffic information to other ATMS. c. Responses to HAZMAT and Emergency vehicle routing requests. d. Responses for historical information requests. e. The operational status of the ATMS. f. Incident Status reports g. Special Event/Construction data.	
COSP 100.2	COSP shall support transmitting digital data using multiple transmission media including: a. Radio. b. Microwave. c. Twisted pair and coaxial cable. d. Fiber-optic cable.	
COSP 100.3	COSP shall support output data rates of TBD minimum rate and TBD maximum rate.	
COSP 100.4	COSP shall provide a voice interface for transmitting the following types of data: a. Interregional traffic information from to other ATMS. b. Responses to HAZMAT and Emergency vehicle routing requests. c. Responses to for historical information. d. The operational status of the ATMS systems. e. Data updates to TBD databases (e.g., HAZMAT). f. Incident Status reports g. Special event plans and requests for support.	
COSP 100.5	COSP shall transmit voice data using multiple transmission media including: a. Radio. b. Telephone.	

COSP 101	**COSP shall provide an interface for transmitting video surveillance data.**	Video surveillance can be re-routed to external systems.
COSP 102	**COSP shall transmit data using commercially available protocols.**	Utilizes IVHS standard protocols. Standard protocols for IVHS have not yet been developed and are pending the IVHS architecture study results.
COSP 103	**COSP shall extract, format, and transmit data from the ATMS database.**	Utilizes a DBMS SQL API.
COSP 103.1	COSP shall package the data and transmit in accordance with prescribed output format requirements..	
COSP 104	**COSP shall provide an interface with the I/O Manager to accommodate the transmission of regular data to external systems or agencies, The I/O Manager can call on COSP to transmit a set of data at a predetermined time or to invoke another application to generate the data and then transmit that data to the proper destination across the communication channel managed by this subsystem.**	The interface to the I/O Manager shall bc provided via the client/server model, Unix process scheduling commands, or a TCP/IP socket or POSIX message queue.

SURVEILLANCE IMAGE PROCESSING (MSIP)

ID	REQUIREMENT AND FUNCTIONAL SPECIFICATION	IMPLEMENTATION SPECIFICATIONS
MSIP 100	**The MSIP subsystem shall provide a system interface with the Input Stream Processing subsystem to receive raw image data for processing from CCTV cameras in the field.**	The interface will transmit the image data to the MSIP process. A hardware interface (video card, fiber-optic comm links) and software interfaces will be necessary. Processing could be done in the field or in the TMC. Communication bandwidth is minimized if processing is done in the field.
MSIP 101	**The MSIP subsystem shall have the capability to extract traffic parameters from the image data.**	Existing systems which provide most of these functions include AutoScope.
MSIP 01.1	The MSIP subsystem shall have the capability to process the image data and calculate volume, density, speed, and queue-length of the traffic flow. It will also calculate the vehicle delays. The output results shall be broken down to an appropriate level (e.g., by lane, approach etc.) and stored in the TMC DBMS.	
MSIP 102*	**The MSIP subsystem shall have the capability to classify vehicles. The classification of vehicles should be 95 percent accurate and take less than 30 seconds.**	Case histories shall be stored in a database that supports the analysis process by allowing attributes of vehicles to be catalogued for later recall for comparison.
MSIP 103	**The MSIP subsystem shall have the capability to support any detection zone configuration manually entered through the operator interface in the Traffic Monitoring and Environmental Monitoring subsystem.**	The GUI for CCTV control (zoom, pan, tilt, detection zones) is in the Traffic and Environmental Monitoring subsystem; that GUI has the capability to provide the placement of the detection zone anywhere within the view of the camera and at any orientation. The operator interface also supports the creation and modification of detection zones by using the mouse to draw the detection lines and boxes on the monitor. Default detection zones are used if none are provided.
MSIP 103.1	The MSIP subsystem shall have a default detection zone that will be used if a detection zone is not specified.	
MSIP **103.2**	The MSIP subsystem shall have the capability to calibrate itself when the setting , of the camera is altered.	
MSIP 104*	**The MSIP subsystem shall have the capability to detect incidents from the raw images (aided by the numerical data, e.g., loop detector data or traffic data extracted from images). Incidents should be detectable within 30 seconds of their occurrence:** **< 1% false alarms** **99% detection fraction.**	This is done by performing image analysis. A candidate technique is the training of a neural network to detect incidents and classify vehicles from raw images.
MSIP 104.1	The MSIP subsystem shall have the capability to identify and classify traffic conditions from raw images.	Case histories shall be stored in a database that supports the analysis process by allowing attributes of verified incidents to be catalogued for later recall for comparison.

MSIP 104.2	The MSIP subsystem shall have the capability to process the images on a wide-area basis. The term "wide-area" applies to full camera view (i.e., within and beyond the defined detection zones) and correlating the image data received from various camera locations by understanding their relative positions. (This requirement is subject to the needs of the incident detection algorithm)	
MSIP 105	**The MSIP subsystem shall support and interface with the Traffic and Environmental Monitoring subsystem to provide notification when an incident has been detected from a raw image.**	This interface will be sorted by a TCP/IP socket or POSIX Message queue.
MSIP 106	The **MSIP subsvstem shall have the capability to store the raw image, and shall have an interface with the TMC DBMS. The storage of a raw image should occur when an incident is detected. Storage allows for later recall by operators for their analysis of performance and further monitoring (co-allocated with TMC DBMS and TMC Hardware and Software Monitoring).**	The interface to the DBMS is provided via a SQL API. This function is intended to support the monitoring of the software performance. One may also want to have 1 -minute pre-accident video archive readily available so that when incidents are automatically detected they can be analyzed or reconstructed for verification or analysis purposes.
MSIP 107	**The MSIP subsystem shall have the capability to retrieve any previously stored raw image data from the TMC DBMS (This requirement is subject to the needs of the incident detection algorithm).**	Interface requirements are dependent on the location of the MSIP If MSIP is located in field processors, the interface is local, otherwise communication and remote access to DBMS is necessary. In both cases, the access to a DBMS is provided via an SQL API.
MSIP 108	**The MSIP subsystem shall have the capability to interface with the Data Validation and Derivation subsystem to provide it with the derived traffic data and detected incidents.**	Assuming validation functionality is allocated to the DBMS, this interface is via an SQL **API.** If validation performed using custom code, this interface shall be provided via a TCP/IP or POSIX message queue.
MSIP 109	**The MSIP subsystem shall have the capability to perform under restricted visibility conditions such as low-light or adverse weather, e.g., rain, fop, snow, etc.**	The specific requirements for performance under low visibility conditions will be determined during design.
MSIP 110	**The MSIP subsystem shall have the capability to perform under traffic conditions ranging from under-saturated to over-saturated conditions.**	(same as above)
MSIP 111*	**The MSIP subsystem shall have the capability to use any video image so that this subsystem could be utilized within the existing CCTV (closed-circuit television) systems within the Traffic and Environmental Monitoring subsystem.**	Independent cameras for the purpose of performing image analysis shall bc avoided.
MSIP 111.1	In the case when an incident has been detected, the camera can be pointed to the incident for manual verification of monitoring of the incident. During this period of time, the SIP image processing algorithm shall remain off.	

ISSUES:

We anticipate a camera will be used for two purposes:

2

a. Image processing.

b. Occasional manual monitoring.

During the period when the camera is used for-manual incident verification and monitoring, automated image analysis will not be performed. If this assumption proves to be invalid, either redundant cameras are required or the **required** data has to be synthesized by another subsystem.

TRAFFIC AND ENVIRONMENTAL MONITORING (MTEM)

ID	FUNCTIONAL REQUIREMENTS & SPECIFICATIONS	IMPLEMENTATION SPECIFICATIONS
MSTEM 100	**MTEM shall provide access to all data needed for the monitoring of traffic and environmental conditions.**	Data Previously stored in the TMC DBMS would have been previously validated with respect to level 1 and level 2 validation independent of the allocation of the DDVA subsystem. It **is not** likely that context-based validation would be previously performed.
ITEM 100.1	MTEM shall retrieve pre-validated traffic and environmental measurement data from the TMC DBMS. The data being retrieved includes: a. Loop detector data (individual or previously aggregated). b. Traffic data from image-based surveillance (e.g., Autoscope). c. Traffic data from vehicle probes. d. Incident detection data previously computed by the Image Processing Subsystem. e. Environmental sensor data (organic to ATTRC). f. External automated source data (e.g., weather forecasts). g. Any pre-loaded non-automated data (i.e., a previously reported accident).	We distinguish between traffic measurement and traffic state data. Measurements represent the measured values; state data represent a model-based estimate of the traffic state. For example, the input to a Kalman filter is the measurement, the output is the state.
MTEM 100.2	MTEM shall accept and process manual inputs of potential incidents through the Common GUI and/or direct interface to external sources (e.g., 911 dispatch log).	Incident reports received via phone or other non-automated means are entered by the Operator via the User Interface
ITEM 100.2.1	MTEM shall have the capability to process both formatted and unformatted inputs.	Unformatted inputs may include voice data necessitating voice recognition software.
ITEM 100.2.2	MTEM shall transparently interface with the DDVA to alter the context-based parameters used in data validation.	Context-based parameters are stored in the DBMS. Updates to parameter values are received from the MTEM User Interface.
ITEM 100.3	MTEM shall provide access to any video surveillance camera selected by the Operator or the application.	
MTEM 100.3.1	MTEM shall provide the capability for the Operator to specify several CCTV display default options: a. Automatic display of highest probability incident location camera(s). b. Automatic cycling of the display of the n most likely incident locations through m TMC monitors (n>m). c. Manual operator selection of **camera(S).**	MTEM shall rank the detected incidents (maybe a priority queue algorithm) and depending on the number of available monitors in the TMC, cycle through the most likely incident locations. The optimum number of monitors depends on the tradeoff between the human factors issue, dealing with the number of simultaneous monitors to be viewed, versus the potential time lost in detecting an incident.
MTEM 100.3.2	The Operator shall have the capability to control the positional parameters of the camera (zoom, pan, tilt).	These capabilities are available in current CCTV systems.
MTEM 100.3.3	The MTEM subsystem shall have the capability to support the operator to define and **modify** detection zones from the workstation. The detection zones are used to configure the area to perform automated incident detection by the Surveillance Image Process subsystem.	
103.3.1	MTEM subsystem shall have the capability to provide placement of the detection zone used by the Surveillance Image Processing subsystem anywhere within the view of the camera and at any orientation.	The operator interface shall have the capability to support the creation and modification of detection zones by using the mouse to draw the detection lines and boxes on the monitor.

MTEM 100.3.4	MTEM shall have the capability to direct the video output from any camera to either a monitor or a workstation.	
MTEM 101	**MTEM shall process traffic measurement data to yield current state estimates of traffic densities, queues, speeds, and volumes for each network link.**	The definition of a link is driven by the input data requirements of the various traffic models. MTEM shall perform nominal value replacement in cases where data is unavailable due to failed detectors. In cases where a controller or an entire subsection is down, nominal value replacement may involve simulation. This function may involve several other support systems including the Component Simulation Model Subsystem. The need to store derived measures depends on whether there exists a requirement for the derived data elements by other application. Depending on performance, the derivation requirement may be allocated to those applications.
MTEM 101.1	MTEM shall process the vehicle probe traffic measurements to extract (if necessary) the data needed by the traffic state estimation model (allocated to the Input Processing Subsystem-cited here for reference).	
MTEM 101.2	MTEM shall be capability to derive single and aggregate traffic measures needed for estimating traffic states and store them in the TMC database	
MTEM 101.2.1	MTEM shall have the capability to derive single and aggregate traffic measures needed for estimating traffic states and store them in the TMC database.	
MTEM 102*	**MTEM shall automatically <u>fuse</u> the traffic state estimates, the manual inputs and the incident likelihood estimates from the Image Processing Subsystem into an overall <u>estimate of the incident state and likelihood</u> for each link. Estimates are provided for all links and intersecting nodes including freeways and arterials.**	The fusion algorithm yields a likelihood estimate for an incident. The algorithm may be numerical (a weighted sum of likelihoods as determined by independent data sources) or procedural (rule-based system). (see TIMS 100) In this context, surveillance data includes raw measurements from loop detectors and sensors that emulate loop detectors, as well as derived measures and estimates, depending on the detection algorithm. Detection of severity requires image processing, although some measure of severity may be inferred from the impact of the incident on traffic flow. At each sensitivity level there exists a trade-off between the false alarm and detection fraction. Automatic verification involving automated procedures is considered part of the detection algorithm. Different detection algorithms (California, APID, McMaster, Neural Networks) may be necessary for different traffic and environmental conditions. This capability is related to context-based validation.
MTEM 102.1	In determining the incident state, MTEM shall make an initial assessment of the severity and capacity reduction associated with the incident, and the expected duration (<u>this requirement is for an initial determination only-the Incident Management Subsystem will monitor the incident.</u>	
MTEM 102.2	TEMD shall have the capability to automatically detect incidents within 30 seconds of their occurrence from traffic surveillance data, differentiated by type and severity, for each network link. Automated incident detection is also allocated to the Image Processing Subsystem for direct processing of CCTV outputs.	
MTEM 102.2.1	MTEM shall have the capability to adjust to sensitivity level of the automated incident algorithm within the following ranges: a. False alarm rate < 10% b. Detection fraction > 95%	
MTEM 102.3	MTEM shall provide incident state estimates under all traffic and environmental state conditions, i.e., under low, moderate, and high volume, as well as good and bad weather conditions.	

MTEM 102.4	MTEM shall be capable of detecting incidents on all roadway types: freeways and surface streets.	Incident detection at intersections can be implemented using image processing.
MTEM 103	**MTEM shall have the capability to verify the occurrence of incidents once identified by automated detection.**	Verification is supported by CCTV monitoring. In cases where CCTV coverage is not available and where police verification has not occurred, several detection cycles have to be observed.
MTEM 103.1	MTEM shall prepare and issue requests for incident verification to the Remotely Controlled Surveillance Unit.	
MTEM 103.2	MTEM shall issue a notification to the Incident Management Subsystem when each new incident is verified.	Once an incident is verified and the DBMS loaded with initial data, TIMS is activated.
MTEM 104	**MTEM shall process environmental measurement data to produce current estimates of weather variables, temperature, type of current precipitation, and roadway surface conditions.**	This process may involve data fusion of multiple sources: ATMS environmental sensors, and external weather information from NWS, radio stations or private weather information providers.
MTEM 104.1	MTEM shall produce current local estimates of emissions for selected air pollutants.	Surveillance system also includes pollution sensors that can detect vehicle emissions.
MTEM 105	**MTEM shall detect traffic and environmental surveillance and external system equipment faults based on the processing involved in state estimation. Sensor types include:** a. Loop detectors and other traffic sensors (IR, acoustic). b. Environmental sensors. c. Video cameras. d. Vehicle probes. e. External systems.	As part of its data processing, MTEM may directly access the validation routines in the Data Validation subsystem.
MTEM 105.1	MTEM shall provide information on equipment fault detection to the Maintenance Management Scheduling Subsystem.	
MTEM 105.1.1	MTEM shall enter a failure log transaction in the TMC DBMS.	
MTEM 105.2	MTEM shall verify detected faults of ATMS equipment.	Visual or manual fault verification may not be timely enough, and is not possible for many sensor types.
MTEM 105.2.1	MTEM shall enter a context change signifying the fault to be used in the validation process (same as MTEM 102.2.2).	Automatic verification is a TBD requirement.
MTEM 105.3	MTEM shall report potential faults to external systems from which data is being received.	MTEM shall schedule a failure log entry report with the I/O Manager for output dissemination.
MTEM 106	**MTEM shall process the link-based traffic and environmental states to prepare summaries which characterize the current state of the network, and highlight traffic and environmental abnormalities.**	Characterization of traffic conditions may be in terms of LOS for individual links. Characterization at section/subsection level needs to be determined.
MTEM 107	**MTEM shall have the capability to compute the likelihood of incidents on network links based on traffic and environmental conditions.**	Incident likelihoods based on historical accident rates factored by current environmental and traffic conditions.

MTEM 108	MTEM shall interface with the TMC DBMS to store the computed link-based and summary traffic and environmental state estimates as well as the incident states, equipment faults, and context changes.	
MTEM 108.1	MTEM shall support offline analysis of incident detection and failure monitoring by maintaining "case histories" of false detections and failed detections. (This requirement is co-allocated to the DBMS and to the software monitoring function in TMC Hardware & Software Monitoring Subsystem).	Every detected incident that is not verified will be marked as failed verification in a "verify field." The incident log will be maintained in the data archives for future offline analysis.
MTEM 109	MTEM shall have an operator interface suitable to control processing, and to view the current traffic and environmental state, summaries, and abnormalities.	MTEM's User Interface will superimpose real-time monitoring information atop the underlying map. Different levels of abstraction of the underlying map and the displayed information will be available with the lowest level displaying the detailed geometric features at individual junctions. Higher levels correspond to street maps and tour maps. Various icons and graphic displays are used to represent traffic and environmental situational information (e.g., air quality contours).
MTEM 109.1	MTEM shall provide an online incident report form through which the User can manually enter incident information received via phone, etc.	
MTEM 109.1.1	MTEM will automatically enter the captured information in the TMC DBMS where it will be integrated with other available information.	
MTEM 109.2	MTEM shall have real-time GIS/map display capabilities	
MTEM 109.3	MTEM shall have the capability to control the detection sensitivity parameters, aggregation of parameters, and map view through the GUI.	
MTEM 109.4	MTEM shall have the capability to provide a singe network-wide display, multiple displays on several monitors, or multiple displays on one monitor.	The overall MTEM display configuration shall customized at system setup to the TMC site and its hardware/software configuration. Capabilities to change the configuration will be provided.

Additional Detail on Approaches for Incident Detection:

The Traffic and Environmental Monitoring Subsystem is envisioned to contain a suite of AI technologies that assist in the detection, verification, and evaluation of traffic incidents due to non-recurrent traffic congestion. The suite will consist of model-based, case-based, and rule-based reasoning systems. The use of model-based expert system technology has been proven in other domains, and could easily be applied to the Traffic and Environmental Monitoring Subsystem. The basis for this methodology is to use sophisticated, high-fidelity simulators to generate expected behaviors for a correctly behaving system. Algorithms are then used for detecting and isolating anomalies. Incident detection is performed by comparing the actual incoming data with the simulated or expected data. Differences are reported to an internal system blackboard. From there, intelligent reasoning can be performed to isolate the source of fault; this is based on causal information that is built into the model. Case-based and rule-based expert systems would generally be applied for less complex incident detection and isolation, where there is a preconceived idea of what is going to happen. A probable area for their implementation would be the identification of recurrent congestion, or recurrent accident locations. In this case, rules can be assembled to monitor the network for known conditions. It is apparent that the successful application of these technologies is necessary for effective Traffic and Environmental Monitoring.

Processing of raw sensor data may be based on any of several approaches — each specifically appropriate to facility type (freeway, surface street) and detected operational parameters (e.g., high volume freeway section, critical intersection).

Development of the approaches for incident detection will be coordinated with the current "Incident Detection Issues" project, and with the expected "Surface Street Incident Detection" project.

Processing of incident-related information entails both formatted and unformatted reports [formatted and/or unformatted textual reports on incidents, e.g., police CAD incident reports (formatted), or cellular phone reports (unformatted)]. Automatic processing of unformatted reports requires natural language processing techniques to extract useful information. Formatted reports require parsing of fields, association of text to normalized network/geometric representation to capture location, and parsing of other fields to characterize type of incident.

VEHICLE TRACKING (MVTR)

ID	REQUIREMENT AND FUNCTIONAL SPECIFICATION	IMPLEMENTATION SPECIFICATIONS
MVTR 100	**The MVTR subsystem shall display and track AVI registered vehicles on a GUI. AVI registered vehicles by definition are any vehicles whose position (and other data, such as speed) is available *in real time from an AVI/AVL or other-similar systems.**	Vehicle tracking systems are available commercially. MVTR may require tailoring to 3rd party products to obtain positional information and to tailor the GUI. The GUI must comply with the OSF/Motif style guidelines.
MVTR 100.1	MVTR subsystem shall support a GUI for the display and tracking of probe vehicles.	
MVTR 100.2	The GUI shall consist of a map display with vehicles currently being tracked superimposed on the map.	This implies animation by superimposing icons on a map display.
MVTR 100.3	The GUI shall update the location of tracked vehicles on the display in real time.	
MVTR 100.4	The GUI shall support zooming and panning capabilities for the map display.	
MVTR 100.5	The GUI shall allow all probe data to be displayed (exact location, speed, etc.) for highlighted vehicles.	
MVTR 101	**The MVTR subsystem shall have the capability for the user to select either individual vehicles or classes of vehicles for display and real-time tracking.**	Vehicles to be tracked must declare themselves (e.g., IDS) to the system. For emergency vehicles responding to a specific incident an assignment will be made and notification transmitted to this system by the Incident Management subsystem.
MVTR 101.1	The MVTR subsystem shall have the capability for the user to select individual vehicles to be tracked bv either selecting an available probe vehicle from a system-provided sorted list or by providing the probe vehicle identification.	
MVTR 101.2	The MVTR subsystem shall have the capability to track groups of vehicles identified by classes. At minimum. the tracking subsystem shall support emergency vehicles, regular probe vehicles, and HAZMAT classes. The user can provide the class name or select one from a system-provided list.	
MVTR 101.3	The MVTR subsystem shall also support a special class - an accident class. An accident class allows the user to track vehicles that have been assigned to an accident. Support for identifying accidents **by** name (or location) or from a system-provided list will be provided.	
MVTR 102	**The MVTR subsystem shall have the capability to track more than one vehicle or more than one class simultaneously.**	The actual number of vehicles that can be tracked depends on several factors: CPU capability, # of CPUs, monitor size and resolution, size of traffic network, customer requirements, etc.
MVTR 103	**For display purposes, a dedicated symbol shall uniquely identify which class (if any) a probe vehicle belongs to when it is displayed. A vehicle may belong to only one class.**	The symbol could be a graphical icon representation of each vehicle class.

MVTR 104	**For display purposes, a dedicated symbol shall uniquely identify the type of vehicle. At minimum, there shall be support for police cars, fire trucks, ambulances, tow trucks, and maintenance vehicles.**	The symbol could be a graphical icon representation of each vehicle class.
MVTR 105	**The MVTR subsystem shall support an electronic interface to the Incident Management System to receive assienments of vehicles to current outstanding accidents.**	Provided via a TCP/IP socket or POSIX message queue.
MVTR 106	**The MVTR subsystem shall support an electronic interface to the TMC DBMS to receive current probe data for tracking and display.**	Provided via a DBMS SQL API. The probe data for trackable vehicles is loaded into the DBMS by the Input Stream Processing subsystem, from which it is directly received from **external systems.**

DATA VALIDATION SUBSYSTEM (DDVA)

ID	REQUIREMENT AND FUNCTIONAL SPECIFICATION	IMPLEMENTATION SPECIFICATIONS
DDVA 100	**DDVA shall provide user access via a GUI which will include standard functions such as pull down menus and icons.**	Provided through the Common GUI.
DDVA 100.1	DDVA shall permit the user to retrieve the validation procedures for any data element.	
DDVA 100.1.1	DDVA shall provide access control to all functions including stored formulas, procedures and (min, max) limits and user input parameters.	
DDVA 100.1.2	Access control to DDVA routines through API as well as direct User access to DDVA software is controlled and managed by the Configuration Management Subsystem.	DDVA routines are managed as is all other TMC software through the Configuration Management Subsystem. Access to source code is limited to the SA.
DDVA 100.1.3	DDVA controls user access to applications that provide parameter input and override functions.	Update to certain parameters used in DDVA routines is controlled using the capabilities of the DBMS to control access at column level; if DBMS does not provide such capabilities, functionality will be provided by application code.
DDVA 100.2	DDVA shall permit the SA/DBA to create a new formula or change an existing formula on-screen and store the resulting expression. DDVA shall prompt the user for confirmation prior to making any changes(co-requirement with DBMS data dictionary).	
DDVA 100.3	DDVA shall have the capability to display current values of each (min, max) limit along with its corresponding parameters.	(Min, max) bounds on data elements are determined by parameterized procedures. When the values of the parameters are changed, the corresponding values of the (min, max) limits are also changed. The context is represented in terms of the parameters.
DDVA 100.4	DDVA shall accept user- or application-defined overrides to pre-stored parameters (physical value constraints or context-base?) used in data validation routines.	
DDVA 100.4.1	Overrides to parameters representing physical value constraints are controlled by the system/database administrator.	Physical value constraints cannot be altered by applications and require DBA action.
DDVA 100.4.2	DDVA shall deactivate a user/application input parameters which represent context after a user-specified time limit. At the time the parameters are input, the user will define the time limit.	Implementation of DDVA 100.4.2 may be by timestamping and monitoring parameter values.
DDVA 100.5	DDVA shall have the capability to display any user-selected data input stream (real-time).	Real-time input to the validation routines can be monitored through a user interface window. This is also a software monitoring function.
DDVA 101	**DDVA shall support multiple levels of validation:** a. Level 1: Format/syntax. b. Level 2: (min, max) range checks and set membership - static filters. c. Level 3: Context-based, or dynamic filters. d. Level 4 User or application validated.	Level 1: Simple format checks on field types. Level 2: Static filters can be used to represent physical constraints (e.g., upper limit on occupancycl, lane volume < 2000 veh/hour). The (min,max) limits are stored and managed by the TMC Database.

DDVA 101.1	DDVA shall accept user- or application-defined context parameters to be applied in determining the limits of context-based filters	Level 3: Context-based (min, max) limits are derived data elements that are treated as are other data elements of this type. They are automatically adjusted based on TOD, special events, etc. Context parameters are data elements stored in the DBMS. Context-based limits may be functions of several parameters. These functions may be recomputed when any of their parameter values change. This capability may be implemented by the DBMS through stored procedures. Level 4: In some cases, applications may pre-validate data as part Of their processing. In these case, or when a user declares the validity of a data element, the DDVA will not re-validate. Levels 1 and 2 can be implemented in several wa;s which distribute the functionality. Mandatory validation can be performed by the DBMS; Level 3 performed by applications using validation routines. DDVA can be implemented totally or partially as a server or as a linked library at each workstation.
DDVA 101.2	DDVA shall, based on the update flag setting, update the value of any context-based limit whenever any of its parameters is updated.	
DDVA 101.2.1	DDVA shall permit the setting of an ‘ update flag’ to control the update frequency: immediate update, update every x sec, update off.	
DDVA 102	**DDVA shall permit the specification of the mandatory validation levels to be applied to each data element (the specification may include several levels of mandatory validation.) This is an SA/DBA function.**	Level 1 and 2 mandatory validation is easily implemented in DBMS.
DDVA 102.1	DDVA shall enforce mandatory validation for any updates to the database.	
DDVA 103	**DDVA shall be accessible through an API from any application requesting an optional validation on any data element.**	DDVA routines are library functions that can be called from within any application. Applies to all levels but more likely to Level 3 validation if Levels 1 and 2 are considered mandatory.
DDVA 104	**As part of the validation process, DDVA will take appropriate actions depending on the results Of the validation and whether it is mandatory or optional:** a. <u>Mandatory Validation:</u> if data is valid, DDVA shah execute the database Update in the language of the DBMS. Otherwise, an error message will be sent to the application/user. It is the application’s responsibility to determine further processing actions (e.g., loading nominal values). b. <u>Optional Validation</u>: Results of the validation returned to the application.	If mandatory validation is performed under DBMS control, applications can execute SQL Updates; otherwise, a UPDATE function needs to be used which performs the validation and, in turn, issues the SQL Update. In the case where a context-based filter detects invalid surveillance or external system input data, the application shall set a failure bit on the data element and post a failure log entry, if the failure has not been previously detected. If the failure is not subsequently confirmed, a context-limit error message is sent to the GUI. The user will have to make a decision on further processing.

DDVA 105	**DDVA shall provide a customizable interface to relational databases.**	Depends on implementation. Portions of the DDVA that are allocated to the DBMS may not be DBMS independent.
DDVA 105.1	DDVA shall interface with ANSI Standard SQL supported databases.	DDVA shall NOT use any database extensions that are not supported by a majority of RDBMS vendors (ORACLE, SYBASE, INFORMIX, etc.)
DDVA 106	**DDVA shall process the validation routines for each element within the time interval determined by the frequency of input to the Input Stream Processing Subsystem.**	The performance requirement is end-to-end (e.g., not all DBMSs support the same use of stored procedures.
DDVA 106.1	DDVA shall be capable of processing multiple validation requests simultaneously.	The implementation of DDVA as a server will meet this. requirement.

ISSUES:

Several issues which depend on implementation detail remain to be resolved with respect to DDVA. Levels 1-3 may be entirely allocated to the DBMS depending on performance. Some context-based validation may be more efficiently performed using library functions not managed by the DBMS or within the applications deriving the data. Three general guidelines apply:

a. If multiple applications update the same data element, validation belongs within the DDVA.

b. If the same data validation routine is used by multiple applications (with different context parameters), the routine is a candidate for DDVA.

c. The validation should be managed by the application if the validation context parameters are only useful for validation purposes, are captured by the single application which derives the data element, and will not be stored in the database. This can be implemented in two ways: (1) the validation is part of the application, (2) the validation is a non-DBMS routine called by the application which managed its inputs and outputs.

DOCUMENT AND FILE MANAGEMENT (DDFM)

ID	REQUIREMENT & FUNCTIONAL SPECIFICATIONS	IMPLEMENTATION SPECIFICATIONS
DDFM 100	**'The DDFM subsystem shall support the retrieval of documents from an internally managed software library.**	This system could be implemented using a text DBMS (e.g. Metamorph, Basis) or a commercially available Document Management System that meets these requirements. For the source code, Unix Source Code Control System (SCCS) or Revision Control System (RCS) are possible candidates.
DDFM 100.1	The subsystem shall provide a list of all document titles that are available for retrieval from the library.	
DDFM 100.2	The subsystem shall provide a capability to search for keywords in the titles of documents available in the library. Searching in case-sensitive mode shall be provided via a search option.	
DDFM 100.3	The subsystem shall provide a capability to search for keywords in the text of selected documents. Searching in case-sensitive mode shall be provided via a search option.	
DDFM 100.4	The subsystem shall receive requests to retrieve documents.	
DDFM l00.5	The subsystem shall retrieve requested documents and display their contents.	
DDFM 101	**The DDFM subsystem shall provide support for browsing the contents of each document.**	If a commercially available product is used it must provide searc capabilities, otherwise this will need to be custom code.
DDFM 101.1	The browsing of the contents shall be provided in a display area separable from the selection of documents to be retrieved.	
DDFM 101.2	The browsing shall support scrolling of the text one line at a time or a page at a time.	
DDFM 101.3	Support for book marks shall be provided.	This can be provided by implementing internal structures that track marks the user has made, that indicate locations that are to be his personal "quick references." Lists of marks can be provided from a menu in the GUI.
DDFM 102	**The DDFM subsystem shall provide indexes and tables of contents to quickly obtain data of interest from each document.**	Most commercial text DBMSs, if used, have this capability
DDFM 102.1	The subsystem shall provide support to automatically move from the index location to the corresponding location in the text.	
DDFM 102.2	The subsystem shall provide support to move back to the index from the text.	

DDFM 103	**The DDFM subsystem shall have a report capability. Reports may be saved to a file or sent to the printer or both.**	If commercial software is not used, this can be implemented in Unix by saving to a file or piping to a printer.
DDFM 103.1	The report capability shall allow the entire document or only selected portions to be printed.	
DDFM 103.2	The report capability shall allow the entire document or only selected portions to be saved to a file.	
DDFM 104	**The DDFM subsystem shall support a GUI that will support retrieving, browsing, reporting and searching (via text searches, indexes, or bookmarks) of documents.**	If commercial software is not used, this functionality will be provided by the Common GUI. If commercial software is used the GUI shall conform to the OSF/Motif style.
DDFM 105	**The DDFM subsystem shall provide a bookshelf capability. A bookshelf capability is used to group types of documents together. For instance, all documents relating to maintenance and repair of field assets might be grouped together under one bookshelf.**	If commercial software is not used, this will be implemented in Unix by using directories and links to organize into groups, where a book could belong to more than I group.
DDFM 105.1	The DDFM subsystem shall allow for the creation of new bookshelves.	
DDFM 105.2	The DDFM subsystem shall provide support listing all existing bookshelves.	
DDFM 105.3	The DDFM subsystem shall allow documents to be added to an existing bookshelf.	
DDFM 105.4	The DDFM subsystem shall allow documents to removed from an existing bookshelf.	
DDFM 105.5	The DDFM subsystem shall allow an existing document to be classified under more than one bookshelf without having to duplicate the document.	
DDFM 106	**The DDFM subsystem shall provide support for adding new documents to the library.**	If commercial software is not used, this will be accomplished with the Unix CP command.
DDFM 107	**The DDFM subsystem shall provide support for removing existing documents from the library.**	If commercial software is not used, this will be accomplished with the Unix rm command.
DDFM 107.1	The subsystem shall provide support so that when a document is removed from the library, all references to that document from existing bookshelves are also automatically removed.	
DDFM 107.2	The subsystem shall only allow documents to be removed if the user has sufficient privileges.	

INTER-TMC DATA EXCHANGE SUBSYSTEM (DIDE)

ID	REQUIREMENT & FUNCTIONAL SPECIFICATION	IMPLEMENTATION SPECIFICATIONS
DIDE 100	**DIDE shall provide 2-way exchange of structured data between two or more TMC's cooperating in the implementation of area-wide traffic management.**	Two implementation options are available depending on the hardware and software configurations within the TMCs: one involving developed software and using the scheduling capabilities of the I/O Manager; the other using replication technology available from DBMS vendors (e.g., ORACLE, SYBASE).
DIDE 100.1	DIDE shall transparently interface with the TMC DBMS to capture the data being exchanged.	Conceptually, the system maintains a log file of update transactions to the tables being replicated. At regular intervals, the log file is transmitted to the replicated sites where updates to the respective tables are undertaken.
DIDE 100.1.1	DIDE shall provide a 2-way translation of the TMC data to/from the common data exchange format. This process may involve some data derivation (e.g., 15 min. counts are being exchanged but only 1 min. counts are available in the TMC DBMS).	The data being replicated includes the traffic data being sent from the "local TMC" to the TMC managing area-wide control as well as the control data being sent back to the "local TMC." The common data exchange format in this context is meant to denote the structure of the tables/files being replicated, which may not be the same as the tables/files in which the data is stored in the TMC DBMS.
DIDE 100.1.2	DIDE shall provide customized translators from/to non-standard databases and files resident in local TMCs. This capability meets the requirement of having to interface with TMCs which do not have a standard DBMS but which still participate in wide area exchange of data.	If the current system employs a DBMS which is non-relational, or if the data resides in memory, DIDE and the translation software must be customized and integrated with the existing software. Transparent two-way data exchange is difficult unless the existing system already has appropriate interface points and routines. In the case where the target system is relational but non-standard, the translation function is added to the replication process.
DIDE 100.2	DIDE shall provide the capability to schedule the exchange at User-determined intervals.	Depending on the implementation, this function is either provided by the I/O Manager or provided as part of the COTS Replication product.
DIDE 100.2.1	Data exchange from the "local TMC" to the "wide-area control TMC" shall be scheduled at specified time intervals, which can be adjusted by the User.	The Replication interval is defined at system setup time and can be altered by the DBA through a user input procedure supported by the GUI.
DIDE 100.2.2	Data exchange from the "wide-area TMC" to the "local TMC" can be immediate or scheduled.	
DIDE 101	**DIDE data exchange format shall comply with the DBMS data format.**	

DIDE 102	**DIDE shall maintain the configuration management of the data exchange agreements/formats.**	The tables being replicated are managed by the systeni - master site and replicated sites. The table formats (DDL) are maintained by the DBMS dictionary. This functionality is automatically provided if a COTS replication product is used.

ISSUES:

Several issues remain to be solved with respect to the specific allocation of functionality between the TMC DBMS, DIDE, I/O Manager, Input and Output Stream Processing, Output Dissemination, and Data Ingest & Monitoring. The resolution of these issues is dependent on the eventual design of the system, driven primarily by performance requirements, the potential need to interface to existing non-standard TMCs, the timing requirements for the data interchanges, and the use of COTS software.

In a fully distributed and homogeneous ATMS data architecture, the DIDE functions would be subsumed within the distributed DBMS. In a loosely coupled system with TMCs with non-relational DMBSs, DIDE would comprise gateways and extensive translation software. Within a standardized architecture using COTS-provided support for data replication, the need for extensive translation is minimized and the data interchange I/O functions allocated to the CISP and COSP systems can be subsumed by TDES.

TMC DATABASE (DTDB)

ID	REQUIREMENT AND FUNCTIONAL SPECIFICATION	IMPLEMENTATION SPECIFICATIONS
DTDB 100	**DTDB shall provide access to ALL data necessary for TMC operations including the non-local data necessary for the TMC to cooperate in area-wide traffic management.**	Database models to be evaluated include relational and network and object-oriented. Prime consideration will be given to database performance requirements and support for application software interface requirements (see DTDB 101 for additional data).
DTDB 100.1	DTDB shall provide both direct access and application program interface.	Direct database access via a Data Manipulation Language such as Structured Query Language is mandatory both in interactive mode (e.g., User) and via an application program interface.
DTDB 100.1.1	DTDB shall provide online direct User access to ALL data (alphanumeric, map, geo-referenced) needed for the operation of the TMC.	Similar requirements exist for the access to the geographic/map data. At the present time there do not exist any standard database languages for GISs.
DTDB 100.1.2	DTDB shall provide an application program interface for data retrieval and update of structured, map, and geo-referenced.	Depending on the ultimate design of the Subsystem to ATMS data architecture, update capabilities may be local or global. For the purpose of this specification it is being assumed that updates are stricly local.
DTDB 100.2	DTDB shall interface with the Inter-TMC Data Interchange retrieve and send data needed for area-wide traffic control coordination.	The design option reflected in this specification is based on data replication technology provided by various RDBMS vendors. Other options based on non-replicated distributed databases will be considered.
DTDB 100.3	DTDB shall provide access to multiple users/applications simultaneously (ten operators shall be supportable as well as all applications).	
DTDB 100.3.1	DTDB shall support concurrent control.	The database server will support concurrency control in a distributed environment pending the selection of a distributed data architecture within the TMC.
DTDB 100.4	DTDB shall comply with industry standard DML and storage formats.	The DTDB shall provide 2PL and 2PC protocols (or some equivalent) to guarantee the consistent state of the databases. GIS concurrency control is not very sophisticated.
DTDB 100.4.1	DTDB shall comply with industry standards for structured data.	ANSI Standard SQL and FIPS 127 will be used for relational databases.
DTDB 100.4.2	DTDB shall comply with applicable map and geographic data storage standards.	Current standards do not exist for GISs. FIPS 173 Spatial Data Transfer Standard applies. Other applicable standards for GIS include FDIS and DXF.

DTDB 101	**DTDB response time requirements are application dependent and include error and cleanup processing (e.g., referential integrity). Four categories are defined:** a. <u>Real-time</u> - real-time applications include I/O, monitoring and some control functions. b. <u>Time critical online</u> - time critical online applications are those which effect, or whose results will effect, control strategy selection and implementation. Select response time: < 2 sec. Map/GIS redraw response time: < 2 sec GIS spatial query: < 4 sec. c. <u>Online</u> - online applications include some system management functions whose results do not impact TMC traffic control Select response time: < 5 sec. Map/GIS redraw response time: < 5 sec. GIS spatial query response time: < 10 sec.	Response time requirements are dependent on the applications' response time requirements. For example, in a centralized control system with 5000 intersections where central communicates with controllers every 1 second interval, 1 second detector data is accumulated in controller memory and stored in the database at 5-60 second intervals. This translates into a requirement for 80-1000 updates per second which can be supported by current technology (ORACLE has reported rates as high as these using parallel servers for tcpB transactions). The inclusion of the requirement to process vehicle probe data at 1 minute intervals does not significantly alter this range. The need to prioritize transactions depends on the overall data architecture as well as the performance capabilities of the database servers. Sufficient H/W processing speed may compensate for this requirement. Not all RDBMSs support the prioritization of transactions. In these cases, it may be necessary to write application code to provide this capability. In a UNIX environment, some vendors are beginning to provide real-time extensions to UNIX, which should facilitate the development of such software.
DTDB 101.1	DTDB shah have the capability to prioritize DTDB transactions to maintain real-time performance in response to processing requirement bursts.	This derived requirement is implementation dependent. One can design for sufficient processing capacity to handle requirements with almost 100 percent reliability.
DTDB 101.2	DTDB shall estimate the response time and inform the user or the application if a response time to a query will require more than a reasonable amount of time. A reasonable amount of time for most instances will be less than 3 seconds.	
DTDB 102	**DTDB shall provide a user-friendly GUI for System Administration (DBA) functions and ad hoc queries.**	Common GUI shall incorporate the User Interface provided by the DBMS as well as the generation of reports through DBMS-provided report generators (e.g., ORACLE Forms). Other capabilities such as online help will be developed as part of the GUI.
DTDB **102.1**	DTDB shall support the user in building custom reports of database extracts.	
DTDB **102.2**	DTDB shall have the capability to store previously built custom reports and "canned queries."	
DTDB 102.3	DTDB shall allow the user to access all DBMS functions through a graphical interface.	
DTDB 102.4	DTDB shall provide online help for database functions.	
DTDB 102.5	DTDB shall provide access to the Online Document Subsystem for retrieval of DBMS procedures and training materials.	

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DTDB 103	**DTDB shall provide access control to the database and its functions.**	Overall access control to the system is provided by the GUI. Additional controls using the security capabilities of commercial DBMS (e.g., GRANT command for RDBMS) are possible. Row and column level access control is not available for all DBMS products. For access to GIS maintained data, controls can be implemented at the layer and tile level for some vendor products.
DTDB 103.1	DTDB shall allow the DBA to establish privileges on the database as a whole or on individual tables, views, or procedures.	
DTDB 103.2	DTDB shall allow the granting of privileges to "authorization types," such as public, group, user, or role, corresponding to different job positions within the TMC.	
DTDB 103.3	The DTDB shall provide access control to map/GIS data.	
DBMS 103.4	DTDB shall provide access control procedures (login, passwords, etc.)	
DTDB 103.5	DTDB shall maintain a log of unauthorized access.	
DTDB 104	**DTDB shall provide dictionary facilities for defining, maintaining, and updating TMC database structures, maps, and geographic data structures**	Dictionary facilities are supported by most RDBMS vendors. The extent of support for GIS is limited particularly in the flexibility of altering the index structures and/or modifying the defined structures.
DTDB 104.1	DTDB shall provide a user-friendly interface for creating new tables and GIS layers, and defining attributes.	PIPS 156 is applicable for RDBMS dictionaries.
DTDB 104.2	DTDB shall provide support for creating and modifying primary and secondary search indices on database attributes.	It is presumed that baseline map and geographic data will be available and obtained from external sources.
DTDB 104.3	DTDB shall permit the addition of new tables, GIS layers and attributes to existing structures without bringing down the database.	RDBMSs support different index structures including BTREE and HASH structures and allow these structures to be dynamically created.
DTDB 104.4	DTDB shall provide the capability to store the various database files (data, checkpoint, journal, dump, etc.) on different disk volumes.	The storage of various database tables and volumes on different disks prevents a single point of failure and improves the overall performance of the DBMS.
DTDB 104.5	DTDB shall allow the storing of database tables across multiple disk volumes.	
DTDB 104.6	DTDB shall maintain the integrity of the database.	
DTDB 104.6.1	DTDB shall perform data element format checks (data type, field length, etc.).	This requirement conesponds to data validation level 1 and is supported by most RDBMSs.
DTDB 104.6.2	DTDB shall maintain the referential integrity of the database.	Most RDBMSs support some form of referential integrity checking.
DTDB 104.6.3	DTDB shall have the facilities to define valid value constraints on table attributes.	The extent of this requirement will depend on the design decision to implement ALL validity checking within the DBMS, including context-based procedures (see specification for the Data Validation Subsystem).

DTDB 104.7	DTDB shall maintain an integrated view of ALL TMC data through an integrated conceptual data model such as an ERD (there is NO current requirement to automatically reflect conceptual data model changes in the logical database structures).	ERD can be maintained outside the DBMS using an application program such as a CASE tool. Not all DBMS vendors support this requirement.
DTDB 104.7.1	DTDB shall be capable of referencing alphanumeric data to digitized map data and presenting an integrated view to the User Interface.	GIS provides geo-referencing of relational data to spatial data maintained in the GIS. Map data can be updated if it is stored in a GIS. If a decision is made not to use a GIS, map updates will be performed through developed code. Even in the former case, it is likely that some application code using GIS primitives will be required to make the updates of lane geometries relatively easy. Recall that the baseline map data will likely be obtained from external sources but that lane geometric configurations may have to be input by TMC personnel as part of system setup.
DTDB 104.8	DTDB shall provide capabilities to update map data (requirement needs to be validated).	
DTDB 105	**DTDB shall provide automated and procedural support for loading the TMC database.**	Loading and data translation routines not commercially available need to be developed.
DTDB 105.1	DTDB shah provide facilities for processing map and GIS data received from external sources.	
DTDB 106	**DTDB shall support both automatic and manual backup of the TMC database.**	Backup procedures will be available through online help provided by the GUI, and access to complete DBMS documentation through the Document Management Subsystem. Automatic backup capabilities are supported by commercial RDBMSs. Archives of TMC data will be provided on magnetic tape, optical disk or CD ROM. Database archives will be managed like other automated files by the Configuration Management Subsystem.
DTDB 106.1	DTDB shall mirror the data necessary to support the real-time operation of ATMS.	
DTDB 106.2	DTDB shall provide automated capabilities and procedures for Checkpoints, Dump files, Journals, and Transaction Logs.	
DTDB 106.3	DTDB shall provide procedures for creating, storing, and managing archives of the database.	
DTDB 106.3.1	The user shall be able to specify those elements of the database which are to be archived on a regular basis. For example, network geometric data need not be archived; only changes to the baseline need be stored.	
DTDB 106.3.2	Management of the archives shall be the responsibility of the Configuration Management System.	
DTDB 107	**DTDB shall provide automated and procedural support for the** recovery **of the TMC database in case of failure.**	DBMS recovery supported by commercial DBMS capabilities to "mirror" the database. Procedural support will be provided through online help and access to DBMS documents.The recovery procedures will guarantee that the database will be recovered to the last committed transaction. The current transaction will be lost unless it can be recovered from the mirrored database. Upon recovery, DTDB shall assure the synchronization of the real-time data in the "mirrored" database with the data recovered from the Checkpoint (for online and lesser priority data).
DTDB 107.1	DTDB shall be able to recover its real-time and time-critical data within 5 minutes of failure detection. Recovery Of online and priority data shall be within 2 hours.	

ISSUES:

Several issues remain to be solved with respect to the allocation of functionality to the TMC DBMS, In certain cases the resolution of these issues is dependent on the eventual design of the system, driven primarily by performance requirements and the potential need to interface to existing non-standard TMCs.

The primary issues are:

1. Location of validity checking within the TMC architecture. The current specification leaves open the allocation of validity checking between the DDVA and DTDB Subsystems with provisions made for some context-based validation within applications on an exception basis. Furthermore, the specification of the TMC DBMS requires the capability to support format checking and full validity checking, pending the resolution of this issue.

2. The overall data architecture of ATMS will effect the potential requirements of the DBMS and its relationship to the Inter-TMC Data Interchange Subsystem. Various alternatives are possible in a "mature ATMS environment:" distributed homogeneous system, multi-database distributed system, and a cooperating system. The particular selection of any of these options will have significant effect on the low-level requirements.

3. For the purpose of this specification, it has been assumed that the requirement for managing the "knowledge base" is not levied on the DBMS. Rather, rules and AI application schemas are managed by the applications themselves.

4. This issue concerns the deployment of the new DBMS and other Support Systems being developed under this contract and the potential requirement to support current applications. If such a requirement exists, additional translation software will need to be built.

INCIDENT MANAGEMENT SUBSYSTEM (TIMS)

ID	REQUIREMENT AND FUNCTIONAL SPECIFICATION	IMPLEMENTATION SPECIFICATIONS
TIMS 100	TIMS **shall acquire and process incident information necessary to classify and assess the incident.**	The information needed will be retrieved from the TMC DBMS or input by the Operator.
TIMS 100.1	TIMS shall be activated by the MTEM subsystem after an incident has been verified.	After an incident is verified, an alarm is set in the User Interface (a verified incident is also posted on the Monitoring screen).
TIMS 100.2	TIMS shall support the collection of data needed to classify the incident. The overall incident identification process shah take into account incident location, type, and severity. a. Location: freeway main lane, freeway shout freeway median, on-ramp, off-ramp, service road, etc. b. Type: accident, stalled vehicle, cargo spill, environmental condition, construction (for planned events). c. Severity of incident: number and size of vehicles involved, number of lanes blocked, property damage only/iniury/fatality, type of cargo involved.	NTEM is activated and sets up the Incident Mgt input screen on the display. For planned events, the I/O Manager activates a user alarm and initiates the TIMS application. Incident data which has been previously processed through the MTEM as part of the incident detection and verification function is read by TIMS when the application is activated. Additional data is collected by user prompts as part of TIMS processing.
TIMS IOO.2.1	TIMS shall retrieve incident data from the TMC DBMS.	
TIMS 100.2:2	TIMS shah provide automated interfaces to incident information sources such as 911 logs.	
TIMS 100.2.3	TIMS shall provide interfaces to other sources from which information is gathered and entered by the Operator through the User Interface: a. Phone/fax. b. Radio broadcasts. c. CCTV system component of the MTEM.	
TIMS **101**	TIMS **shall perform Incident management for both planned (e.g., construction or special-event related) and unplanned incidents (e.g., accident).**	
TIMS 101.1	TIMS shall be capable of managing as many as 1 O-20 incidents/hour.	Client-server software architecture will support this requirement.
TIMS 101.1.1	TIMS shall have the capability to prioritize incidents and prompt the Operator for needed information.	Incident prioritization is based on severity, need for multi-agency coordination, and traffic impacts.
TIMS 101.1.2	The User Interface will facilitate the tracking of multiple incidents through alarms, color coding schemes, and multiple window management.	When a single operator is responsible for tracking multiple incidents, the user interface may incorporate an internal event log which drives the window manager in terms of setting alarms, displaying the correct windows automatically, etc.

TIMS 101.2	TIMS shall support the Operator in assessing the overall operating conditions surrounding the incident and the nature of the incident. The following requirements must be considered: a. <u>Capabilities of the organization</u> in terms of: 1. Equipment availability, status, and location. 2. Personnel availability. 3. Operating procedures. b. <u>Likelv duration of incident</u> I. From historical experience. 2. Computed from prediction algorithm. c. <u>Potential impact on traffic flow.</u> 1. Route. 2. Time of day. 3. Traffic volumes. d. <u>Status of the primary and diversion routes</u>. 1. For potential diversion. 2. For releasing traffic information.	Incident situation assessment is supported through access to status information in the TMC DBMS. The assessment of duration and traffic impacts can be supported by a rule-base and/or analogical algorithm which can retrieve similar past incidents. The use of Al paradigms is likely to support other TIMS requirements for defining and updating the incident response (TIMS 10 1.2 and TIMS 101.3). The rule-based component will support the procedural aspects; the analogical component is effective for matching on historical data.
TIMS 01.2	TIMS shall determine the initial emergency incident site response plan. Initial response may involve immediate decisions relating to: a. <u>Personnel and Equipment:</u> I. Who is at the scene. 2. Who else should be sent to the scene. 3, Who to inform. b. <u>Real-time motorist information:</u> 1. Signs. 2. HAR. 3. Radio. 4. TV broadcasts.	Contingency plans are stored in the TMC DBMS as alpha-numeric and text data. Procedures are stored in the Document Management system and can be retrieved through TIMS via an API. The initial response does not include traffic control measures given the software architecture reflected in this specification. Thal function resides within the Traffic Control System which operates in parallel with TIMS to handle the incident. TIMS becomes a client for the traffic control system to develop the appropriate traffic strategy.
TIMS 101.2.1	TIMS shall retrieve elements of the contingency plan which are stored in the TMC DBMS.	
TIMS 101.2.2	TIMS shall permit the modification of the contingency plan as appropriate to create the initial emergency incident site response plan.	Contingency plan modification is supported by the User Interface.
TIMS 101.2.3	TIMS shall store the modified plan in the DBMS. If a procedural modification is necessary, changes can be entered in the proper documents through the Document Management Subsystem.	

TIMS 101.3	TIMS shall permit the update to the initial response plans as the incident is monitored. The updates will be stored in the DBMS.	As the operator reviews the current plan in the context of the evolving traffic conditions and incident status, the need to modify the plan may arise. The updating process shall include determination of when incident site management is no longer needed, or when traffic congestion has dissipated to the point that special traffic control is no longer needed. Communication with response agencies may be automatic or manual (e.g., auto dial-up). Options include relaying CCTV images to emergency response agencies.
TIMS 101.4	TIMS shall support emergency incident site response.	
TIMS 101.4.1	TIMS shall communicate incident state information and response procedures to responsible agencies.	
TIMS 102	**TIMS shall have the capability to maintain emergency response vehicle Ids for each incident being managed, and make that information available to external Subsystems.**	Emergency vehicles assigned to the incident must register their Ids with the system. This function can be partially automated using AVI technology. The user will indicate the request graphically on the screen and initiate the routing application. Routes can be automatically transmitted to response agency or vehicle. Once tagged, emergency vehicles can be tracked. Vehicle IDs are passed to the Vehicle Tracking Subsystem.
TIMS 102.1	TIMS shall interface with the Individual Vehicle Routing Subsystem to request a route computation for emergency vehicles.	
TIMS 102.2	TIMS shall interface with the Vehicle Tracking Subsystem to track locations of emergency vehicles responding to an incident.	
TIMS 103	**TIMS shall interface with the Traffic Control Subsystem to cooperatively determine and manage the traffic control strategy for the incident.**	
TIMS 104	**TIMS shall maintain a complete log of all incident data.**	The initial incident log entry is defined by the monitoring system when the incident is verified. TIMS maintains that entry for the duration of the incident. Image processing techniques will permit the extraction of accident data from the video. The availability of such technology will facilitate the clearance of the accident site.
TIMS 104.1	The incident log shall be archived on a daily basis as part of the overall TMC database archive process.	
TIMS 104.2	When CCTV coverage of the incident site is available, TIMS shall capture and store the videotape covering the incident.	
TIMS 105	**TIMS shall have a GUI that supports the input and maintenance of incident data and supports incident site management.**	User interface functions of TIMS are integrated with the user interfaces of NTEM, TTCS, and TWTM. The interfaces are managed by the window manager of the workstation to display in a multi-window environment all the information needed by the operator. An expert system may be used to drive the selection of data input items.
TIMS 105.1	Incident data input shall be facilitated through an input template (i.e., form). Depending on user inputs, some fields may be masked.	

TIMS 105.2	TIMS user interface shall have the facility to modify the rules being used within the rule-oasea software component. The capability shall exist to browse the rule-base, recall a specific rule, modify a rule, and add new rules.	Any modifications to the rule base are subject to software configuration management and access control.
TIMS 105.3	TIMS shall support the full customization of the screen layouts and workflow management at the specific site.	The user interface layouts, the names of agencies, phone numbers, and operational rules are established at system setup.

NOTES ON CANDIDATE APPROACHES:

The level of responsibility that ATMS has in managing incidents is the greatest single determinant of the functions the Incident Management Subsystem may perform. Incident management requires that ATMS should be the initial agent for coordinating incident responses. It is possible that once the response team arrives at the incident scene, that coordination will become the responsibility for some other agency (e.g., police).

Several possible situations are:

a. Maximum responsibility, in which all coordination, and all strategic decisions are focused through ATMS.

b. Major responsibility, in which coordination and all strategic decisions are shared between ATMS personnel and like personnel at one or more cooperating agencies.

c. Supporting responsibility, in which ATMS personnel control significant response resources, but respond to direction from one or more external agencies.

d. Minimum responsibility, in which ATMS merely provides the information it has available to other agencies, but does not directly participate in the response.

TRAFFIC CONTROL SUBSYSTEM (TTCS)

ID	REQUIREMENT & FUNCTIONAL SPECIFICATION	IMPLEMENTATION SPECIFICATIONS
TTCS 100	TTCS **shall support various options for selecting and implementing operational traffic control strategies for networks and freeway systems with as many as 5000 junctions. TTCS strategies include:** a. Local autonomous - elements of the control network function independently. For example, network subsections or intersections are autonomous. b. Local coordinated - individual sections or intersections are coordinated (e.g., progression). c. Area-wide - a TTCS section or the entire system is managed as a unit for the purpose of preventing the onset of congestion. For freeway TTCS this corresponds to the application of an area-wide ramp metering algorithm. Traffic restraint tactics may also be used in support of this strategy both at the network and sub-network level. d. Congestion - the system is managed to prevent the spread of congestion. In surface street networks, which already operate in a queue management mode in an attempt to prevent congestion, traffic restraint is employed. Freeway TMC's may reduce metering rates. e. Incident- the system must exercise demand measures to alleviate the resulting congestion. TTCS's equipped with CMS may employ route diversion in coordination with TWTM. Traffic control measures in the vicinity of the incident are likely to be congestion measures. f. Mixed Strategy the system potentially applies a different strategy to each section and manages the flow at the interfaces. This type of overall strategy is presumed in other than very low volume conditions.	TTCS shall have the capability to implement a range of strategies from isolated intersection control, to arterial control, to network wide. The implementation can be mixed: a congested arterial may be under a queue management strategy while.. simultaneously another uncongested section is being optimized for delay minimization. The distinction between area-wide and congestion strategies is not clear and only if it is the case that different tactics apply, are these strategies distinct. During the design phase, the determination will be made whether to maintain or alter this set of strategies.
TTCS 101	**TTCSs (freeway, surface street) shall have the capability to implement various tactics in support of the selected strategy. Tactics include both signal control as well as demand management (short- and long-term).**	Current control systems, as well as RT-TRACS, do not implement the full set of functions (particularly demand). These have to be separately integrated. To the extent that demand management is a wide-area phenomenon, TWTM provides the needed functionality.

TTCS 101.1	TTCSs shall support various signalization control modes at the network. section, arterial, and intersection levels based on their organic surveillance capability and the overall TTCS control architecture. a. Fixed Timing Plans and Plan Selection -corresponds to UTTRC I- 1.5 GC control with TTTRC, TRSP or User Select implementation options. In TRSP mode, timing plans are selectable from a library. This mode is also user selectable in special event and other contingency plan situations. b. Adaptive Plan Generation- in this mode frequency of plan generation is a function of flow conditions. Current systems, such as UTTRC 2 GC, use a 5- 10 minute re-optimization period; SCOOT has the capability to re-optimize each cycle. Adaptive control at an intersection as well as an arterial includes the implementation of OPAC and NOVA. c. Failure Mode - in case of failure or when implementing contingency plans, the system may revert to a fixed plan. This can be done at system level, section level, or individual intersection leve.. d. Intersection and Ramp Meter Control- Detailed specifications are provided in RT-TRACS Functional Specifications for intersection control operational modes. Intersection control is required both from the context of overall network control and as an isolated intersection.	For the purpose of this specification, it is assumed that corridor systems are wide-area systems. This classification reflects the fact that the decision framework for corridor systems is similar to that of wide-area systems, particularly if the freeway and surface street component systems are managed by different jurisdictions. Control modes reflect existing TTCS architectures and capabilities. RT-TRACS preliminary design includes both a strategy and control mode selection process. Centralized architectures include UTCS and SCOOT; SCATS represents a multi-level architecture although it isn't clear whether the central computer has any system-level control functions. An arterial version of OPAC is under development. Other control systems include UTOPIA, PRODYN, GACTS, and DART. Intersection control capabilities are specified by NEMA, 170, and SBC 179 Controller specifications as described in: Farradyne Systems, inc., Functional Specifications Real-Time Traffic-Adaptive Control System (RT-TRACS) FHWA Contract DTFH61-92-C-00001, April, 1993, pp. 18-20.
TTCS 101.2	TTCS shall interface with the TMC I/O Manager to receive and implement a control plan.	The I/O Manager initiates a TTCS process, which accesses the DBMS to read the control plan, and implements it. This may involve an interface to the TTCS's internal event scheduler.
TTCS 101.3	TTCS shall support the real-time re-definition of sub-networks (or sections) for the purpose of implementing various control modes. This requirement imposes a lower level implementation requirement on the communication system of the TTCS.	If all the intersection controllers communicate with central, the reconfiguration can be logical. Fixed communication architectures between intersections and area computers do not support this requirement.
TTCS 101.4	TTCS shall have the capability to implement additional access control options including: a. Ramp By-passes - HOV treatment at ramp meters. b. Changeable Message Signs - needed for information dissemination and for the execution of route diversion options. c. Reversible Lanes and HOV - can be operated in TTTRC mode or in a TRSP mode with appropriate switch time. d. Priority treatment - interface to APTS for priority treatment of transit vehicles. Can ultimately be extended to include all HOVs. e. Signal preemption - essentially a local intersection control option for emergency vehicle, railroad and drawbridge operations. f. Parking restrictions - require CMS and operated in TTTRC mode. g. Information dissemination - messages through HAR.	All of these control options require separate control modules where overall strategy determination is performed by the top-level controller in a manner similar to TWTM. The distinction is that TWTM strategies cross TMC boundaries. These access options are specified in the RT-TRACS functional specification (Farradyne, pp. 16-18). The implementation of these control options may also require additional surveillance for monitoring, verification, and enforcement. Parking restrictions are difficult to implement in real time, but parking information dissemination and the integration of parking availability and routing is a viable option.

TTCS 101.5	TTCS shall have the capability to simultaneously evaluate multiple tactics/plans for subnetworks, arterials, intersections.	The evaluation of TRTC-determined options is supported by the AIMM managed library of models and the overall client-server architecture (see AIMM specifications).
TTCS 102	**TTCS shall collect and process surveillance system inputs from the portion of the TTCS surveillance network which is under its scope of responsibility. Surveillance system data is used to adjust intersection signal timing (for actuated signals), measuring flow and detecting incidents for freeway TMCs and to determine MOE for signal plan determination. Accuracy requirements for al direct surveillance measurements are in excess of 95 percent.**	It is assumed that surveillance detectors which are fully integrated within the control system (e.g., loop detectors at intersections connected to local controllers) are managed by the control system; other forms of surveillance, such as probe vehicles, are not. CCTV surveillance has been allocated to the Image Processing and the Traffic and Environmental Monitoring Subsystems. An alternate design allocates camera surveillance to the TTCS.
TTCS 102.1	TTCS shall be able to accommodate a requested change in the level of aggregation of raw surveillance data performed at the field controller/computer level. The lowest level count should correspond to the frequency of the communications with the top-level or mid-level controller.	The aggregation period can be modified by a command message from the TMC. From a practical perspective, 1 sec counts may not be meaningful, but the capability should be available to request as low as 5 sec counts.
TTCS 103	**TTCS shall select a control strategy and corresponding tactics and plans based on its assessment of traffic MOE and information it receives from IVHS and non-IVHS external systems.**	Information exchange with other TMCs participating in wide-area management is supported by DIDE. The interface with other IVHS systems is dependent on the overall IVHS system architecture. One architecture has a single TWTM node as the central ATMS information exchange node. In another configuration, TWTM is distributed to support the requirements of ATIS and route guidance.
TTCS 103.1*	TTCS shall inform TWTM of its intended control plan under both normal operations and in response to detected incidents.	
TTCS 103.2*	TTCS shall incorporate the TWTM-determined demand projections in its strategy and tactic selection process.	
TTCS 103.2.1*	TTCS shall generate short (cycle-based) and mid-term projections (<5 minutes) of link volumes using TWTM demand projections along with additional historical and real-time data. The 5-minute projections are updated every minute on a rolling horizon basis.	The 15-minute network load forecasts generated by TWTM are used as input to a finger assignment process which generates 5-minute link level forecasts. Statistical methods can be used in conjunction with the assignment to generate these forecasts. (see Stephanedes, Y., : "Improved Estimation of Traffic Flow for Real-Time Control," Transportation Research Record 795, pp. 28-39).
TTCS 103.3*	TTCS shall incorporate TWTM's regional weather estimates with its own state estimates to aid in its strategy and tactic selection process.	TTCS control shall reflect projected weather conditions by disseminating advisories to drivers via CMS and adjusting speed controls. Route selection functionality (if allocated to TTCS) will also be impacted by weather conditions.
TTCS 103.4*	TTCS shall predict the congestion effects (i.e., propagation) of incidents in its control area. These impacts, along with its action plan, shall be sent to TWTM (related requirement TTCS 103.1).	Congestion propagation is a function of network geometry, travel demand, and control system capabilities in adapting to changing conditions.

TTCS 103.5	TTCS shall interface with the Incident Management System to receive incident notification and data and to respond to a request for priority treatment for emergencyvehicles.	A verified incident will potentially trigger an incident strategy selection by TTCS (see TIMS 103).
TTCS 103.6	TTCS shall develop simulated MOE or surveillance information if direct measurements from field sensors are not available.	Simulated data may be used by TTCS for strategy selection for output dissemination through CMS.
TTCS 104*	TTCS shall implement TWTM-generated control directives.	TWTM control objectives which increase throughput or constrain traffic flow may be translated into signal progression, reverse progression, or priority routes. Objectives which reflect the need to dissipate emission hot spots may be translated into the placement of a larger weight on the 'stops' variable in the plan generation model formulation.
TTCS 104.1	TTCS shall have the capability to translate TWTM directives given in terms of control objectives and tactics to specific control plans for implementation.	TWTM tactics are translated into a specification of control modes at all levels of the control hierarchy and the determination of specific control parameter adjustments. For example, TWTM may suggest constraining the inbound flow across a bridge into a congested area. TTCS could translate this into a reduction in the number of inbound lanes. At a more detailed level, TWTM may specify a progression tactic and a throughput requirement along a specific route; TTCS would determine the required offsets and splits.
TTCS 04.2	TTCS shall implement TWTM-generated control constraints at its boundaries with other TI'CSs.	
TTCS 04.3	TTCS shall implement a control plan specified by TWTM at the network or section level.	The control plan may be resident at the TMC DBMS and referenced by TWTM, or may be transferred from the TWTM node.
TTCS 105	**TTCS interface with other TMC Support Systems as well as with TWTM** is **through the TMC DBMS and the DIDE, which shall provide for a 2-way data transfer of control directives and surveillance data between the TWTM node and the** TMC.	TMC Support Systems denote those systems developed by the Loral Consortium on the ATMS Support System Contract or other applications which have standard database interfaces which correspond to the TMC DBMS standard.
TCS 105.1	TTCS shall have an automated interface to the TMC DBMS for loading processed surveillance measurement as well as intended strategies/control plans.	The assumption is that the TTCS shall 'push' the data and that the loading software is part of the TTCS (see DIDE 100.1.2).
TTCS 105.2	TTCS shall have an automated interface to the TMC DBMS for retrieving data needed for its operation as well as data being transferred from the TWTM node. The data includes traffic state data derived from non-organic surveillance sources (e.g., probe vehicle data and CCTV processed by the Input Stream processing Subsystem).	Data interfaces to the TMC DBMS are required for several TTCS modules including the internal event scheduler.

TTCS 106	**TTCS shall provide a TMC GUI that supports the need to accept control commands and display syitem logs as well as to develop strategies online by a transparent interface to the Integrated Model Manager Subsystems.**	
TTCS 106.1	The TMC User Interface shall provide a map-based real-time network view of traffic, weather, and air quality conditions. Intersection level displays shall be provided at operator request.	This requirement is supported by the MTEM at the TMC.
TTCS 106.2	The TMC User Interface supporting the TTCS shall provide a real-time display of control information: strategic and tactical. Displays of the operational effectiveness of the TTCS elements shall be provided. Displays shall be provided at any level ranging from a signal intersection, to a section, to the entire network.	Displays of alphanumeric data are superimposed on the underlying map.
TTCS 106.3	TTCS's outputs shall be displayed on individual workstations, a wall map, or both.	The wall map displays are projections of the workstation displays.
TTCS 106.4	The Operator can start or terminate system-wide logging activities via an operator command.	
TTCS 106.5	An emergency shut down of the system can be enabled via an operator command. All controllers go offline.	
TTCS 107	**TTCS shall provide a user interface at the field sites for monitoring and diagnostics.**	A plug-in monitor to the field computer shall provide standard user interface capabilities for conducting field diagnostics and monitoring.
TTCS 108	**TTCS shall provide the required internal communication links between devices at all levels of its control architecture.**	Communication frequency with field controllers depends on control system architecture with 1/sec for centralized systems.
TTCS 109	**TTCS shall monitor the operation of its surveillance system, the internal communication system, the local intersection controllers, CMS, and other access control devices under its scope of responsibility.**	The entire range of monitoring functions within the TMC are split between the various subsystems. To maintain the integrity of the control system in managing the hardware resources, and in view of the capabilities of existing systems, those monitoring functions which reflect H/W status monitoring have not been re-allocated. By contrast, "data quality" monitoring has been re-allocated to the MTEM and the DDVA subsystems).
TTCS 109.1	TTCS shall perform monitoring functions of its surveillance equipment for the purpose of identifying failed sensors or sensors operating outside of normal range (allocated to MTEM. Cited here for reference).	
TTCS 109.2	TTCS shall monitor its internal communications and perform failure processing in accordance with requirements set forth in the RT-TRACS Functional Specifications Document.	
TTCS 109.3	TTCS shall monitor the operation of all controller monitors and field computers by processing the conditions identifiable through the equipment's failure protocols.	
TTCS 109.4	TTCS shall monitor its own performance by processing its surveillance data to produce MOE, which it uses in its own operation or which it may share with TWTM.	The generation of traffic state estimates is allocated to the MTEM subsystem. To the extent that MTEM cannot comply with the real-time requirement of TTCS, TTCS may need to internally generate its own MOE data.

TTCS 109.5	TTCS shall log equipment failures in the TMC DBMS and set the appropriate alarms to the User Interface and Maintenance Subsystems.	
TTCS 110	**TTCS shall provide for graceful performance degradation if any of its components or communication links fail.**	Fail safe signal operation is guaranteed by flash mode controller operation.
TTCS 110.1	Individual controllers shall have a fail safe mode in case of complete failures.	
TTCS 110.2	Each element in the control hierarchy shall be able to operate autonomously in absence of any communication with higher level control elements.	Area computers have control strategy selection capability in terms of signal timing plans. The overall control effectiveness will be degraded when the top-level controller is inoperative since this specification & all for cooperative processing.
TTCS 110.3	Communication traffic between the TWTM node and a particular TMC shall be automatically routed via another TMC when a communication link fails.	
TTCS 110.4	TTCS shall have the capability to select and implement strategies in absence of TWTM demand forecasts by developing its own forecasts or by reverting to **a non-adaptive mode.**	Historical demand forecasts based on TOD can be used on lieu of TWTM projections.

The primary issue to be resolved deals with the scope of control of the TTCS. If we permit an arbitrarily large system (5000 intersections, for example) then a TTCS with capabilities as specified above would in essence be able to perform the functions that are required of TWTM; that is, subnetwork coordination. The only difference is that we are requiring TWTM to perform environmental and air quality assessments to deal with a non-homogeneous network, and to consider a potentially more varied set of access control and output dissemination functions,

A second issue deals with the allocation of ATMS surveillance requirements. For the purpose of the current specification, it has been assumed that any sensors connected to field equipment whose primary function is the implementation of control are components of the control system. This leaves surveillance cameras as part of the ATMS surveillance system. Loop detectors used for incident detection on freeways can fall into either category. The distinction is not important as long as we allocate all surveillance data capture, necessary communications with the TMC, as well as the TMC data loading to the control and surveillance systems.

Given the allocation of surveillance data capture to the TTCS, the related monitoring for failed equipment is partially located within the TTCS and partially within the MTEM.

Finally, it is assumed that control systems which employ traffic optimization models to generate plans in real time (e.g., SCOOT and TRANSYT) may do so in a distributed fashion (i.e., in the field computers). As a consequence, separate versions of the optimization model(s) may be required in addition to those managed by the Integrated Modeling Manager.

WIDE-AREA TRAFFIC MANAGEMENT SUBSYSTEM (TWTM)

ID	REQUIREMENTS & FUNCTIONAL SPECIFICATIONS	IMPLEMENTATION SPECIFICATIONS
TWTM 100	**TWTM can be located at any TMC within the 'ATMS region' already having local area responsibility.**	ATMS network must support data interchange between all TMC pairs within an ATMS region defined by the cooperating TMCs. If TWTM is permanently located in one regional TMC, fewer comm lines are required. The TWTM node requires TMC DBMS and DIDE for data transfer and access.
TWTM 100.1	TWTM can be accessed from any of the cooperating TMCs	TWTM architecture is client-server with the client resident at all potential nodes.
TWTM 101	**TWTM shall have an electronic data transfer interface to other regional ATMS systems.**	Regional ATMS must comply with overall data architecture and standards.
TWTM 102*	**TWTM shall have the capability to select and implement integrated, region-level transportation management strategies:** a. <u>TMC autonomous</u> - individual control systems and TMCs operate independently. b, <u>Local coordination</u> - coordination between individual control systems is localized (e.g., coordination between a ramp meter and the adjacent interchange). c. <u>Area-wide</u> - the system is managed to prevent the onset of congestion by proper metering of flow at boundaries between the respective TMCs. d. <u>Congestion</u> - the system is managed to prevent the spread of congestion by resorting to traffic constraint tactics and limited diversion through routing information dissemination to ATIS. e. <u>Incident</u> - the system must exercise stringent demand measures to alleviate the spread of congestion. TWTM employs route diversion as well as various information dissemination options to ATIS and other external systems. HOV relaxation options may be considered. f <u>Mixed Strategy</u> the system potentially applies a different strategy to each TMC. This type of overall strategy is presumed in other than very low volume conditions.	A transportation management strategy is defined as the overall management plan which can make significant changes in the flow of traffic or its concomitant effects and which is intended to affect traffic over significant geographical areas for relatively long periods of time, TWTM's Selection model must be multi-objective with capabilities to alter the importance assigned to each objective. The selection algorithm is AI-based, using Case-Based or Expert system paradigms. Selection model has built-in representation of the operating policies and inter-jurisdictional agreements. Representation can use a rule-based system. The selection process incorporates current as well as projected conditions. TWTM shall execute DTA in descriptive mode with current traffic input data, to determine network congestion effects in absence of routing. Driver behavior model in DTA must reflect driver decisions in absence of specific routing instructions. The definition of similar types of integrated strategies was given in: <u>**Coordinated Operation** of Ramp Metering and Adjacent Traffic Signal Control Systems</u>, Farradyne Systems, Inc., FHWA Contract DTFH61-89-C-00006. TWTM constitutes a client requesting service from the Integrated Modeling Manager to perform strategy evaluation.

WTM 02.1	TWTM's regional strategies employ both traffic management and demand management tactics. a. Integrated surface street and freeway control. b. HOV and reversible lane controls including preferential signal control. c. Route diversion directly through CMS or via ATIS (includes vehicle routing). d. ATIS pre-trip planning and in-trip route diversion for spreading the demand spatially and temporally. e. ETTM interfaces for real-time congestion pricing (preliminary decision was reached that demand pricing will NOT be done in real time). f. Interfaces to HAR and radio/TV stations. g. Dissemination of parking availability information (parking will not be managed by ATMS, but parking availability data may be disseminated to ATIS and may be incorporated into route calculations in a centralized routing scenario).	TWTM must have capability to automatically construct a complete modeling scenario using pre-defined scripts corresponding to each selected strategy and group(s) of tactics. The definition of scripts is a function of the capabilities of the Modeling System. The H/W and OS must support multi-processing; the number of simultaneous evaluation runs which the system must be capable of running is to be determined in Task D. Specification of strategy to be evaluated is provided within the TWTM user interface (the client part of TWTM).
WTM 02.1.1	TWTM's selected strategies shall reflect area-wide objectives including both traffic and environmental considerations: congestion, emissions, mobility, etc.	
WTM 02.2	The tactics implemented in support of the selected strategies shall reflect both individual jurisdictional operating policies as well as inter-jurisdictional operating agreements and procedures.	A tactic is a traffic control option which singly or in combination with other tactics is implemented in support of the chosen strategy.
WTM 02.3	TWTM shall base its strategy and tactic selection on 15-minute forecasts of traffic state estimates. The forecasting period should be adjustable (10-60 minutes).	The baseline forecasting period is 15 minutes.
WTM 02.3.1	TWTM shall interface with the ADTA to develop 10-30 minute network load forecasts.	
WTM 02.3.2	TWTM shall generate regional air quality and weather summaries using state estimates received from TMCs which it will use in selecting a regional strategy and corresponding tactics.	A TWTM may need to generate simulated data in cases where direct measurements are not available. This is applicable to both strategy determination and information dissemination.
WTM 102.3.3	TWTM shall predict the area-wide congestion effects (propagation) of incidents.	
WTM 102.4	TWTM shall support various modes of strategy selection and tactics development. Automated: strategies and tactics are selected and evaluated in real time based on forecasted conditions. The selection/evaluation process is repeated every 5 minutes on a rolling horizon basis. The operator is not in the loop during the process, but is permitted to view the selection and override. The Integrated Model Manager functions as a server providing	

TWTM 102.4 (cont'd)	evaluation results to the TWTM client based on pre-defined evaluation scripts. Operator Online: strategies/tactics are suggested by the system but the evaluation involves the operator participation in an online mode through the Integrated Model Manager and the various simulation/optimization models. This interaction is conducted through the GUI. Operator Offline: new strategies and tactics are developed and evaluated offline based on historical data on incidents. They are stored for subsequent use (Historical Data Analysis Subsystem).	For each combination of tactics, an evaluation script defines the models to be executed given the scenario at hand.
TWTM 102.4.1	TWTM shall have the capability to automatically select a strategy/tactic based on historical experience and adapt the strategy to the present conditions.	
TWTM 102. 4.2	TWTM shall have the capability to automatically evaluate the chosen strategy by transparently executing traffic models in the Integrated Model Manager.	
TWTM 102.4.2.1	TWTM shall have the capability to simultaneously evaluate multiple strategies for a given area or for different areas.	
TWTM 102. 4.3	The TWTM User Interface shall provide a transparent interface to the Integrated Model Manager for online evaluation of the selected strategy.	
TWTM 103*	**TWTM shall implement a set of tactics corresponding to its selected strategy in real time through electronic interfaces with TMCs in the ATMS region. TWTM's recommendations shall include:** a. Demand projections - effectively represents a non-intervention strategy. b. Control objectives or suggested tactics for each of the traffic control systems in the region. c. Control constraints at specific control systems' boundary locations. d. Control plan (i.e. specification of a tactic) for one or more of the control systems or any of their sub-elements. TWTM shall not develop control plans; rather it will have access to plans which have been demonstrated to be effective in the past.	It is assumed that the top-level controller of each TWTM is located within a TMC. TWTM to TICS interface-recommended strategy, tactic, plan. TTCS to TWTM interface-planned strategy, local monitoring data (surveillance, incidents, etc). Incidents are initially detected by local control systems which make the initial response. If the incident is projected to have an area-wide effect, TWTM may intervene in traffic management. Options: (1) TWTM can simulate the TTCS decision process and project effectiveness, (2) CBR capturing historical experience in similar situations.
TWTM 103.1	TWTM shall interface with the top-level controller of each traffic control system. TWTM shall NOT have a direct interface to the traffic control systems' area computers or field sensors and effectors.	
TWTM 103.2	TWTM's decision to intervene shall be based on its determination of each control system's effectiveness in dealing with the projected conditions and travel demands.	
TWTM 103.2.1	TWTM shall interface with the traffic control systems in the region to receive each system's control plan when responding to detected incidents.	
TWTM 103.2.2	TWTM shall have the capability to project the effectiveness of a control system's selected strategies or plan.	This is the primary basis for determining whether or not intervention is required.

TWTM 1104*	**TWTM's integrated strategies shall be implemented through real-time electronic interfaces with external systems involved in regional transportation management.**	ATIS interface can be supported by DIDE at TWTM and ATIS nodes. ATIS can handle further distribution of data. A direct interface between TMCs and ATIS is also possible for accommodating some of the data requirements depending on the overall ATMS/ATIS architecture.
TWTM 104.1	Primary interface shall be with ATIS.	Interfaces to CVO systems also depend on the overall architecture.
TWTM 1.04.2	Secondary interfaces with APTS and CVO shah be accommodated either through ATIS or directly.	
TWTM 105	**TWTM shall monitor the effectiveness of its selected strategy/tactics and update the case data used for strategy/tactic selection.**	This requirement reflects a design which uses AI tools such as Case-Based-Reasoning for initial strategy selection. The case library is updated by storing all information within “case templates.” These templates include pre-intervention monitoring data, selected strategy and post-intervention monitoring data. The library update may involve some offline analysis.
TWTM 105.1	TWTM shall automatically store traffic and strategy selection data in the TMC DBMS for offline analysis of case histories.	TWTM’s monitoring requirement is satisfied by the MTEM at the TWTM node.
TWTM 106	TWTM shall provide the user with a graphical interface which supports the monitoring and strategy selection processes including the transparent interface to other support systems.	This TWTM requirement is coallocated with the common GUI requirements. GUI shall support layering of views. A base-map layer, a traffic layer, air quality layer, etc. Views can be superimposed. This can be implemented using a GIS for managing the layers, or through developed software.
TWTM 106.1	TWTM’s user interface shall provide a map-based real-time regional view of traffic, weather, and air-quality conditions.	These displays also constitute GIS layers (e.g., suggested routes display overlaying the base map).
TWTM 106.2	TWTM’s user interface shall provide a real-time display of wide-area control information, strategic and tactical. Displays of the operational effectiveness of the local control systems shall be provided.	Any view can be directed to a wall map,
TWTM 106.3	TWTM’S outputs shall be displayed on individual workstations, a wall map or both.	
TWTM 107*	**When local TMC's fail or lose connection to the regional network, TWTM shall continue to generate integrated strategies for the connected TMC's.**	For communication line failures the data can be rerouted through another TMC. Communication subsystem will monitor and reroute. For TMC failure, TWTM can still develop strategies at all other TMC boundaries. One may consider nominal values based on historical data.
TWTM 107.1	Local TMC’s disconnected from the TWTM node as a result of communication failures or TWTM node failure will operate autonomously.	(See above for comm line failure.) TTCS can always operate autonomously of TWTM and each TTCS’s field equipment can operate autonomously of the top-level controller.

TWTM 108	**TWTM will interface with the TMC DBMS to retrieve all data needed for its operation.**	The TMC DBMS shall provide access to the global data. Non-local data is loaded to the DBMS by DIDE.
TWTM 108.1	The local DBMS's logical model encompasses the global data (allocated to DBMS).	Overall TMC data model is a global ATMS model which represents all the data. At any given TMC, only 'local' portions Of the data are loaded. At the TWTM node the database contains global data.

ISSUES:

Several issues remain to be solved with respect to the specific interface between the TWTM and the individual control systems. In the intervention mode, we need to analyze the situations in which intervention, at various levels, will yield more effective control than can be realized by simply providing demand projections to the individual adaptive control systems. During ATMS deployment, where not all participating TMC's are adaptive, one can see the potential benefits of an advanced TWTM within the region.

Other issues relate to the specific interfaces with external systems and the corresponding data requirements and the resolution of the demand forecast module both temporally and spatially (path-based or link based). The present specification requires 15-minute forecasts with the assumption that the short-term and mid-term (5 minute) forecasts are performed by the individual control systems. No assumption was made on the spatial form, although, if TWTM is to be able to generate tactics and plans, it will probably need to do so on the basis of link flows.

Finally, an implementation issue has surfaced with respect to the MTEM functions that are regional versus local. TWTM, if collocated in the same TMC with a TTCS, still requires the "regional monitoring" of conditions. The local MTEM, if tasked with supporting both requirements, can conduct them in parallel since the requirements are real-time or one can define two distinct MTEMs, one for TWTM, the other for local monitoring

INDIVIDUAL VEHICLE ROUTING (TIVR)

ID	REQUIREMENT & FUNCTIONAL **SPECIFICATION**	IMPLEMENTATION SPECIFICATIONS
TIVR 100	**This system shall ingest data describing the request for "special" routing: origin, destination, time of trip-start. Optionally, a designated path can be specified. Furthermore, the type of vehicle(s) involved, routing constraints (e.g., desired speed of travel, preferences, etc.) and trip classification will be ingested.** **Requests can originate from other subsystems [e.g., Input Stream Process (external** CVO **routing requests), Incident Management (Emergency vehicle requests)]** or **from the operator.**	Operator requests are entered through the Common GUI. Requests may be made by phone other means; Operator uses system to determine route and return to request. The Common GUI conforms to OSF/Motif style guidelines. Requests from other subsystems are handled via a TCP/IP or POSIX message queue API, These requests activate route computation and pass (to this system) either the parameters or a pointer to the DBMS for the details of the routing request. After routes are determined they are loaded into the DBMS and scheduled for dissemination with the I/O Manager. Vehicle-TMC communication is dependent on the ATMS architecture (reference Output Stream Processing).
TTVR 100.1	This system shall accept requests from an operator for a special trip.	
TTVR 100.2	This system shall accept requests from the Incident Management support subsystem to route emergency vehicles.	
TTVR 100.3	TTVR subsystem shall interface to the Input Stream Processing subsystem to directly receive routing requests for external systems (e.g., CVO).	
TTVR 100.3.1	This system shall accept requests from external IVHS element: Fire, Police, Mayor, EMS, CVO, HAZMAT, State, other approved sources.	If route request requires control system action, an interface with the appropriate control system is necessary.
TIVR 101	**TIVR support subsystem shall compute the optimal routes for specified types of trips: Emergency Service; Law Enforcement; Fire and Incident Response;** HAZMAT.	Routes are computed using a routing algorithm that has knowledge of the state of the traffic network.
TIVR 102	**TTVR subsystem shall ingest information from the TMC DBMS needed for determination of optimal route based on current traffic conditions and for the details of routing requests. This includes static network data, and real-time surveillance and control information.**	Provided through a DBMS SQL API.
TIVR 103	**TTVR subsystem shall compute optimal path from vehicle's current position (if it is a probe vehicle) or from its estimated** position **(based on its previous path segment, if any, the** elapsed **time from last update, and recorded speeds on the traversed links), to its intended destination.**	Optimal path is computed using a "best" route algorithm. Algorithm can be a version of a shortest route where link cost is a representation of "best."

TIVR 104	**TIVR subsystem shall send path (route) and status information to the I/O Manager for dissemination to external systems or agencies.**	Computed routes are scheduled for output with the I/O Manager or can be sent asynchronously by activating an Output Stream Processing process. This interface is handled via a TCP/IP Or POSIX message queue API.
TIVR 104.1	The system shall communicate selected status information to the IVHS element that submitted the request.	
TIVR 105*	**TIVR subsystem shall periodically monitor vehicle's travel and determine the time for next path update. /Reserved/.**	If vehicle is registered via AVI, it can be tracked using the Vehicle Tracking subsystem and its current location made available for routing updates.
TIVR 106	**TIVR subsystem shall accept multiple requests for routing simultaneously. For concurrent requests, coordinate paths for each vehicle so as to avoid, or minimize the consequences of, conflicting paths.**	Aggregate routing information is maintained to facilitate coordination.
TIVR 107*	**TIVR subsystem shall communicate with applicable Traffic Control systems (surface or freeway) the need for providing favored treatment for guided vehicle.**	The route can be passed to the Traffic Control Subsystem which can implement a prioritized treatment plan with direction of travel.
TIVR 108	**TIVR subsystem shall present displays to the operator describing the status of each trip: location, speed, destination, control response, projected route; and archive these data (co-requirement with the Vehicle Tracking subsystem}.**	Reference the Vehicle Tracking subsystem,
TIVR 109	**TIVR subsystem shall interface to the TMC DBMS for the storing of non-persistent routing details prior to dissemination to external systems.**	Provided via a DBMS SQL API.

AUTOMATED CONTROL SOFTWARE DOWNLOADING (SACS)

ID	REQUIREMENT & FUNCTIONAL SPECIFICATION	IMPLEMENTATION SPECIFICATIONS
SACS 100*	**The SACS subsystem shall receive requests to transmit new control software, data, or diagnostics to selected field controllers or processors.**	The user interface shall provide a template for specifying target locations, equipment, configurations, software modules to be sent, etc. The requests may originate from within the TMC or from outside the TMC (provided that the TMC supports remote access).
SACS 100.1	SACS shall provide a mechanism to select field controllers or processors in the field that are to receive new control system updates.	
SACS 100.1.1	SACS shall allow controllers to be selected individually, all within a given subnetwork, all controllers for the network, or by kind.	
SACS 100.2	SACS shall provide a mechanism for the operator to select and retrieve the executables and files managed by the Document and File Management that are to be transmitted to remote field controllers or processors (reference SM 105).	Field equipment needs to have the capability to go on standby (e.g., flash mode) while software is being loaded or diagnosed. Also need to run remote diagnostics.
SACS **100.3**	The files retrieved shall be either executables for control software updates or data files. For instance, a data file could be sent that would allow the controller to update its dynamic communication network (assuming wireless, configurable, communication links).	
SACS 101	**The SACS subsystem shall provide an interface with the TMC DBMS subsystem to obtain data related to the current configuration of hardware and software in the field. The TMC DBMS subsystem shall provide details on software versions, hardware versions, dates installed, etc., for selected components in the configuration. In particular, it should provide executable tile names for executables. This will allow the file to later be retrieved from Document and File Management subsystem.**	This could be provided via an SQL API.
SACS 102	**The SACS subsystem shall provide an interface with the Configuration and Inventory Management subsystem to update the configuration of field controllers and processors (control software and dynamic communication links).**	Depending on the architecture, the configuration update can be made directly to the DBMS.
SACS 103	**The SACS subsystem shall log all changes to the configuration of the field equipment.**	A DBMS interface or directly to a file.
SACS 104	**The SACS subsystem shall provide an interface with the Document and File Management subsystem to select and retrieve files and executables (reference SM 100.2).**	Software will be stored in operating system tiles, which are located in directories. The file names themselves should be referenced in the “configuration,” but maintained by the Configuration and Inventory Management Subsystem.

SACS 105*	**The SACS subsystem shall provide an electronic interface with field equipment to transmit software, data, or diagnostic procedures to the field and to receive verification back from the field.**	The connectivity shall be provided by the Traffic Control System's communication links to the field equipment. A remote access to the field equipment computer is required. The operating system at the local controller must support network protocols to exchange information with the TMC. The protocol of choice is TCP/IP.
SACS 105.1	The SACS subsystem shall transmit control software executables to selected controllers and processors in the field.	
SACS 105.2	The SACS subsystem shall transmit data to field controllers and processors that will allow the controllers to reconfigure their dynamic communication network.	
SACS 105.3	The SACS subsystem shall transmit diagnostic procedures to field controllers and processors that will support testing and diagnosis.	
SACS 105.4	The SACS subsystem shall provide support to restart control software.	
SACS 105.5	The SACS subsystem shall receive verifications from field equipment that transmissions were correctly received and incorporated.	
SACS 105.6	The SACS subsystem shah update the configuration by sending updates to the Configuration and Inventory Management subsystem once verification is received (reference SM 103).	Once diagnostics have been checked and the configuration has been changed, an entry will be made to update the configuration.
SACS 106	**The SACS subsystem shall support a GUI for displays, queries, reports, and commands.**	This is supported by the Common GUI, and conforms to OSF/Motif style.
SACS 106.1	The SACS subsystem shall provide a GUI that supports the interactions between the user and the Document and File Management subsystem (reference 100.2).	
SACS 106.2	The SACS subsystem shall provide a GUI that supports the interactions between the user and the TMC DBMS (reference SM 102).	
SACS 106.3	The SACS subsystem shall provide a GUI that supports the interactions between the user and the field equipment (reference SM 106).	

CONFIGURATION AND INVENTORY MANAGEMENT (SCIM)

ID	REQUIREMENT & FUNCTIONAL SPECIFICATION	IMPLEMENTATION SPECIFICATIONS
SCIM 100	**The SCIM subsystem shall support both configuration management and inventory management.**	This system will reside on top of the DBMS and will use DBMS forms or custom code.
SCIM 101	**The SCIM subsystem shall manage the configuration of hardware and software assets both in the field and in the TMC.** The hardware and software in the field can include surveillance and control equipment, communication links, and the associated software. More specifically this includes computers, peripherals, controllers (processors), loop detectors, environmental sensors (visibility, pollution, temperature, precipitation), physical communication links (to signal heads, detectors, to a central computer or an adjacent controller), signals, ramp meters, CMS, HAR, and CCTV cameras. The software in the field can include all operational software (source code, object code, and executables for control and monitoring) and associated data, operating systems, and application support tools (compilers, libraries, DBMS, etc.). The hardware in the TMC can include communication links, support system hardware, and external communication system interfaces. More specifically this includes front-end communication equipment and physical communication links, computers, monitors, peripherals, inter-computer communication links, etc. The software in the TMC can include Support System applications (executables, source code, object code) and associated data, operating systems, and application support tools (compilers, libraries, DBMS, etc.).	The configuration is maintained in the DBMS in the form of tables which can be accessed through ad hoc queries as well as reports.
SCIM 101.1	The configuration management element shall maintain records from the TMC DBMS for each piece of hardware that will track its type, location, manufacturer, model number, installation date, purchase date, modification or servicing history and other technical details associated with specific type of hardware component. Support shall be provided to display and print these records.	

SCIM 101.2	The configuration management element shall maintain records from the TMC DBMS for each piece of software that will track is creation date, function, author, modification date and history, and other technical details (compilers and other tools required to rebuild). Support shall be provided to display and print these records.	
SCIM 101.3	The configuration management element shall maintain records from the TMC DBMS that define a common network representation. The common network representation defines the communication network between controllers, detectors, signals, and the TMC. It also defines the state of each component in the network (e.g., working, requires servicing, abnormal). Support shall be provided to display and print these records.	
SCIM 102	**The SCIM subsystem shall accept requests for updates to a hardware or software configuration or component.**	This shall be meet in two ways: through the Cnmmon GUI and through an application API. Updates to a configuration will be done through a GUI panel that conforms to the OSF/Motif Style Guide. The updates will be stored in the DBMS. The GUI will accept requests for configuration or inventory updates, display current configuration and inventory data from the TMC DBMS, and facilitate report capabilities
SCIM 103	**The SCIM subsystem shall perform inventory management.**	The configuration is maintained in the DBMS in the form of tables which can be accessed through ad *hoc* queries as well as reports. Order quantities for spare parts will be generated based on Estimate Order Quantity (EOQ) formulas using data maintained in the DBMS. Time to order will be provided in monthly reports provided to the user.
SCIM 103.1	The SCIM subsystem shall maintain inventories, obtained from the TMC DBmS, of spare parts and all TMC assets.	
SCIM 103.2	The SCIM subsystem shah generate order quantities and time to order estimates. Time to order estimates shall be displayable and printable.	
SCIM 104	**The configuration shall support an interface with the Document and File Management subsystem to deposit (add or overwrite) and retrieve request files (source code, object code, executable code, data).**	When a new file is added to the configuration, the Document and File Management Subsystem will be notified. This will be provided through an application API. POSIX message queues or TCP/IP sockets will be used.
SCIM 105	**The SCIM subsystem shall support an interface with the TMC DBMS to retrieve configuration and inventory data.**	This subsystem resides on top of the DBMS. DBMS forms could provide this capability or custom software could be developed

SCIM 106	**The SCIM subsystem shall an electronic interface with the Automated Control Software Downloading subsystem to receive electronic updates to the configuration of software in the field. The updates may be either control software updates or updates to the communication network for a particular controller (assuming a wireless communication network).**	This will be provided through an application API. POSIX message queues or TCP/IP sockets will be used.
SCIM 107	**The SCIM subsystem shall facilitate an electronic interface with the Data Validation subsystem to send updates to the DBMS.**	This will be provided through an application API. POSIX message queues or TCP/IP sockets will be used. Depending on the allocation of the validation functions, some or all of the validation may be performed by the DBMS.

EVENT PLANNING AND SCHEDULING (SEPS)

ID	REQUIREMENT & FUNCTIONAL SPECIFICATION	IMPLEMENTATION SPECIFICATIONS
SEPS 100	**The SEPS subsystem shall receive notices of planned events, either construction or special event plans, from an electronic system interface or a human interface.**	External sources of event information can submit information on a regular basis (e.g., weekly or monthly) in accordance with a pre-specified notation (format) and protocol. The pre-specified notation will be understandable by this system. The protocol shall be File Transfer Protocol (FTP) for systems that have remote access and are transmitting files. The format shall at minimum contain the following field: time, date, activity name, activity type, location (address or XY coordinate), duration, and annotations (specifying resources, traffic demands, special requirements, etc.). For special events, a field for expected attendance will be provided. For construction events, a field for lanes closed will be provided. Event notices entered by the operator will use the services of the Common GUI.
SEPS 100.1	The SEPS subsystem shall have the capability to receive event notices automatically via an electronic interface.	
SEPS 100.1.1	The SEPS subsystem shall have an electronic interface with other systems capable of automatically downloading construction or special event plans.	
SEPS 100.2	The SEPS subsystem shall have the capability to receive manual entry event notices via an operator interface.	
SEPS 100.2.1	The operator interface shall support the manual entry of required information needed to satisfy an event notice for this subsystem.	
SEPS 1002.2.	The SEPS subsystem shall have the capability to support manual entry of notices for construction, special events, or unplanned events.	
SEPS 100.2.2.1	The SEPS subsystem shall receive manual entry notices for planned construction events.	
SEPS 100.2.2.2	The SEPS subsystem shall receive manual entry notices for planned special events (e.g., parade, football game).	
SEPS 100.2.2.3	The SEPS subsystem shall receive manual entry notices for contingency planning (unplanned) events (e.g., planning for an incident).	These types of notices are not deposited onto the event calendar.
SEPS 101	**All event notices shall be logged to a separate log file.**	Provides an audit trail for all inputs. All inputs are written to either the DBMS or an operating system file.
SEPS 102	**All event notices shall be placed on a system event schedule (calendar) to be used for planning purposes by TMC staff, external agencies, and for traffic control purposes.**	The system schedule is implemented using a linked list or table sorted by type.

SEPS 103	**The SEPS subsystem shall develop scenarios for use in contingency planning for planned and non-planned events (e.g., incidents). For planned events the scenario will be partly provided. For incidents, support for development of the entire scenario will be provided.**	The user shall use the event data to construct a complete scenario or multiple scenarios. These scenarios are the basis for which action plans can be developed.
SEPS 104	**The SEPS subsystem shall provide a system interface to the Integrated Modeling Manager to determine traffic control strategies.**	Traffic scenarios (including all data need for running traffic models) are developed within the Modeling Manager which can be brought up as a separate application on the workstation. A linkage is created between the Event ID, the scenario data, and the output results.
SEPS 104.1	The SEPS subsystem shall develop event plans for planned events by interacting with the Integrated Modeling Manager, the user, and the Document and File Management System.	
SEPS 104.2	The SEPS subsystem shall develop contingency plans for incidents by interacting with the Integrated Modeling Manager, the user, and the Document and File Management System.	
SEPS 105	**The SEPS subsystem shall provide a system interface to the Document and File Management system to retrieve past plans and to modify or generate new plans.**	The DBMS may be used in conjunction with the Document and File Management Subsystem to actually store contingency plans An application API to the DBMS and the Document and File Management Subsystem is used to retrieve contingency plan information. The Document and File Management Subsystem will store the text and procedures associated with the contingency plan.
SEPS 106	**The SEPS subsystem shall provide a system interface with the TMC DBMS to obtain transit schedules for use in event planning.**	Provided via an application API.
SEPS 107	**The SEPS subsystem shall provide a system interface with the Data Validation and Derivation system for writing traffic control strategies and event information back to the TMC DBMS.**	Provided via an application API.
SEPS 108	**The SEPS subsystem shall provide a system interface with the I/O Manager to handle the scheduling of control system plans and external agency outputs.**	The traffic control plan corresponding to a planned event can be scheduled for implementation by automaricatiy logging an event entry in the I/O Manager (scheduler). The event entry will include an event time, id, control plan id, etc.
SEPS 108.1	The SEPS subsystem shall support an electronic Interface with other external systems or external agencies that may require planned construction or special event data. This electronic, external system interface will be managed by the I/O Manager.	Provided via an application API, using TCP/IP sockets or POSIX

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SEPS 108.2	The SEPS subsystem shah schedule implementation of derived traffic control plans for planned events with the I/O Manager, which will ultimately feed the Traffic Control Systems at the proper time.	
SEPS 109	**The SEPS subsystem shall have an operator interface. The operator interface will be graphical and interactive.**	This service will be provided by the Common GUI, which will conform to the OSF/Motif Style Guide.
SEPS 109.1	The operator interface shall support the manual entry of event types consisting of planned events or notices for contingency plans. The entry shall encompass the fields that will compose format of the prespecified notation.	
SEPS 109.2	The operator interface shall support the graphical representation of the event schedule via a schedule timeline.	
SEPS 109.3	The operator interface shall support manual scheduling of a planned event.	The major functionality of this subsystem is to assemble a comprehensive event calendar for various types of events (construction, special); however, this system also provides the capability to actually schedule events. In this case, support is provided to recommend the best times to schedule events based on knowledge in the event calendar and historical data.
SEPS 109.4	The operator interface shall have report capabilities.	
SEPS 109.4. I	Report generation shall have the capability to be sorted alphabetically or chronologically.	
SEPS 109.4.2	The operator interface shall support hard copy printout of event schedules.	
SEPS 109.4.3	The operator interface shall support hard copy printout of event notices.	
SEPS 110	**The SEPS subsystem shall support the automatic and manual scheduling of events.**	Manual requests are handled through the Common GUI. Automatic requests are handled through a system API (e.g., FTP).
SEPS 110.1	The SEPS subsystem shall support manual scheduling where an event can be placed on the schedule at the user's discretion, regardless of pending conflicts.	
SEPS 110.2	The SEPS subsystem shall support automatic scheduling where each event notice is automatically placed on the schedule at a specific time.	
SEPS 111	**The SEPS subsystem shall have support for managing at least two different schedules (event, construction).**	Implemented using a new internal structure (e.g., class, linked list, etc.)
SEPS 112	**The SEPS subsystem shall be capable of scheduling a maximum 1,440 one-minute events per day. It is expected, however, that this is not realistic since the typical special event is 4 hours, and the typical construction event ranges from 1 day to several months or years.**	The resolution of the internal structure shall have sufficient length to accommodate the maximum number of activities.1
SEPS 113	**The event schedule shall support event scheduling up to 5 years in advance.**	(same as above)

MAINTENANCE MANAGEMENT SUBSYSTEM (SMMS)

ID	REQUIREMENT & FUNCTIONAL SPECIFICATION	IMPLEMENTATION SPECIFICATIONS
SMMS 100	**SMMS shall receive equipment failure inputs from electronic or human interfaces. This system shall support a scheduling capability to schedule repairs for failure reports.**	The electronic interface shall be provided with other systems that detect failures. This interface will be supported via POSIX message queues or TCP/IP sockets.
SMMS 100.1	The scheduler shall have an electronic interface with other systems capable of automatically detecting failures or monitor usage of various ATMS assets.	
SMMS 100.1.1	The scheduler shall interface to the TMC Hardware and Software Monitoring subsystem to electronically receive failure events.	
SMMS 100.1.2	The scheduler shall interface to the Input Stream Processing to electronically receive communication failure events.	
SMMS 100.2	The scheduler shall have the capability to ingest failure reports manually via a operator interface.	
SMMS 100.2.1	The operator interface shall support the entry of required information needed to satisfy a request for the scheduler.	The format shall at minimum have a time, failure type, origin.
SMMS 100.2.2	SMMS shall have the capability to ingest various types of requests for maintenance or repair activities.	
SMMS 100.2.2.1	The scheduler shall ingest requests for field surveillance equipment repair or maintenance. These shall include loop detectors, controllers, and CCTV.	
SMMS 100.2.2.2	The scheduler shall ingest requests for field control and signal equipment repair or maintenance. These shall include: Traffic lights, Type-170 Controllers, SBC 68 controllers, NEMA controllers, CMS, and Ramp meters.	
SMMS 100.2.2.3	The scheduler shall ingest requests for repair or maintenance of communications interfaces between the field and the TMC.	
SMMS 100.2.3.4	The scheduler shall ingest requests for roadway infrastructure repair or maintenance. These shall include things like pothole fixes, salt crew, and re-surfacing.	
SMMS 100.2.3.5	The scheduler shall ingest requests for TMC Hardware and Software repair or maintenance. This shall include all the hardware and software resources within the physical confines of the TMC, including DBMS, hardware components, software process, and communication links.	
SMMS 101	**All requests shall be logged to a separate log file. Requests that need to be scheduled will also be routed to the scheduling process.**	The failure log will be maintained in the DBMS.
SMMS 102	**The scheduler shall interface to the TMC DBMS to obtain maintenance data for the failed asset.**	Provided through an API to the DBMS.

SMMS 103	**The scheduler shall have an operator** interface. The operator **interface will be graphical and interactive.**	Support provided by the Common GUI. The Common GUI will conform to OSF/Motif style guidelines.
SMMS 103.1	The operator interface shall support the manual entry of all request types. The entry shall encompass the fields that will compose format of the request notation.	
SMMS 103.2	The operator interface shall support the graphical representation of the maintenance or repair schedule via a schedule timeline.	
SMMS 103.3	The operator interface shall support the graphical representation of resource utilization overtime.	
SMMS 103.4	The operator interface shall support manual scheduling of an activity.	
SMMS 103.5	The operator interface shall have report capabilities.	
SMMS 103.3.5.1	The operator interface shall support hard copy printout of schedules.	
SMMS 103.3.5.2	The operator interface shall support hard copy printout of requests.	
SMMS 103.3.5.3	The operator interface shall support hard copy printout of requests that were not scheduled.	
SMMS 104	**The scheduler shall support automatic and manual scheduling of activities.**	Provided by a scheduling algorithm. Activities include repairs for failed components and preventive maintenance.
SMMS 104.1	The scheduler shall support manual scheduling where an activity can be placed anywhere on the schedule at the user's discretion.	
SMMS 104.2	The scheduler shall support automatic scheduling where each request is automatically placed on the schedule at a specific time, or if a time is not specified, it can be automatically placed on the schedule based on specified constraints and other considerations.	
SMMS 105	**The scheduler shall support rescheduling of activities.**	Provided by a rescheduling algorithm.
SMMS 106	**The scheduling algorithm shall have the capability to perform resource constraint scheduling and resource levelling.**	Algorithm manages the constraints expressed in each activity.
SMMS 106.1	The scheduler shall place the activity on the timeline or identify a conflict within 5 seconds.	
SMMS 107	**The scheduling algorithm shall be goal driven.**	As a parameter to the algorithm, a goal shall be given (e.g., maximize the number of activities).
SMMS **108**	**The scheduler shall support an electronic interface with other external systems for data transfer of maintenance and repair data.**	Provided via APIs implemented using POSIX message queues or **TCP/IP** sockets.
SMMS 108.1	The scheduler shall provide a capability to integrate additional interfaces that will provide failure information.	

SMMS 108.2	The scheduler shall interface to the I/O Manager to schedule failure logs or report outputs to external agencies or systems.	
SMMS 109*	**Support shall be provided for the automatic paging of maintenance personnel for certain failures.**	Service is available through paging vendors. This works in conjunction with system-generated events.
SMMS 110	**Support shall be provided to derive Mean Time Between Failures (MTBF) and Mean Time Between Maintenance (MTBM) for failed components.**	Calculated MTBF and MTBM estimates are stored in the DBMS.
SMMS 110.1	Based on the MTBM, the scheduler shall provide support to automatically recommend and schedule preventive maintenance activities.	
SMMS 110.2	The SMMS subsystem shall maintain statistics for usage levels of the various assets (hardware, software, comm links, databases) inside/outside of the TMC.	The usage levels shall be correlated to respective Mean Time Between Failures (MTBF) and Mean Time Between Maintenance **(MTBM).**
SMMS 111	**The scheduler shall be capable of scheduling a maximum 1,440 one-minute activities per day. It is expected, however, that the minimum maintenance and repair activity will take 15 minutes; thus realistically only 96 activities per day could be scheduled in any 24-hour period.**	Internal structures must provide this level of resolution.

TMC HARDWARE AND SOFTWARE MONITORING (STHS)

ID	REQUIREMENT & FUNCTIONAL SPECIFICATION	IMPLEMENTATION SPECIFICATIONS
STHS 100	**The STHS subsystem shall identify system faults within the TMC by continuously monitoring the performance of TMC assets.**	This is likely to require the use of both custom and COTS software. COTS software is available for DBMS and communication monitoring. Some monitoring functions are provided by the operating system for software processes, however, custom Unix scripts will be required.
STHS 1.00.1	The STHS subsystem shall identify hardware faults within the TMC. Hardware faults shall consist of down nodes on the network, resultant from memory, cpu, disk, or other peripheral problems.	
STHS 100.2	The STHS subsystem shall identify software faults within the TMC. Software faults shall consist of, but not be limited to, operating system anomalies, swapped out software processes, down software processes and inter-process communication.	
STHS 100.3	The STHS subsystem shall identify communication faults within the TMC. The communication faults shall consist of faults at the network level (e.g., node to node) and with communication interfaces to external systems,	
STHS 100.4	The STHS subsystem shall identify database faults within the TMC. This is performed by monitoring DBMS resources. This includes database usage (table access counts, number of joins, etc.) and database sizing (database size, table size, etc.).	
STHS 101	**The STHS subsystem shall report failures by facilitating a system interface with the TMC DBMS and the Maintenance Management subsystem.**	The interface will be a TCP/IP or POSIX message queue API. The actual reporting of the failure is logged in the DBMS. Notification is provided to the Maintenance Management subsystem for the scheduling of repairs. All failures do not necessarily require maintenance and repair. Automatic paging is preferred, but not required.
STHS 101.1	**All faults shall be reported to the TMC DBMS, and depending on the priority level of the failure, to the Maintenance Management Subsystem. The highest priority failures will be reported to responsible persons via a pager.**	
STHS 101.1.1	**The STHS subsystem shall log all faults to the TMC DBMS.**	
STHS 101.1.2	**Support shall be provided for displaying the contents on the log file and for updating in real time if it is currently displayed and a new failure is registered.**	
STHS 101.1.3	**Support shall be provided for enabling and disabling audible and visual alarms.**	
STHS 101.1.4	**The alarms shall be generated for high priority failures. The priority levels assigned to failure types will be reconfigurable by the user.**	
STHS 101.1.5	**The STHS subsystem shall provide a paging capability to page appropriate personnel for critical system failures.**	

STHS 101.2	The STHS subsystem shall log failures to a log file.	
STHS 103	**The STHS subsystem shall support a system interface to the Configuration and Inventory Management subsystem to obtain and update current configuration data.**	The interface will be a TCP/IP or POSIX message queue API. The implementation may justify a direct access to the DBMS and not the Configuration and Inventory Management subsystem, in which case an SQL API will be used.
STHS 104	**The STHS subsystem shall have the capability to assign priorities to all types of failures.**	DBMS has knowledge of the types of failures and corresponding priorities.
STHS 105	**The STHS subsystem shall maintain statistics for failures of assets.**	The statistics for the purposes of this system may be easily calculated from DBMS information, and may not require the use of extensive custom software or the use of a statistics package.
STHS 106	**The STHS subsystem shall have an operator interface.**	Provided by the Common GUI and conforms to OSF/Motif style guidelines.
STHS 106.1	The operator interface shall provide a mechanism for reporting failures to a computer display and to a printer. Reports can be sorted by types and priorities.	
STHS 106.2	The operator interface shall provide a mechanism for displaying status or state data for all monitored assets.	
STHS 106.3	The operator interface shall provide a mechanism for displaying the usage levels of all monitored assets.	

ATMS COMPONENT SIMULATIONS MODELS (AACS)

ID	REQUIREMENT AND FUNCTIONAL SPECIFICATION	IMPLEMENTATION SPECIFICATIONS
AACS 100 **partial**	**The AACS subsystem is a repository of models that simulate external data sources entering the TMC. This includes:** a. Video Data. b. Traffic Surveillance Data - loop detectors, area-wide detectors, queue length detectors, acoustic detectors, optical/infrared (image processing) detectors, bus detector, sonic, radar, light emission, etc. c. Weather and Environmental Surveillance Data - visibility detectors, fog detectors, ice detectors, precipitation (sleet, snow, rain) detectors, temperature detectors (road and air), pollution detectors. d. Trip planning data or O-D data. e. Parking Surveillance Data. f. Ground vehicle probe data. g. AVI priority data. h. Interregional traffic information from other ATMS. i. HAZMAT and Emergency vehicle routing requests. j. MAYDAY messages. k. Requests for historical information. l. The operational status of external systems. m. Environmental data including weather and pollution levels. n. Data from external systems or databases (e.g., HAZMAT). o. Signal preemption data such as vehicle location and speed. p. Incident Status reports. q. Special event plans and requests for support. r. Transit Data (e.g., bus schedules -- routes, headways, stops).	The simulation of each of the above input types will be accomplished through separate simulation models for each data stream. Some the of the models function as data generators (e.g., the simulation of a routing request). Other models are similar to finite state automata (FSA); they model a state machine, with 1 or more states; in each state a different behavior is modeled. In this case the models receive information that transition them to a new state. A loop detector simulation model, for instance, needs to know when a control plan changes so that it can model the new behavior (co-requirement with traffic simulation models).
AACS 101	**The AACS subsystem shall provide an interface to the Input Stream Processing subsystem for each of the data streams being simulated. This interface will facilitate the entrance of the raw data into the system.**	This could be provided via a TCP/IP socket or POSIX message queue.

AACS 102	**The AACS subsystem shall provide an interface into the TMC DBMS to receive any necessary data. The traffic and environmental surveillance models, for instance, will require knowledge of current control strategies/tactics/plans to accurately simulate raw data (i.e., "smart simulation," this is a co-requirement with the Traffic Simulation Modes subsystem). Likewise, the probe vehicle simulation models will ingest the routing patterns computed by the Dynamic Traffic Assignment models and will represent the responses of Probe Vehicle drivers to route guidance information in the simulated data. Also required from the database, is static network data (e.g., geometries), and configuration data (setup data that specifies the location, and type of each sensor, controller, signal head, etc.).**	This could be provided via an SQL API.
AACS 103	**The AACS subsystem will provide a graphical user interface for the user to interact with the various simulation models.**	This is supported by the Common GUI. The GUI will comply with Motif Style Guide.
AACS 103.1	The user interface shall allow a simulation scenario to be configured.	
AACS 103.1.1	The configuration of the scenario entails the selection of data streams to be simulated; and the selection of corresponding models (in cases where there is not a one-to-one mapping between a data stream and a model).	
AACS 103. 1. 1.1	For the simulation of traffic and environmental surveillance data, the operator will specify signal controller and sensor types by node.	
AACS 103.1.2	The configuration of data streams that need spatial and temporal reference will be accommodated. For instance, to simulate traffic and environmental surveillance feeds, the system will require a reference point that will map to a specific location on the analysis network (e.g., XY coordinates, or other identifiers).	
AACS 103.1.2.1	The configuration of a simulation scenario shall permit the selection of an analysis network for the purposes of simulating traffic and environmental surveillance data. The selection of a network will allow the corresponding actual configuration (types and locations of sensors) of the network to be retrieved from the TMC DBMS. Once, the configuration data is obtained, the selection of models to use will be automatic.	
AACS 103.1.3	The configuration of the scenario shall also permit the specification of any necessary run control data.	
AACS 103.1.4	The configuration of the scenario, involving environmental simulation (which includes the environmental data that could come from vehicle probes or from the simulation of environmental sensors themselves), shall permit the initial specification of environmental conditions (e.g., temperature, pollution levels, precipitation, etc.).	

AACS **103.2**	The user interface shall ingest manually entered events via an operator interface during (real-time) simulation.	
AACS 103.2.1	The operator shall be able to input a failure mode for any specified component such as a detector, a controller or communication line at any point in time.	
AACS **103.2.2**	The operator shall specify the "penetration" of Probe Vehicles, by vehicle type, as well as the information transferred between the **TMC** and the vehicle.	
AACS **103.2.3**	The operator shall specify output options of all simulated components in real time.	
AACS **103.2.3.1**	The operator shah be able to control the types of outputs from probe vehicles.	
AACS **103.2.3.2**	The operator shall select those loop detectors that will display on/off state in animation format, including calls to the controller, and those for which states condition, over time, will be accessed and archived. //Reserved//,	
AACS 103.2.3.3	The operator shall specify locations of Changeable Message Signs. //Reserved//.	
AACS **103.2.3.4**	The operator shall specify local (i.e., controller-based) processors of a distributed control architecture. (Each such controller will execute a specific algorithm) //Reserved//.	
AACS **103.2.3.5**	The operator shall specify controller-based data acquisition. fusion. and communication protocol. //Reserved//.	
AACS 103.3	The GUI shall provide displays for the simulated data for selected streams.	
AACS 103.3.1	For each simulated component, the simulator shall have an output module which provides graphical and text information to the operator. This module will include both static and animation (for probes) graphics. The animation can be provided in real time (i.e. in parallel with the simulation model's execution).	
AACS 104	**The component simulation models shall microscopically replicate, to the same level of detail as the devices themselves, their output data, structure, transmission rates, and protocol information.**	The accuracy and meaningfulness of the simulated data is a function of the level of sophistication for each model. For instance, the speed output from a loop detector might be generated a number of ways: a. Less Sophisticated - random number generator. b. Sophisticated - based off of historic or archived data for a similar context. c. More Sophisticated - based on historic data and responsive to changes in traffic control.
AACS 104.1	Depending upon the level of sophistication of the model, it should also stochastically cause certain components of the system to fail on a probabilistic **basis.**	

DYNAMIC TRAFFIC **ASSIGNMENT SUBSYSTEM (ADTA)**

ID	REQUIREMENT AND FUNCTIONAL SPECIFICATION	IMPLEMENTATION SPECIFICATIONS
ADTA 100	**ADTA shall interface with the Integrated Model Manager for Transferring data to/from other TMC support systems.The interface shall support both the stand-alone use of ADTA as well as transferring data between ADTA and other systems e.g. TWTM).**	4 traffic assignment application is spawned by the integrated Modeling Manager (AIMM), an application server. AIMM sets up the ADTA input files and processes the outputs, directing them to the client applications.
ADTA 100.1	ADTA shall transfer the computed MOE to TWTM via the Model Manager for he purpose of determining the onset or spread of congestion.	Depending on the implementation of the assignment algorithm, a direct interface to a traffic simulation program may be required.
ADTA 101*	**ADTA shall operate in a descriptive mode to perform a path-based traffic assignment of a time-dependent O-D table within the context of a prescribed scenario that represents both demand and supply characteristics. While in this mode, ADTA shall support regional requirements for network loads as well as TCS requirements of link volume projections. The primary uses of the descriptive assignment outputs are:** a. <u>Regional Level:</u> Forecasting 15 minute network loads at key interface points at TCS boundaries. The required assignment interval is a function of the size of the network. For small networks a 15minute interval is probably sufficient; for large networks, TWTM may require 30-minute, or even longer, intervals to develop long-term strategies. Evaluating potential TWTM strategies in concert with a detailed traffic simulation model. b. <u>TMC Level:</u> Developing 5-minute link volume forecasts (see above) for use by TCS control algorithms in developing the mid-term forecasts.	In a descriptive mode, ADTA solves a user optimal traffic assignment problem. Supply characteristics are an input to the process including network geometry and characteristics, as well as the control strategy. ADTA may need to support multiple levels of network abstraction. The lowest level corresponds to the representation in detailed traffic simulations. At the highest level, only major arterials and interchanges need to be modeled. ADTA shall execute at 5-minute intervals at the regional level. The update frequency requirement at the TMC for 5-minute forecasts is every 1 minute. These timing requirements will be investigated during the design phase.
ADTA 101.1	ADTA shall have the capability to automatically adjust the assignment time interval depending on prevailing conditions and the size of the network for which the assignment is being determined (note that ADTA has the capability to assign a partial O-D over a sub network).	
ADTA 101.2	Demand characteristics to be considered by ADTA include, in addition to the O-D matrix, the unique characteristics and demographics of travelers in the region which influence travel behavior. For example, ADTA should recognize multiple user classes in terms of availability of ATIS equipment and knowledge of the network.	ADTA shall model multiple user classes for each 0-D pair. User classes also reflect behavior; for example, some users may be more averse to route diversion.
ADTA 101.3	ADTA shall be able to simulate an assignment for a frequently changing O-D matrix where any node in the network can be potentially considered as an origin. That is, the origin-destination coordinates are not fixed.	

ADTA 101.4	ADTA shall provide sufficient detail for specifying the traffic control strategies being implemented, the network representation, and driver behavior to achieve an acceptable level of accuracy in the resulting assignment.	
ADTA 101.4.1	ADTA shall have the capability to simulate the driver behavior in response to the various control modes, particularly CMS and route diversion.	In the simplest case, behavior is represented by a probabilistic choice model for each user class which yields, for each event, the number of travelers responding, by response category type'. Some access control functions are modeled via the network representation. Others are reflected in the "control logic" at network nodes. The required representation depends on the function of ADTA. For developing link-specific MOE one requires a detailed representation; for developing regional loads, it is Only essential that sufficient detail be provided to capture drivers' route choices. CMS and other information dissemination functions can be modeled using "information nodes." Vehicles within the range of an information node will activate their driver behavior logic.
ADTA 101.4.2	ADTA shall employ path travel times that are consistent with Iink times derived from simulation/optimization programs being used for traffic control determination.	
ADTA 1O1.4.2.1	ADTA shall represent the full range of access control functions potentially available in a mature IVHS environment, including: a. Various traffic signal control modes. b. Ramp meters. c. CMS. d. Reversible lanes. e. HOV lanes. f. Broadcast information to vehicles via ATIS, HAR, etc.	
ADTA 101.4.2.2	ADTA shall interface with a traffic simulation model to compute various MOE used in the assignment process. The simulation model shall have the capability to simulate incident conditions, including traffic accidents, construction delays, weather, etc. The required detail in the simulation model is dependent on the ADTA function being performed. For developing network loads, the requirement is to maintain consistency of travel time calculations and maintaining certain flow constraints. For evaluating TWTM strategies one must also have the capability to represent the various control options, which requires a finer level of detail including the incorporation of individual driver behavior to specific controls (e.g., CMS message recommending diversion). It is noted that nmning a dynamic traffic assignment with a detailed simulation will meet both requirements.	ADTA 101.4.2.2 is a derived requirement which represents an implementation detail. The computation of traffic MOE could be internal to traffic assignment, although current research is not in this direction. Several traffic simulation models are candidates for consideration including CORFLO, and CORSIM. The interface between the dynamic assignment and the simulation can be of two types: a. Run assignment -> compute turn % -> simulate. b. Imbed the dynamic assignment within the simulation.
ADTA 102	**ADTA shall be capable of solving large-scale realistic networks (e.g., Los Angeles metro area) both in terms of geometric features, traffic control features, and network loading.**	Networks of this size. may commise over 5000 nodes and as many links. The processing requirement is not likely to be met by standard workstations; parallel processing and multi-computing platform architectures need to be evaluated (Mahmassani, H., et. al. <u>A Review of Dynamic Assignment in Traffic Simulation Models for ATIS/ATMS Applic</u>ations, Center for Transportation Research, University of Texas at Austin, FHWA Contract April 199 1).

ADTA 103*	**ADTA shall provide both real-time capabilities as well as support for offline evaluation activities.**	Real-time requirements are driven by need to update travel demand projections.
ADTA 103.1	ADTA shall develop a complete assignment of the full O-D matrix within the time window required by TWTM to develop a projection of link loads (15-minute projection every 5 minutes). The TWTM time window includes the time to synthesize an O-D matrix, run the assignment, and perform any subsequent manipulations /calibrations required outside the ADTA program.	
ADTA 104*	**ADTA shall support the evaluation of TWTM-developed strategies/tactics in real time and online (user in the loop) through a direct interface to a traffic simulation program for generating network and path-based MOE.**	Implementation depends on overall configuration (see ADTA 101.
ADTA 105	**ADTA shall have the capability to assign a partial O-D matrix. A partial matrix is defined as a partial set of O-D pairs. The requirement to deal with incomplete O-D data is allocated to the O-D Synthesis process.**	The partial O-D matrix defines a subnetwork over which the ODs will be assigned. In cases where any of the subnetwork links are on paths between O-D pairs which are not internal to the subnetwork, accommodations must be made. For example, a coarse O-D assignment on the full network can generate subnetwork O-D estimates (entry and exit point O-D) which can be assigned to the detailed subnetwork.
ADTA 106	**ADTA shall operate in normative mode to develop a "system optimal assignment" of the given full or partial O-D matrix.**	System optimal assignment is defined as the assignment of the O-D matrix such that the overall system-level objective (e.g., average speed, travel time) is minimized/maximized. The system optimal assignment DOES NOT involve the determination of the optimal control plan corresponding to the optimal routes. When in normative mode, one cannot imbed the traffic assignment within the traffic simulation model.
ADTA 106.1	ADTA shall have the flexibility of redefining the weights associated with the various objective function MOE including traffic and environmental.	
ADTA 106.2	ADTA shall have the flexibility to specify the "best" routes between a given O-D pair. The "best" routes will be processed by TWTM to determine routing instructions to CMS or ATIS.	
ADTA 107	ADTA shall compute path-based travel time estimates accurately to within expected travel time variation on the paths for the given traffic conditions.	This requirement is co-shared with the accuracy for the O-D processing and the overall forecasting responsibility of TWTM, which may fuse DTA data with other sources (e.g., probe data). Travel time variances will be determined during Task D.

ISSUES:

Several key performance issues relating to the ADTA Subsystem remain to be solved. These issues arc primarily related to the size of the problem to be dealt with, the level of simulation detail including the representation of driver behavior and the assignment time interval. For the purpose of this specification, we have assumed a 15-minute assignment period update; every 5 mmutes on a rolling horizon basis. It remains to be determined whether a 30-minute interval with 10-15 minute updates is sufficient for regional load determination.

Another issue deals with the synthesis of the origin-destination (O-D) matrix and the potential relationship between the ADTA Subsystem and the O-D synthesis process- For the same reason that one would interface a DTA model with traffic simulation to maintain travel time consistency,one must mamtain travel time consistency between the0-D synthesis problem and the traffic assignment problem. We have kept the two processes separate in this specification for convenience in dealing with the ADTA Subsystem as a complete package so as to increase modularity.

HISTORICAL DATA ANALYSIS (AHDA)

ID	REQUIREMENT & FUNCTIONAL SPECIFICATION	IMPLEMENTATION SPECIFICATIONS
AHDA 100	**The AHDA subsystem shall receive requests for analysis of historical data from an operator interface.**	The subsystem is likely to utilize a commercial product for performing statistical analysis (e.g., SAS). The operator defines the analysis requirement, analysis parameters, data sets via a GUI provide by the Common GUI or provided by the statistical analysis toolset (commercial product). The toolset supports various analysis and display options, including simple retrievals from the DBMS.
AHDA 100.1	The AHDA subsystem shall have the capability to schedule the generation of routine reports (such as weekly data, monthly data, etc.) in an automated fashion by providing an interface to the I/O Manager.	
AHDA 100.2	The AHDA subsystem shall have the capability to receive manual entry requests for data analysis via an operator interface.	
AHDA 100.2.1	The operator interface shall support the manual entry of required information needed to satisfy a data analysis request for this subsystem.	
AHDA 101	**The AHDA subsystem shall have the capability to interface and retrieve the necessary data (both historic and current) from the TMC DBMS through the use of queries or reports.**	The analysis toolset shall support a standard interface (e.g., SQL) to the TMC database.
AHDA 101.1	The AHDA subsystem shall have the capability to generate reports.	Reports shall be customizable by the user.
AHDA 101.2	The AHDA subsystem shall have the capability to store generated reports and corresponding query information for future retrieval and use.	Stored in either operating systems files or files maintained by the DBMS or the toolset package, but managed by this system.
AHDA 101.3	The AHDA subsystem shall have the capability to store query information (script file) that generates the results.	
AHDA 101.4	The AHDA subsystem shall have the capability to store the reports in a file.	
AHDA 101.4	The AHDA subsystem shall have the capability to retrieve the previously saved query information.	
AHDA 101.5	The AHDA subsystem shall be capable of retrieving previously stored reports from the TMC DBMS.	
AHDA 101.6	On request for a stored report, the AHDA subsystem shall have the capability of searching for the specific report (analysis file) in the DBMS.	
AHDA 101.7	The operator interface shall provide the capability for key-word search and provide alphabetical list of stored reports.	
AHDA 101.8	Support shall be provided for the user to generate reports in specified formats. Support shall be provided to modify the formats as necessary.	

AHDA 101	**The AHDA subsystem shall have the capability to perform statistical analysis as needed.**	The statistical analysis package shall have full capabilities to perform minimum, maximum, mean, median, mode, sum, standard deviation, percentiles, etc.
AHDA 103	**The AHDA subsystem shall provide an operator interface. The operator interface shall be graphical and interactive.**	The GUI will be provided by the Common GUI subsystem. If a commercial product is used it should comply with OSF/Motif style guidelines.
AHDA 103.1	The operator interface shall support the manual entry of requests for historic data. The entry shall include the fields that completely specify the request.	
AHDA 103.2	The operator interface shall support selection of appropriate report format.	
4HDA 103.2.1	The operator interface shall support selection of predefined report formats from a menu.	
4HDA 103.2.2	The operator interface shah support creation and modification of report formats graphically and/or from a menu.	
AHDA **103.3**	The operator interface shall support hard copy printout of reports.	
AHDA 104	**The AHDA subsystem shall provide a system interface to the** I/O **Manager for scheduling dissemination of the report to the appropriate entity.**	An event entity and a time will be provided to the I/O Manager, via an API (TCP/IP or POSIX message queues). The event ID will later be used to recall the corresponding report to be generated and transmitted to the appropriate locations at the requested time. Note: The I/O manager schedule data to be output to external agencies and processes to be run.
AHDA 105	**The AHDA subsystem shall provide a system interface to the I/O Manager for scheduling regular reports that need to be generated by this subsystem. This could involve reports that need statistical analysis and user control and/or input.**	Provided by an application API. POSIX message queues or TCP/IP sockets can be used. For applications that require user input control, an alarm shall be sent to the GUI.
AHDA 106	**The AHDA subsystem shall provide a system interface to the Data Validation for storing the generated reports in the TMC DBMS.**	Provided via an API with the DBMS (e.g., SQL).

INTEGRATED MODELING MANAGER (AIMM)

ID	REQUIREMENT & FUNCTIONAL SPECIFICATION	IMPLEMENTATION SPECIFICATIONS
AIMM 100	**AIMM shall manage all models included within the ATMS. It will manage all inputs and outputs from each model. This includes collecting and formatting data so that it is compatible with what is expected by the various models, and vice versa. This is a necessary and desirable function to provide, since most of the models have already been developed or will be revised for IVHS compatibility.**	AIMM overall software architecture is that of a server which receives requests from various TMC applications (e.g., TWTM). The request includes the definition of the model to be executed and sufficient data to define a modeling scenario. This may be in the form of direct data transfer of data and control parameter values as well as pointers to database files containing the necessary data. AIMM's function is to construct the input files, execute and monitor the program, reformat the outputs as per the requesting applications requirements and respond with the results. Part of the server process may also include prompting for needed user inputs. A more intelligent version of AIMM would have it determine the appropriate model(s) based on the evaluation requirement.
AIMM 100.1	AIMM shall manage the interface to all Traffic Simulation models. This includes all of the macroscopic and microscopic level models.	It is presumed that many of the models do not have standard data formats.
AIMM 100.2	AIMM shall manage the interface to the Signal and Control Optimization models.	When running a series of models, AIMM will manage the data transfer in memory. In cases where the data formats of the models do not coincide, AIMM will undertake the necessary conversion.
AIMM 100.3	AIMM shall manage the interface to the Dynamic Traffic Assignment model.	Dynamic traffic assignment, although it is a simulation/optimization model, is considered separately since it comprises a distinct support system.
AIMM **100.4**	AIMM shall transfer data between various models.	
AIMM 101	**AIMM shall obtain the necessary model inputs from the TMC DBMS. This includes static network data (i.e., geometries), incident data, real-time surveillance or traffic state data (link speeds/volumes, link turning volumes, parking capacities by location, etc.), suggested routing information, O-D data or tables, transit schedules and data, environmental data (rain, snow, fog, icy pavements, temperature, pollution varying both spatially and temporally), vehicle classes and composition, and current traffic control strategies/tactics/plans (current strategies/tactics/plans for signals, CMS, HAR), and archived or historic data.**	The DBMS will contain most data needed by the various models. AIMM shall extract the data using SQL queries and reformat in the required input file format for the models. Non-DBMS data processed by AIMM includes data that is input by the operator (e.g., scenario data) or data passed from client applications (e.g., TWTM control strategy).

AIMM 102	**AIMM shall support a GUI to support the interaction between the user and the various models. The GUI shall support entering and displaying data.**	The User Interface will Drovide all capabilities supported by the Common GUI. Additional capabilities include those based-on spatial queries supported by the GIS. For example, on the MTEM network display, the user can graphically indicate the area for which a strategy is being developed or tested. The network 'objects" within the selected area constitute the subnetwork to be modeled.
AIMM 102.1	The GUI shall support the capability to allow the operator to define a scenario. A scenario will capture the size and scope of the analysis network, the control input data, the surveillance input data, traffic flow input data, traffic composition, etc. The input data may be real-time data or archived/historic data. A scenario shall facilitate the configuring of the system prior to executing any simulation or modeling. This includes defining which input data will be used, as well as describing the run control data (including execution speeds -- real-time and hyper real-time variability). This subsystem shall also support dynamic (interactive) changes to the configuration during run-time.	Components of each scenario can be defined automatically via an interface to the TTCS, TWTM subsystems.
AIMM 102.1.1	The GUI shall permit the user to interactively change the simulation environment as execution proceeds (e.g., to introduce/remove a lane closure, incident, surveillance anomaly, special event, maintenance event, etc. anywhere in the analysis network).	Current simulation model(s) will need to be enhanced to accommodate this requirement. AIMM shall process an interrupt from the User Interface. An interrupt variable set by AIMM is monitored by the simulation and when set, causes the program to go into a state awaiting user input.
AIMM 102.1.2	The GUI shall permit storing and retrieval of predefmed configurations {scenarios) and associated outputs. Case histories will be maintained for faster online access times.	Predefined scenarios can include fixed timing plans or other control strategies.
AIMM 102.2	The GUI shall support the capability to display output data in various forms. The level of detail and the format shall be tailorable by the user. The output can be graphical or alphanumeric and shall be sent to either the GUI or to a file.	For animation displays, two implementations are possible: real-time and post simulation time. In the latter case, trajectory positions of each vehicle will be stored during the simulation so that interpolations can be performed to present an animation display. If the simulation can be run faster than real time, the second option is preferred since one has the capability to speed up or slow down the animation as needed.
AIMM 102.3	The GUI shall support Operator functions to create, store, and print reports.	This requirement can be implemented using DBMS report generation functions. AIMM will support the transfer of simulation outputs to the DBMS from where it can be retrieved for reporting purposes (see AIMM 103).
AIMM 102.3.1	The report capability shall support the capability for pre-defining reports.	
AIMM 102.3.2	The report capability shall support the capability for predefining file formats for interfacing with other components.	
AIMM 103	**AIMM shall provide a TMC DBMS interface to load analysis and modeling. This may involve an additional interface to the Data Validation subsystem.**	AIMM shall process the simulation output file, extract the data of interest and load the TMC DBMS in accordance with the DBMS data model. AIMM shall access data validation routines prior to loading. Level 1 and 2 validation that is performed by the DBMS will be done automatically.

AIMM 103.1	AIMM shall support the capability to archive simulation output data. The user shall have the capability to specify at run time whether the data is to be archived.	Overall archiving requirement defined at setup time and supported by the DBMS. Runtime "save" declared by the operator through the user interface.
AIMM 104*	**AIMM shall provide an electronic system interface to the Traffic Control subsystem.**	In automated mode, when a request is received, a complete scenario is built from data in the DBMS, and data received as part of the request.
AIMM 104.1	The interface shall receive requests for the evaluation a potential control strategy/tactic/plan from the Traffic Control subsystem.	The scenario building routine may prompt the user for additional data as needed.
AIMM 104.2	The interface shall provide support to receive requests for the determination of optimized control strategy/tactic/plans from the Traffic Control subsystem **(e.g., TRANSYT). //Reserved** //.	The execution of signal control optimization may, depending on implementation, be allocated to the Traffic Control Subsystem.
AIMM 104.3	The interface shall return MOE or optimized control tactics/plans to the Traffic Control subsystem.	
AIMM 105*	**AIMM shall provide an electronic system interface to the Wide Area Traffic Management subsystem.**	(See AIMM 104)
AIMM 105.1	The interface shall receive requests for the evaluation of a potential wide area control strategy/tactic/plan from the Wide Area Traffic Management subsystem.	
AIMM 105.2	The interface shall return MOE or optimized control tactics/plans to the Wide Area Traffic Management subsystem.	
AIMM 106*	**The AIMM server shall be capable of meeting online operator requirements as well as real-time constraints for strategy development and evaluation.**	AIMM shall support online planning requirements which may be employed by the traffic engineer in interactively developing and evaluating traffic management strategies in a non time-critical mode. When developing and evaluating strategies for real-time implementation, AIMM functions in a time-critical mode. In this mode, timing constraints are imposed on the model runs to meet the overall strategy implementation schedule. For example, if demand projections are updated every 5 minutes, AIMM must have the capability to prioritize its processes (and resources) to meet that requirement.
AIMM 107	**AIMM shall provide an interface to a statistical analysis package for use in post simulation analysis. This package shall provide graphing, plotting, and display of traffic data in multiple formats.**	If the user wishes to transfer simulation outputs to a statistical analysis package or other drawing program, that option is available in the AIMM user interface. Three implementation options are considered: client-server where AIMM is the client to the statistical application, file transfer (similar to import facilities in MAC and DOS environments), and DBMS exchange (covered under AIMM 103).

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AIMM 108	**AIMM shall have the capability to process multiple client evaluation requests. Requests can be of two general types:** a. Evaluation of multiple strategies for a given subnetwork. b. Evaluation of strategies for multiple subnetworks.	Each evaluation request may consist of a single model run or a sequence of several models. For example, a route diversion evaluation may consist of a traffic assignment model run followed by a detailed traffic simulation model run to evaluate the computed routes. Multiple simulation runs are likely to require significant memory and processing power. Two implementation options are possible, one using a multiprocessor, the other based on multi-computing. For example, NETSIM can run on one machine, DTA on another. In this configuration the AIMM is distributed and must provide the added functionality of managing the distributed resources.
AIMM 109	**AIMM shall have the capability to run selected model(s) automatically or on a regular basis.**	Certain models, such as DTA, may need to be run on a regular schedule. The scheduling process is a function of the I/O Manager which in this case becomes a client to AIMM. Other cases include those in which a given model is run regularly to evaluate selected strategies developed by TWTM or TTCS. The current design has the client application specifying the model to be run.

ORIGIN-DESTINATION PROCESSING SUBSYSTEM (AODP)

ID	REQUIREMENT & FUNCTIONAL SPECIFICATION	IMPLEMENTATION SPECIFICATIONS
AODP 100	**AODP shall interface with the Integrated Modeling Manager for transferring data to other TMC support systems. The interface shall support both the stand-alone use of AODP as well as transferring data between AODP and other systems (e.g., Dynamic Traffic Assignment).**	AODP is one of the models being managed by the AIMM (see AIMM specifications). Within that software architecture, the transfer of data between models may be through the DBMS, or may be entirely in memory.
AODP 101	**AODP shall synthesize an AODP matrix using real-time traffic data. The data sources available for AODP synthesis include:** a. Real-time link volumes computed by MTEM. b. Information collected from ATIS and ETTM (both current and forecasted). c. Historical origin-destination and link volume information.	The origin-destination synthesis process may be based on a mathematical programming formulation (e.g., linear programming) whose objective function represents deviations between observed link volumes and those predicted by the implicit assignment in the synthesis process.
AODP 101.1	AODP shall have the flexibility to develop a partial AODP matrix for portions of the regional network.	Partial origin-destination information can be factored based on historical and actual data and built into the formulation via the constraints.
AODP 102	**AODP shall have the capability to forecast the synthesized AODP matrix over the assignment period required by dynamic traffic assignment, currently assumed to be 15 minutes.**	The synthesized origin-destination matrix can be factored by some overall TOD factor or by O-D pair-dependent TOD factors. The TOD factor may in turn be computed based on a comparison of the current matrix with historical matrices. The forecasting process must incorporate information on future origin destinations received from ATIS.
A0DP 103	**AODP shall provide both real-time capabilities as well as support for offline evaluation activities.**	(See timing requirements for ADTA.)
A0DP 103.1	AODP shall be able to synthesize an AODP matrix within the time window required by TWTM to develop a projection of link loads (15-minute projection every 5 minutes). [see ADTA 103.11	
A0DP 104	**AODP shall maintain path travel time consistency with traffic assignment in ADTA.**	The origin-destination synthesis and traffic assignment processes can be integrated over a given assignment interval or coupled. In the former case, convergence of the entire process is sought within a single run of the synthesis-assignment process. In the latter case, the results of one period are used as input to the process in the following period (see details text description of AODP).

AODP 105*	**The AODP synthesis process shall be self-calibrating. Short-term calibration, if possible, should be done in real time; low-term calibration of parameters can be done offline.**	The notion of calibration is to evaluate the accuracy of the forecasts developed by ADTA and use these results to modify the AODP model behavior through parameter adjustment.
AODP 105.1	The synthesis process should be sufficiently accurate to meet the overall accuracy requirements for link volume projections imposed on ADTA.	

ISSUES:

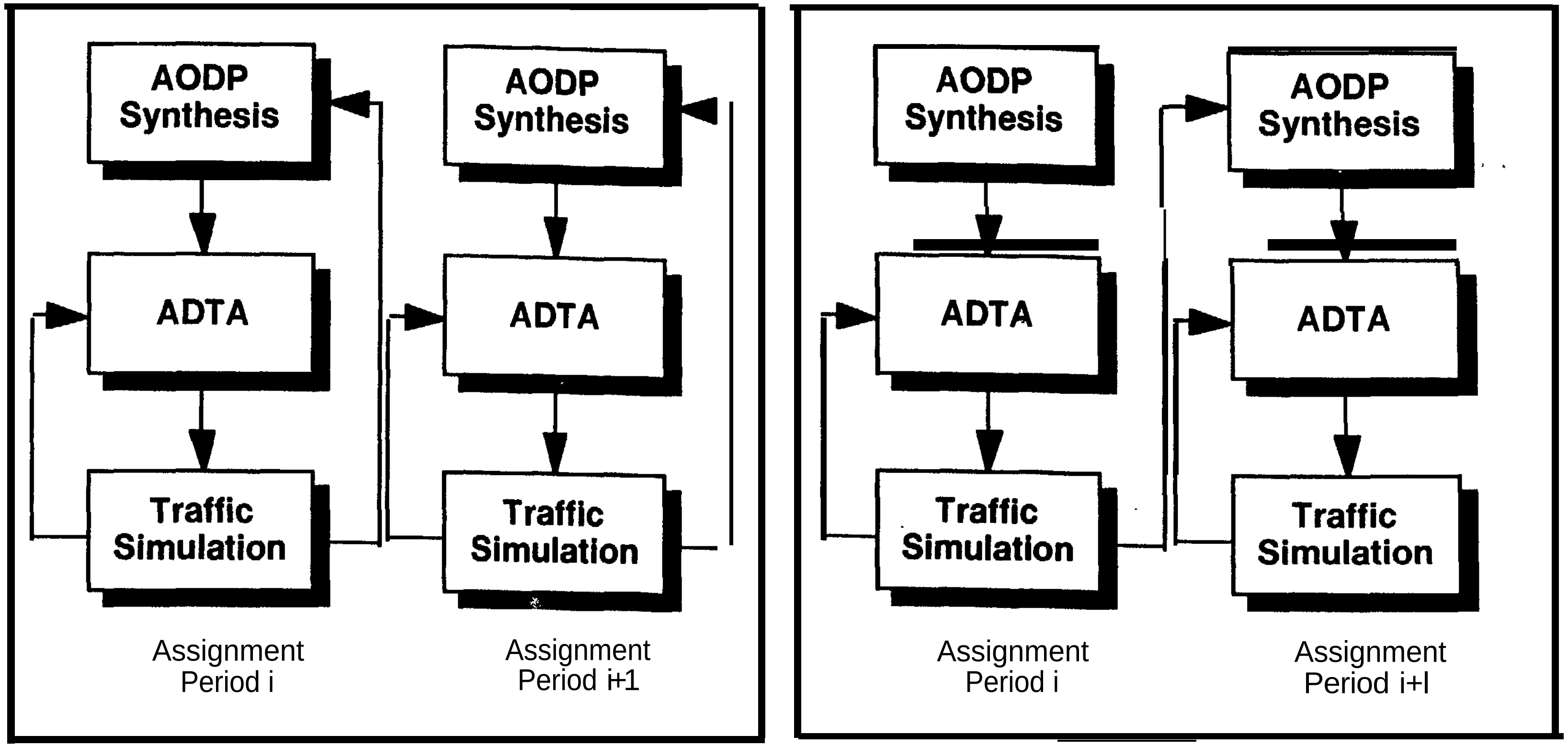
The synthesis process, which essentially solves the inverse of the traffic assignment problem, can employ a variety of model formulations as have been reported m the hterature. Real-time O-D data potentially available through the various ATIS sources must be accommodated m the various formulations. Several issues remain to be solved vis-a-vis the O-D processing, including:

a. Maintaining travel time consistency with the Dynamic Traffic Assignment Subsystem.

b. Forecasting O-D flows for the assignment period of 15-30 minutes.

c. Calibrating the process using all available real-time information.

Item (a) above, has been alluded to in the text. The issue derives from the fact that the O-D synthes is process implicitly performs an assignment of the orgin-destination pairs to the traffic network. That assignment is based on some assumed travel time function, even in the simplest case where a shortest route algorithm is used. The dynamic assignment, which follows, generates updated travel times which may be inconsistent with those assumed in O-D processing. One approach to the problem involves iteration between the AODP and Dynamic Traffic Assignment (ADTA) Subsystems, but this would introduce performance penalties which may not be acceptable. Figure A- 1 illustrates an incremental adjustment process which, while not guaranteed to be absolutely consistent, may produce sufficiently good results. These and other approaches need to be evaluated.



Fully integrated AODP and ADTA

Coupled AODP and ADTA

Legend

ADTA - Dynamic Traffic Assignment
AODB - Origin-Destination Processing

Figure A-I. Incremental Adjustment Process

Issue (b) is applicable to both the AODP and ADTA Subsystems, and deals with the required assignment period which is a function of the size of the network (see discussion in ADTA Specification).

Finally, when attempting to calibrate the O-D processing, one must use the link volume prediction errors. To support this capability, the O-D processor must be based on a model formulation which is parameterized in terms of these prediction errors. Figure A-2 illustrates an integrated O-D synthesis and assignment process with calibration.

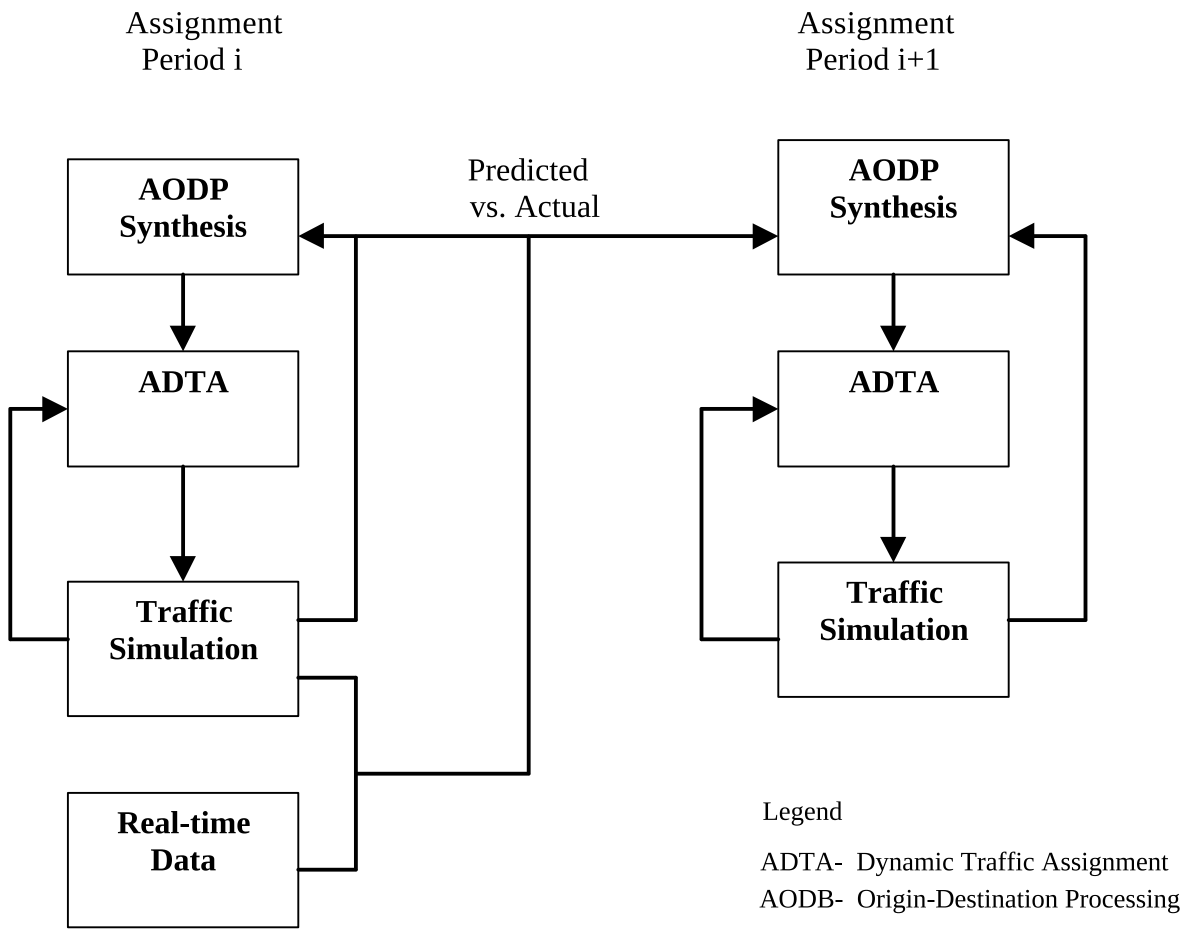


Figure A-2. Integrated O-D Synthesis and Assignment Process

SIGNAL AND CONTROL OPTIMIZATION MODELS (ASCO)

ID	REQUIREMENT & FUNCTIONAL SPECIFICATION	IMPLEMENTATION SPECIFICATIONS
ASCO 100	**The ASCO subsystem is a repository of independent signal and control optimization models for subnetwork, network, and regional level, including both freeways and surface streets (e.g., TRANSYT, PASSER II, SIGOP III, SOAP, MAXBAND). The execution of each of the models is controlled by the Integrated Modeling Manager.**	Each model in the library is a program, one or more simultaneous copies of which can be executed by the Integrated Modeling Manager. All the models in the library are presumed available through FHWA.
ASCO 100.1	ASCO shall support various levels of fidelity as well as model scope. Included are microscopic, macroscopic, and mesoscopic models.	Some of the models in this library are integrated optimization-simulation models. The classification is unimportant. Note that Dynamic Traffic Assignment is considered separately from this subsystem.
ASCO 101	**ASCO shall obtain each model's necessary inputs through an interface to the AIMM. Input data includes:** a. Data directly from the TMC DBMS - static network data (i.e. geometries), incident data, real-time surveillance or traffic state data (link speeds/volumes, turning volumes, parking capacities by location, etc.), suggested routing information, AODP data or tables, transit schedules and data, environmental data (rain, snow, fog, icy pavements, temperature, pollution varying both spatially and temporally), vehicle classes and composition. b. Data from the User Interface - scenario definition data (size and scope of the analysis network, the surveillance input data, traffic flow input data, traffic composition, etc.), run control data, events (modify traffic demand on any entry link, modify turning movements on internal links, failure inputs for any specified component such as a detector, a controller or communication line, change control tactics/plans), etc. This data may come initially at startup (scenario configuration) or dynamically during run-time.	It is presumed for this specification that each model's data structures do not necessarily correspond to the DBMS schema. All data needed by the models will be extracted from the DBMS and formatted in accordance with the required input file formats.
ASCO 102	**ASCO shall produce a wide array of information that shall be stored in the TMC DBMS for use by real-time, online, and offline applications. The outputs will be made available to applications via the TMC DBMS. These inputs will also be made available as outputs to the user via the Integrated Modeling Manager.**	(See specifications for AIMM). Note that in some cases direct transfer of data between models is possible.
ASCO 102.1	The ASCO subsystem shall provide optimal control plans and corresponding Measures of Effectiveness (MOE - statistics describing traffic operations at a high level of detail) on each network link and for each network node.	
ASCO 102.2	The ASCO subsystem shall provide aggregates of these statistics, in accordance with user specifications, over subnetworks and network-wide.	

ASCO 103*	**ASCO shall support the real-time/online Traffic Management activities of the TMC as well as the offline activities.**	
ASCO 103.1	ASCO shall ingest information provided by the Wide Area Traffic Management (TWTM) subsystem which defines the scenario to be used to develop the optimal strategy/tactic/plan. This flow of information is managed by AIMM.	It is not likely that "optimal" wide-area control can be determined in the same sense that network signal control is computed. The models that show the most promise are those which integrate travel demand with route and signal optimization.
ASCO 103.2	ASCO shall ingest information provided by the Traffic Control subsystem which defines the scenario to be used to develop the optimal strategy/tactic/plan. This flow of information is managed by AIMM.	This requirement represents the online use of the models for determining network signal plans or ramp metering strategies.
ASCO 103.3	The models shall be able to execute 15-30 times faster than real time to meet the real-time requirement of the traffic control system (not all models have the same performance requirements).	The allocation of signal optimization models which are used in real-time as part of the Traffic Control System (e.g., TRANSYT as part of SCOOT) to ASCO is an implementation consideration which depends on the overall configuration of the control system software as well as on the performance of AIMM and ASCO. The present specification leaves that issue open.
ASCO 103.3.1	The ASCO subsystem shall have an interface module that shall transform the information provided by the model to the traffic control software, into a format which is compatible with the control software database.	

TRAFFIC SIMULATION MODELS (ATSM)

ID	REQUIREMENT & FUNCTIONAL SPECIFICATIONS	IMPLEMENTATION SPECIFICATIONS
ATSM 100	**The ATSM subsystem is a repository of independent traffic simulation models for subnetwork, network, and region level, including both freeways and surface streets (e.g.,** TRAF). The **execution of each of the models is controlled by the Integrated Modeling Manager.**	**(See** ASCO 100.)
ATSM 100.1	ATSM shall support various levels of fidelity as well as model scope. Included are microscopic, macroscopic, and mesoscopic models.	(See requirement for dynamic traffic assignment.)
ATSM 101	**ATSM shall obtain each model's necessary inputs through an interface to AIMM. Input data includes:** a. ~~Data directly from the TMC DBMS~~ - static network data (i.e., geometries), incident data, real-time surveillance or traffic state data (link speeds/volumes, link turning volumes, parking capacities by location, etc.), suggested routing information, TTCS data or tables, transit schedules and data, environmental data (rain, snow, fog, icy pavements, temperture pollution varying both spatially and temporally), vehicle classes and composition, and current traffic control strategies/tactics/plans (current strategies/tactics/plans for signals, CMS, HAR). b. Data from the User Interface - scenario definition data (size and scope of the analysis network, the control input data, the surveillance input data, traffic flow input data, traffic composition, etc.), run control data, events (modify traffic demand on any entry link, modify turning movements on internal links, failure inputs for any specified component such as a detector, a controller or communication line, change control tactics/plans), etc. This data may come initially at startup (scenario configuration) or dynamically during run-time.	Current models are not capable of using/ processing all the data items listed and would require various enhancements (e.g., weather data as effecting car-following model, discharge headway, free flow speed). Many of the required enhancements deal with the need to simulate the full range of IVHS information dissemination capabilities whose influence on driver behavior must be represented (e.g., route guidance, CMS, HAR). The largest obstacle relates to the need to represent both demand and control within the same model framework and to deal with metropolitan-size networks. Other current contracts with FHWA may address this requirement.
ATSM 102	**ATSM shall produce a wide array of information that shall be stored in the TMC DBMS for use by real-time, online, and offline applications. The outputs will be made available to applications via the TMC DBMS. These inputs will also be made available as outputs to the user via the Integrated Modeling Manager.**	**(See** ASCO 102.)
ATSM 102.1	ATSM shall provide Measures of Effectiveness (MOE - statistics describing traffic operations at a high level of detail) on each network link and for each network node.	
ATSM **102.2**	ATSM shall provide aggregates of these statistics, in accordance with user specifications, over subnetworks and network-wide.	

ATSM 102.3	ATSM shall produce vehicle trajectory data at one-second intervals, to be output to the TMC DBMS.	
ATSM 102.4	ATSM shall provide a history of control actions (e.g., phase durations and sequences, cycle length, offset) over time.	
ATSM 102.5	ATSM shall have an inlerface module that shall transform the information provided by the simulation model to the traffic control software, into a format which is compatible with the control software data base. //Reserved//.	This requirement supports the potential capability of the traffic control system to use simulations in real time to define control strategies.
ATSM 103*	**ATSM shall support the real-time/online Traffic Management activities of the TMC as well as the offline activities.**	(See ASCO 103.)
ATSM 103.1	ATSM shall receive information provided by the Wide Area Traffic Management subsystem which defines the scenario and management strategy/tactic/plan to be evaluated. The flow of information is managed by AIMM.	
ATSM 103.2	ATSM shall receive information provided by the Traffic Control subsystem which defines the scenario and management strategy/tactic/plan to be evaluated. The flow of information is managed by AIMM.	
ATSM 103.3	The models shall be able to execute 15-30 times faster than real time to meet the timing requirements for developing and evaluating strategies (not all models have the same performance requirements).	

APPENDIX B

ATMS FUNCTIONAL INTERFACE AND GENERIC REQUIREMENTS (BASELINE VERSION 2.1)

APPENDIX B

ATMS FUNCTIONAL INTERFACE AND GENERIC REQUIREMENTS

(BASELINE VERSION 2.1)

B.l Overview

The following functions represent basic requirements as derived from the ATMS objectives, as well as requirements imposed upon ATMS by external entities (see Figure B-l). These requirements have been carried over and updated from an earlier report (Task B - ATMS Concept of Operations and Generic System Requirements). Note that changes to requirements are reflected with change bars along the right hand margin. These requirements represent the baseline requirements for the ATMS system, and are thus under configuration control. For further information, a requirements change matrix is located at the end of this section (refer to Table B-3).

The requirements presented here set the foundation for the specific requirements that will be developed for each of the proposed ATMS Support Systems. Each Support System will provide high-level traceability back to these ATMS requirements.

Requirements traceability will be facilitated through the following numbering scheme. First, there is a 4-character identifier to designate the source of the requirement. After the identifier is a numeric designator used to signify the level of the requirement. Table B-l provides a mapping between identifiers and requirements sources.

Note: Requirements with an asterisk after the identifier are anticipated to be long-term ATMS requirements (i.e., met in 2002 not 1997).

Table B-l. Requirements Identifier Mapping

Identifier	Requirements Source
ATMS	Derived from ATMS Objectives
ATIS	Advanced Traveler Information Systems
APTS	Advanced Public Transit Systems
CVO	Commercial Vehicle Operations
AVCS	Advanced Vehicle Control Systems
NWS	Weather
NADB	National Databases
IVHS	Intelligent Vehicle Highway Systems
EMER	Emergency Response
TRAN	Transportation Departments
LAW	Law Enforcement

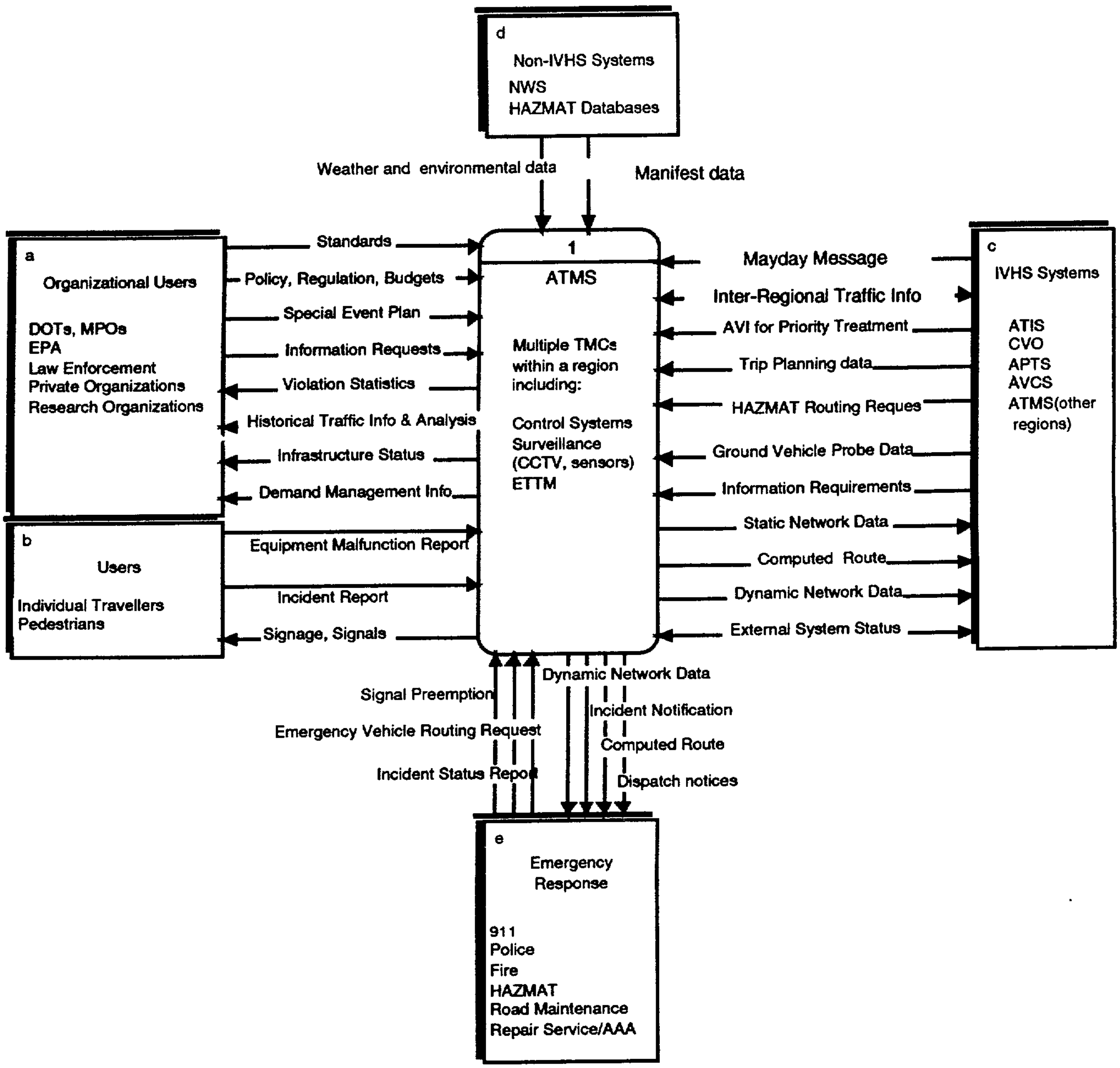


Figure B-1. The ATMS Context Level Diagram

B.l ATMS Derived Requirements

ATMS collects data from various sensor types, probe vehicles, and other sources (e.g., toll collection data) to identify traffic infrastructure conditions.

ATMS 1	ATMS shall collect surveillance data from various sources.
ATMS 1.1	ATMS shall ingest data from point detectors, video, probe, environmental, and voice data.
ATMS 1.2	ATMS shall validate received data. This capability includes range and limit checking.
ATMS 1.3	ATMS shall check data integrity. This capability includes verifying that received data is consistent with the transmitted data.
ATMS 1.4	ATMS shah fuse received data into a common format.
ATMS 1.5	ATMS shall support both long- and short-term data archives.
ATMS 1.6	ATMS shall detect communication and equipment failures.

Based upon data received from various types of infrastructure and environmental sensors, probe vehicles, and other sources, ATMS shall identify and categorize traffic and infrastructure (roadways and other elements of the environment in which vehicles are traveling) conditions. This includes the capability to determine when conditions are normal/abnormal based upon day and time. In the event conditions are abnormal, ATMS shall determine the nature of the abnormality.

ATMS 2	ATMS shall identify and categorize traffic network and infrastructure conditions.
ATMS 2.1	ATMS shall determine derived traffic performance parameters (Level 1 data, which includes determining abnormalities in traffic; e.g., abnormal link speed; abnormal queue-length).
ATMS 2.2	ATMS shall identify and classify traffic conditions, such as recurrent congestion, non-recurrent congestion (Level 2 data, which includes classifications).

Based upon conditions of the traffic network and supporting infrastructure (refer to ATMS 1 and 2), ATMS shall develop and implement traffic control techniques that are both adaptive and predictive. Adaptive techniques allow for adjusting traffic control methods dynamically in real time in response to changing traffic patterns and demands as they occur. Predictive techniques allow for adjusting control methods in response to predicted traffic patterns and demands. Traffic control methods are primarily traffic signal timing strategies, but also include CMS; variable access restrictions; and variable lane use and turn movement restrictions. Other control techniques include dissemination of traveler information providing route selection and route guidance instructions designed to optimize performance of the overall traffic network.

ATMS 3	ATMS shall perform adaptive and predictive strategy traffic control.
ATMS 3.1	ATMS shall develop traffic flow predictions using current conditions, historical data, and O-D data.
ATMS 3.2	ATMS shall assess effectiveness of system in responding to the predicted flow conditions.
ATMS 3.3	ATMS shall generate alternative control strategies based on actual and predicted traffic network conditions.
ATMS 3.4	ATMS shall evaluate alternative control strategies.
ATMS 3.5	ATMS shall implement selected traffic control strategies.
ATMS 3.6	ATMS shall disseminate traffic control information to necessary field components.

Through monitoring traffic and the traffic infrastructure (refer to ATMS 1 and 2) ATMS will be capable of detecting incidents and responding with an effective approach to manage the resolution of the incident in the shortest time, with the least impact to traffic throughput. Consideration for the safety of incident victims and others on the affected roadways is also considered in the incident response. An incident is defined as any non-normal occurrence affecting or having the potential to affect the traffic network's performance. Thus, an incident could involve vehicular traffic directly, such as a collision between vehicles on the roadway, or indirectly as an occurrence in the traffic infrastructure, such as a fallen rock on the roadway. Incident Management will analyze the conditions caused by the incident and employ appropriate traffic control strategies to resolve the incident and restore the network to normal conditions (refer to ATMS 3).

ATMS 4	ATMS shall perform incident detection and management.
ATMS 4.1	ATMS shall detect incidents. Most incidents are defined as unanticipated events resulting in a reduction of capacity or an increase in congestion. Another type of incident that ATMS will detect is an accident under low-volume conditions, which is not readily detectable from traffic flow rates.
ATMS 4.2	ATMS shall classify incidents in terms of traffic network impact, incident seriousness, and human safety.
ATMS 4.3	ATMS shall determine the initial emergency response plan.
ATMS 4.4	ATMS shall contact and coordinate emergency response.
ATMS 4.5	ATMS shall predict incident duration.

ATMS 4.6	ATMS shall predict the impact of the incident on traffic conditions.
ATMS 4.7	ATMS shall determine strategies for responsive traffic control.
ATMS 4.8	ATMS shall evaluate strategies.
ATMS 4.9	ATMS shall implement strategies.
ATMS 4.10	ATMS shall receive and process incident status reports and update response plans.
ATMS 4.11	ATMS shall provide route selection for emergency vehicles.
ATMS 4.12	ATMS shall track emergency vehicles enroute for coordinated signal preemption.
ATMS 4.13	ATMS shall provide estimates of the likelihood of incidents, based on historical data, time of day, location and current environmental and traffic conditions. The estimations will be specific to roadway segments, and differentiated by type, likelihood, location, and severity of the potential incident.

ATMS will manage demand upon the roadways to optimize the performance of the overall traffic network system. Demand management strategies include the ability to employ traffic control techniques (refer to ATMS 3) based upon monitored conditions of traffic and of the traffic infrastructure (refer to ATMS 1 and ATMS 2) with the specific objective of influencing driver behavior to adjust demand.

ATMS 5 — ATMS shall perform demand management.

ATMS 5.1 — ATMS shall determine the need to influence demand.

ATMS 5.2 — ATMS shall develop an integrated traffic control strategy comprising a demand management component consisting of:

a. Route selection.

b. Integrated control strategies implemented with signals, CMS, ramp meters, HOV enforcement, vehicle restriction, etc.

c. Providing environmental and traffic data to external organizations so that actual demand management strategies can be developed (e.g., HOV lanes, congestion pricing, toll pricing, etc.)

ATMS 5.3 — ATMS shall implement control strategies?

ATMS 5.4 — ATMS shall disseminate traveler information (historical data, demand information) to External Systems.

ATMS will maintain static data on the capacity and location of parking facilities and dynamic data on the usage and availability of parking resources as monitored in real time. A more advanced version will predict traffic resource availability based upon traffic and the traffic infrastructure monitoring. ATMS will disseminate these data through ATIS and APTS elements, as well as through Traffic Advisories, to optimize the availability of parking resources to satisfy both individual travelers and transit operators. Individual travelers will use parking information to complete a trip as efficiently as possible, minimizing time wasted on roadways after driving to full facilities. Transit operators will use this capability to achieve efficient modal transitions (i.e., park the car and board the subway). Parking facility information is also important to event management (refer to ATMS 8).

ATMS 6* ATMS shall manage the dissemination of parking information.

ATMS 6.1 ATMS shall monitor parking usage data.

ATMS 6.2 ATMS shall capture parking goals from trip planning data.

ATMS 6.3 ATMS shall predict parking availability.

ATMS 6.4 ATMS shall disseminate parking availability data to External Systems.

ATMS will coordinate with the planners and implementors of infrastructure construction and maintenance activities to minimize the impact of these activities on traffic flow. ATMS techniques will include scheduling construction activities at times when impact to traffic is minimized and traffic control techniques (refer to ATMS 3) appropriate to construction activities.

ATMS 7 ATMS shall manage the impact of construction activities upon the traffic network.

ATMS 7.1 ATMS shall receive construction plans.

ATMS 7.2 ATMS shall evaluate the impact to traffic conditions.

ATMS 7.3 ATMS shall coordinate with construction planners to revise plans and project schedules as indicated by traffic evaluation.

ATMS 7.4 ATMS shall develop temporary revisions to traffic control procedures and strategies as needed.

ATMS 7.5 ATMS shall implement traffic management strategies.

ATMS will coordinate with the planners and implementors of planned special events that are expected to have a significant effect upon traffic to minimize the impact of these activities on traffic flow. ATMS techniques include the scheduling of events at times when impact to traffic is reduced (when this is possible), and traffic control techniques (refer to ATMS 3) appropriate to the event and the anticipated effect upon traffic.

ATMS 8 ATMS shall manage the impact of planned events (conventions, parades, etc.) upon the traffic network.

ATMS 8.1 ATMS shall receive event plans.

ATMS 8.2 Evaluate the impact to traffic conditions.

ATMS 8.3 ATMS shall coordinate with event planners to revise plans and event schedules (as feasible) as indicated by traffic evaluation.

ATMS 8.4 ATMS shall develop temporary revisions to traffic control procedures and strategies as needed.

ATMS 8.5 ATMS shall implement traffic management strategies.

ATIS, ARTS, CVO, and AVCS require the exchange of basic information to accomplish an integrated system approach for IVHS. The information components exchanged are primarily static and dynamic traffic data and traffic infrastructure information.

ATMS 9 ATMS shall perform information management and dissemination to support the integrated operation of all IVHS segments.

ATMS 9.1 ATMS shall disseminate the following data to ATIS, ARTS, CVO, and AVCS elements, and to other regional ATMS entities:

a. Real-time Level 1 traffic information (i.e., traffic abnormalities identified).

b. Real-time Level 2 traffic information (i.e., traffic abnormalities categorized and quantified).

c. Static and dynamic network data (e.g., geometries, roadway environmental conditions, etc.).

d. Historical Level 1 and 2 traffic information.

ATMS 9.2 ATMS shall respond to *ad* hoc requests for traffic network status data and impending planned special events and construction activities.

ATMS requires self-sustaining functions that include the ability to monitor its own internal systems and interfaces, identifying when subsystem components require regular maintenance as well as identifying and suggesting solutions for system malfunctions. This capability will also monitor the actions of ATMS operators, automatically providing operator aid when needed. These system management capabilities will contribute to the objective for an inexpensive system to operate and maintain.

ATMS 10 ATMS shall provide a self-sustaining capability, automatically monitoring the performance of ATMS.

ATMS 10.1	ATMS shall monitor status data.
ATMS 10.2	ATMS shall identify system faults.
ATMS 10.3	ATMS shall determine remedies.
ATMS 10.4	ATMS shall fix system faults.
ATMS 10.5	ATMS shall schedule and perform preventive maintenanc
ATMS 10.6	ATMS shall monitor operator inputs.
ATMS 10.7	ATMS shall support operator performance enhancements.
ATMS 10.8	ATMS shall schedule and respond to equipment malfuncton notices.
ATMS 10.9	ATMS shall schedule and respond to roadway malfunction notices.
ATMS 10.10	ATMS shall manage the configuration of all assets,

ATMS requires the capability to communicate with both IVHS and non-IVHS entities for the purpose of wide-area traffic control.

ATMS 11	ATMS shall provide capabilities to support information exchange within an ATMS entity. This includes necessary communications for TMC-to-TMC data exchange, where each TMC is in the same ATMS region.
ATMS 11.1	ATMS shall disseminate traffic management information within an ATMS entity as indicated by agreed upon Memorandum of Understanding (MOU).
ATMS 11.2	ATMS shall receive traffic management information from inter-regional ATMS entities.
ATMS I 1.3	ATMS shall adjust traffic management strategies as appropriate.
ATMS 12	ATMS Support Systems shall provide simulation to test various components and for operator training.

B.2 Requirements Originating From Other IVHS Elements

The following list details requirements for the IVHS External Systems as a whole. This list is intended to be a synopsis for the ATIS, APTS, CVO, and AVCS entities. Table B-2 is a summary of IVHS External Systems Requirements.

Table B-2. IVHS External Systems Requirements Matrix

Requirement	ATIS	APTS	CVO	AVCS
IVHS 1	v	v	v	v
IVHS 2	v	v	v	v
IVHS 3	v		v	

IVHS externals require static data including roadway information such as highway geometries, restrictions due to long-term construction projects, toll locations, incidents, and historical demand levels at network locations by time of day. ATIS elements, for example, either in-vehicle, hand-held devices for travelers, kiosks, or other fixed elements, will process received static data against dynamic data (refer to ATIS 2) to perform traveler services such as Traveler Advisory, Traveler Service Information, Trip Planning, Route Selection, Route Guidance, and In-Vehicle Signing (refer to ATMS 9).

IVHS 1 ATMS shall provide historical information related to the roadway system to vehicles and other devices.

IVHS 1.1 ATMS shall develop historical traffic-related data.

IVHS 1.2 ATMS historical data will consist of link times, geometries, road restrictions, volumes, control strategies, incidents, etc., by time of day.

IVHS 1.3 ATMS shall transmit historical data to vehicles and other Devices.

Dynamic data is an ongoing and timely record of the traffic network’s current status. It includes such information as control strategies and signal settings in effect, link travel times, demand levels, incidents, events, travel advisory messages (e.g., “Accident Ahead, use alternate routes – Rt. XX”), parking availability, environmental conditions, and restrictions in effect, such as construction projects.

IVHS 2 ATMS shall provide to IVHS entities dynamic, real-time Information regarding the current status of the roadway system. Real-time information includes traffic-related data (link times, volumes, incidents, etc.), travel advisory messages, and parking availability.

Route selection, assumed to be performed by ATIS elements, is assisted by ATMS. Route selection consists of calculating a best route of travel based upon a trip already selected by the traveler in the form of an origin and destination at a particular time. Route selection can be performed to satisfy a number of objectives, a primary one being to provide a trip with the features preferred by the traveler (e.g., quickest, avoid toll roads, avoid freeways, avoid surface streets, scenic routes, etc.). One advantage to having ATMS play a role in routing is the ability to influence demand (and thus, network loading) to optimize the performance of the roadway network at the system level. This is done so that congestion is minimized and throughput is maximized for the roadway system as a whole. If routing was done entirely by ATIS entities (i.e., distributed routing where each vehicle computes its own route) and the ATMS had no input, it would not be possible to influence demand and network loading (since each vehicle is performing their own routing independently) and better utilize the capacity of the roadways. Further, ATMS could not substantially alter/refine control strategies (at least not as well as it could if it had some control over routing), since there would be less statistical control over each vehicle.

IVHS 3	ATMS shall contribute to the route selection process. ATMS shall compute suggested and alternative routes between O-D pairs, which it will transmit (along with real-time traffic information) to IVHS entities (refer to Assumption b. in Appendix D). Routing for individual vehicles however, is not performed (except for HAZMAT carriers and emergency vehicles).
IVHS 3.1	ATMS shall have the capability to receive O-D data from vehicles or aggregated O-D data from other IVHS components.
IVHS 3.2	ATMS shall aggregate (if necessary) and develop suggested routes between O-D pairs.
IVHS 3.3	ATMS shall optimize routes with respect to the requirements of the traffic network.
IVHS 3.4	ATMS shall disseminate real-time suggested route data to IVHS components.

B.3 Requirements Originating From Non-IVHS External Elements

B.3.1 Weather

Weather predictions are an important input required for managing traffic. ATMS will require the capability to receive weather forecast data for anticipating traffic conditions, incident detection, and incident management. This data will be stored for long- and short-term trend analysis.

NWS 1	ATMS will receive and process weather forecast data from commercial and public weather forecast service organizations.
NWS 1.1	ATMS shall receive weather forecast data from public and private services.
NWS 1.2	ATMS shall validate forecast data to ensure it is transmitted from legitimate sources.

NWS 1.3 ATMS shall check data integrity to ensure that the data content is of good quality.

NWS 1.4 ATMS shall archive all received forecast data.

ATMS will pre-process data to extract the appropriate parameters to use as input for managing the traffic network.

NWs2 ATMS will pre-process weather forecast data.

NWS 2.1 ATMS shall identify and extract parameters of interest.

NWS 2.2 ATMS shall assign the forecast to a network area of interest.

In addition to receiving regular weather service broadcasts, ATMS will require the capability to initiate specific forecast data (e.g., near-term "micro forecasts") to support activities such as incident management, where occurrences are unplanned.

NWS 3* Perform *ad hoc* weather forecast requests.

B.3.2 Environment

ATMS will require the capability to receive environmental status data such as air quality levels, from public and private organizations.

ENV 1 ATMS will receive and process air quality data from public and private environmental monitoring service organizations.

ENV 1.1 ATMS shall receive environmental status data from Non-IVHS External systems.

ENV 1.2 ATMS shall validate forecast data to ensure it is transmitted from legitimate sources.

ENV 1.3 ATMS shall check data integrity to ensure that the data content is of good quality.

ENV 1.4 ATMS shall archive all received environmental data.

ATMS will pre-process data to extract appropriate parameters to use as input for managing the traffic network.

ENV 2 ATMS will pre-process environmental data.

ENV 2.1 ATMS shall identify and extract parameters of interest.

ENV 2.2 ATMS shall assign environmental data to a network area of interest.

ENV 3* Initiate transmittal of air quality data.

B.3.3 National Databases

It is assumed that large databases containing data from a national perspective will be required by ATMS. One such database could conceivably maintain information about vehicles transporting HAZMAT.

HAZMAT planning data includes description of planned trips, routes, desired schedules, and the hazardous material's nature. ATMS will retrieve these data from the national database and use this information to coordinate routes and provide advance notice to emergency services and other affected organizations.

NADB l*	ATMS will receive HAZMAT manifest data from a national database.
NADB 1.1	ATMS shah detect HAZMAT carriers without cargo identification from surveillance data.
NADB 1.2	ATMS shall send information queries to the national database.
NADB 1.3	ATMS shall receive and validate data, and check data integrity.

ATMS will use this data to manage traffic and the roadway as HAZMAT carriers travel through the traffic network.

NADB 2*	ATMS will have the capability to receive real-time location information regarding vehicles carrying hazardous materials.
NADB 2.1	ATMS shah receive location data.
NADB 2.2	ATMS shah validate location data.
NADB 2.3	ATMS shall perform route selection for HAZMAT carriers.

As the ATMS monitors and manages HAZMAT traffic, it will send new information obtained to the national database as updates.

NADB 3*	ATMS shall send update data to the national database.

B.4 Requirements Originating From Emergency Response Systems

B.4.1 Emergency Vehicles

This category includes assets used for responding to traffic network problems. Examples of these assets are police, ambulance, fire, and tow trucks.

Emergency vehicles require static data that includes roadway information such as highway geometries, restrictions due to long-term construction projects, past incidents, toll locations, and historical demand levels at network locations by time of day. Emergency operations elements, either in-vehicle or operations centers will process received static data and compare against dynamic data (refer to EMER 2) to perform services such as Traveler Advisory, Route Selection, Route Guidance, and In-Vehicle Signing (refer to ATMS 9).

EMER 1 ATMS shall provide historical information related to the roadway system to vehicles and other devices.

EMER 1.1 ATMS shall develop historical traffic-related data.

EMER 1.2 ATMS historical data shall consist of link times, geometries, road restrictions, volumes, control strategies, incidents, etc., by time of day.

EMER 1.3 ATMS shall transmit historical data to vehicles and other devices.

As with other components within the system, emergency vehicles require dynamic data. Emergency operations elements, either in-vehicle or operations centers will process received static data and compare it against dynamic data (refer to EMER 1) to perform services such as Traveler Advisory, Route Selection, Route Guidance, and In-Vehicle Signing (refer to ATMS 9).

EMER 2 ATMS shall provide to IVHS entities dynamic, real-time information regarding the current status of the roadway system. Real-time information includes traffic-related data (link times, volumes, incidents, etc.), travel advisory messages, etc.

This function, currently performed by emergency operations elements, should be performed by ATMS. Route selection entails calculating a best route of travel based on a trip already selected by the traveler in the form of an O-D at a particular time. Route selection can be performed to provide the quickest, safest route for the emergency vehicle to the desired location (fire, crime, accident). The rationale for providing route selection for emergency vehicles is that ATMS is in the best position to assess the traffic network’s current state. Because of this, ATMS is in the position to select the optimum route for these vehicles. In addition, it is likely that signal preemption will be used by emergency vehicles. ATMS is best suited for accommodating this requirement since it can control signals and coordinate the routes of various responding vehicles.

EMER 3 ATMS shall perform emergency vehicle route selection and updates for individual emergency vehicles.

EMER 3.1 ATMS shall disseminate route selection results to IVHS and non-IVHS elements.

EMER 3.2 ATMS shall optimize the routes based on the current state of the traffic network to facilitate a safe and speedy arrival of emergency vehicles to the incident scene.

Keeping other entities informed about the current status of incidents is an important component of incident management. This function, which could be performed by emergency operations elements in some jurisdictions, could also be performed by ATMS. ATMS would determine when to send a Travel Advisory by continuously comparing real-time traffic, roadway, and environmental conditions against pre-determined categories and guidelines. During an emergency, the ATMS would send frequent and urgent advisories to emergency vehicles in progress to the incident scene (same as ATMS 9).

EMER 4 ATMS shall derive and transmit Travel Advisory Messages to emergency operations elements.

In responding to an incident, an emergency vehicle requires current information regarding the resolution status of incidents in progress, whether it is the incident to which the vehicle is responding or another incident that potentially will be encountered en route.

EMER 5 ATMS shall transmit incident detection and incident management data to emergency operations elements.

Signal preemption is an important tool for promoting rapid response to emergency situations. This capability provides an advanced version of remote signal preemption, where the ATMS manages signals along the route of an emergency vehicle based upon decision processing against these data types: real-time dynamic traffic status, the vehicle's origin/destination goal, route selection, and real-time tracking of the vehicle. An advantage of this approach is that signals can be coordinated between different responding vehicles, for example, two fire companies converging on the same intersection. Note, signal preemption can be performed by the vehicle on the roadway, directly transmitting signal control as the emergency vehicle approaches intersections.

EMER 6 ATMS shall perform signal preemption for emergency vehicles.

Incident management requires that ATMS should be the initial agent for coordinating incident responses. It is possible that once the response team arrives at the incident scene, that coordination will become the responsibility for some other agency (e.g., the police) Based upon real-time tracking of the emergency vehicle's position, the ATMS would analyze dynamic traffic conditions and communicate with the vehicle, providing interactive guidance.

EMER 7 ATMS shall perform emergency vehicle traffic coordination.

EMER 7.1 ATMS shall provide emergency vehicle notification to responding agencies.

EMER 7.2 ATMS shall perform emergency vehicle tracking.

EMER 8. ATMS shall have the capability to electronically interface into existing dispatch databases.

EMER 8.1 ATMS shall have the capability to electronically interface into police and emergency dispatch databases.

EMER 8.2 ATMS shall use the data obtained from these databases to verify incidents, and to better manage traffic around the incident.

B.4.2 Road Maintenance

Road maintenance elements require static data to maintain roadways. Maintenance vehicle operators, either through in-vehicle or operations centers, will process received static data against dynamic data (refer to TOW 2) to evaluate roadway conditions, and to plan and carry out maintenance activities. Maintenance operators will also use the information to perform services such as Traveler Advisory, Route Selection, Route Guidance, and In-Vehicle Signing, to support operators as they plan and carry out trips to maintenance sites.

MAIN 1 ATMS shall provide historical information related to the roadway system to vehicles and other devices.

MAIN 1.1 ATMS shall develop historical traffic related data.

MAIN 1.2 ATMS historical data will consist of link times, geometries, road restrictions, volumes, control strategies, incidents, etc., by time of day.

MAIN 1.3 ATMS shall transmit historical data to vehicles and other devices.

Maintenance vehicle operators, either through in-vehicle or operations centers, will process received dynamic data against static data to evaluate roadway conditions and to plan and carry out maintenance activities. Maintenance operators will also use the information to perform such services as Traveler Advisory, Route Selection, Route Guidance, and In-Vehicle Signing, to support operators as they plan and carry out trips to maintenance sites.

MAIN 2 ATMS shall provide to IVHS entities dynamic real-time information regarding the current status of the roadway system. Real-time information includes, traffic-related data (link times, volumes, incidents, etc.), travel advisory messages, etc.

MAIN 3 ATMS shall provide dispatch notices to maintenance crews for instances where repairs are automatically detected. Additionally, ATMS provides suggestions for preventive action.

B.5 Requirements Originating From Organization Users

B.5.1 Local Jurisdiction Transportation Departments

Local transportation departments have the basic responsibility for developing transportation management policy. The ATMS will accept this information and evaluate it against the current capabilities and make appropriate modifications to system capabilities, processes, or interfaces to comply with the policy. ATMS will prepare and send a response to the transportation department upon completion, indicating the nature of the response to the policy directive.

TRAN 1 ATMS shall receive traffic management policy and budget information, and evaluate and modify transportation management in response.

TRAN 1.1 ATMS shall evaluate policy information against current practice and procedures.

TRAN 1.2 ATMS shall modify and implement procedures as required.

TRAN 1.3 ATMS shall develop budget estimates to meet traffic management policies and objectives.

TRAN 1.4 ATMS shall modify and implement procedures to satisfy approved budgets.

Event planners will negotiate traffic management plans with the transportation department, who will send the information to the ATMS. The ATMS will maintain pre-planned event management strategies, procedures, and capabilities and will recall these from the database to apply appropriately. In rare cases, events will be planned for which there are no sufficient pre-planned strategies. The ATMS will devise and deploy new strategies. The ATMS will prepare and send a response to the transportation department upon indicating the nature of the response to the event.

TRAN 2 ATMS shall receive special event planning information, evaluate, develop, and implement appropriate transportation management capabilities and procedures.

TRAN 2.1 ATMS shall evaluate event plans.

TRAN **2.2** ATMS shall develop traffic management plans.

TRAN 2.3 ATMS shall develop new traffic management capabilities or procedures, if required.

TRAN **2.4** ATMS shall implement traffic management monitor and control strategies for events.

B.5.2 Law Enforcement

LAW 1 ATMS will provide law enforcement entities with violation statistics, as special requests or if required, but will not function to actively enforce the law (e.g., speed limits, HOV) for a general system. Statistics might include compliance to HOV and speed restrictions, but will not be for individual vehicles (though this might be obtainable via CCTV).

Table B-3. Requirements Change Log

Old Requirement Identification	New Requirement Identitication	Type of Change	Rational for Change	Date
ATMS 1		Modified	Incorporated environmental data from environmental sensors as a data source. Even though we have ENV requirements, this change was still accommodated, because the ENV requirements are for ingesting environmental data that is from an asset that is an external system. The ATMS requirements cover data sources that are considered to be organic to the ATMS.	10/93
ATMs 1.1		Modified	Added environmental data to the list of sensors sending data to the ATMS.	10/93
	ATMS 1.6	New	Created a new requirement for the detection of communication and equipment failures. This requirement used to be subsumed by ATMS 2.2.	10/93
ATMS 2.1		New	Added an annotation/clarification in parenthesis.	10/93
ATMS 2.2		Modified	Moved the “communication failures, equipment failures” to an new requirement -- ATMS 1.6. Also, “incidents” was removed since this is covered in ATMS 4.1. Finally, added an annotation in parenthesis.	1 0/93
ATMS 3.6		Modified	Add clarification to end of sentence “to field components.”	12/93
	ATMS 4.13	New	The addition of a requirement that will perform incident prediction.	10/93
ATMS 5.2		Modified	Added "c." which explains how other demand management strategies are developed for ATMS.	1 0/93
ATMS 6		Modified	Flagged as a future requirement (2002).	10/93
ATMS 4.2		Modified	Deleted “facility” since it was misleading.	10/93
ATMS 9.1		Modified	Clarification - “other regional ATMS entities.”	12/93
ATMS 10.5		Modified	Added “schedule,” since a function of the ATMS will be to schedule maintenance activities.	10/93
ATMS 10.8		Modified	Added “schedule,” since a function of the ATMS will be to schedule repairs to equipment.	1 0/93
ATMS 10.9		Modified	Added “schedule,” since a function of the ATMS will be to schedule repairs to the roadway.	1 0/93

Table B-3. Requirements Change Log (Cont'd)

Old Requirement Identification	New Requirement Identification	Type of Change	Rational for Change	Date
	ATMS 10.10	New	ATMS requirement for performing configuration management of all assets.	12/93
ATMS 11		Modified	Clarification for the necessary communication for transmitting data within an ATMS region, i.e., between TMCs.	12/93
ATMS 11.1		Modified	Clarification for the necessary communication for transmitting data within an ATMS region, i.e., between TMCs.	12/93
ATMS 11.2		Modified	Clarification for the necessary communication for transmitting data within an ATMS region, i.e., between TMCs.	12/93
	ATMS 12	New	The addition of requirements for the ATMS Support System that will ensure the accomplishment of design goals.	10/93
	ATMS 12.1	New	The addition of requirements for the ATMS Support System that will ensure the accomplishment of design goats.	1 0/93
	ATMS 12.2	New	The addition of requirements for the ATMS Support System that will ensure the accomplishment of design goals.	10/93
	ATMS 12.3	New	The addition of requirements for the ATMS Support System that will ensure the accomplishment of design goals.	10/93
ATMS 12		Moved	Moved to a system-level requirement in the Task C document -- does not belong here, because it is not an ATMS functional-level requirement,	12/93
ATMS 12		New	Created a new ATMS 12 for all types of simulation.	12/93
	ATMS 13	New	The addition of requirements for the ATMS Support System that will ensure the accomplishment of design goals.	10/93
ATMS 13		Moved	Moved to a system-level requirement in the Task C document -- does not belong here, because it is not an ATMS functional-level requirement.	**12/93**
	IVHS 1.3	New	Requirement to transmit historical data.	12/93
IVHS 3		Modified	Added “alternative” to clarify that ATMS will generate and transmit suggested and alternative routes.	10/93

Table B-3. Requirements Change Log (Cont'd)

Old Requirement Identification	New Requirement Identification	Type of Change	Rational for Change	Date
NWS 3		Modified	Flagged as a future requirement (2002).	10/93
ENV 3		Modified	Flagged as a future requirement (2002).	10/93
NADB 1		Modified	Flagged as a future requirement (2002).	10/93
NADB 2		Modified	Flagged as a future requirement (2002).	10/93
NADB 3		Modified	Flagged as a future requirement (2002).	10/93
	EMER 1.3	New	Requirement to transmit historical data.	12/93
EMER 7		Modified	Added "traffic" to clarify that the ATMS will perform emergency vehicle coordination to the accident scene from the traffic perspective not the logistics perspective.	10/93
EMER 7.1		Modified	Changed "dispatch" to "notification" to clarify that the ATMS will not dispatch emergency vehicles, but rather provide notification to responding agencies.	10/93
	EMER 8	New	New requirement for interfacing into existing dispatch databases.	1 0/93
	EMER 8.1	New	New requirement for interfacing into existing dispatch databases.	10/93
	EMER 8.2	New	New requirement for interfacing into existing dispatch databases.	1 0/93
	MAIN 1.3	New	Requirement to transmit historical data.	12/93

APPENDIX C

ATMS REQUIREMENTS TRACEABILITY

APPENDIX C

ATMS REQUIREMENTS TRACEABILITY

In this Appendix there are two tables. Table C-l will show which Support Subsystems fulfill the high-level ATMS requirements. Table C-l is sorted in alphabetical order by Support Subsystem name. Table C-2 will show a different sorting of the first table. Table C-2 is sorted by the ATMS requirement identifier and it shows which Support Subsystems fulfill the various ATMS requirements.

Table C-I. Support Subsystem to ATMS Requirements Mapping

Support Subsystem	Requirement	Analysis Map from Task B
ATMS Component Simulation Models	ATMS 12	1.1.1.3
Automated Control Sofhware Downloading	ATMS 10.4, ATMS 10.5, ATMS 10.7, ATMS 10.8,	1.3.2.8
Configuration and Inventory Management	ATMS 10.10	1.3.2.7
Data Validation	ATMS 1.2 NWS 1.2 ENV 1.2, NADB 1.2	1.1.2.2, 1.1.2.3
Document and File Management	ATMS 10.7	1.3.1, 1.3.2.2, 1.3.2.4, 1.3.2.6, 1.3.2.11, 1.3.3, 1.3.4, 1.3.5, 1.3.6
Dynamic Traffic Assignment	ATMS 3.1, IVHS 3.2, IVHS 3.3	1.2.2.1(P)
Event Planning and Scheduling	ATMS 7.1, ATMS 7.2, ATMS 7.3, ATMS 8.1, ATMS 8.2, ATMS 8.3, ATMS 9.2, TRAN 2.1, TRAN 2.3	1.2.3.1, 1.2.3.2

Historical Data Analysis	ATMS 9.1d, ATMS 9.2, IVHS 1.1, IVHS 1.2, EMER 1.1, EMER 1.2, MAIN 1.1, LAW 1	1.4.1
I/O Manager	ATMS 1.1 (except point detector) ATMS 5.4, ATMS 6.4, ATMS 7.1, ATMS 7.5, ATMS 8.1 ATMS 8.5, ATMS 9.1, ATMS 9.2, IVHS 1.3, IVHS 2, IVHS 3.1, IVHS 3.4, NWS 1.1, ENV 1.1, ENV 3 EMER 1.3, EMER 2, EMER 3.1, EMER 4, EMER 5, EMER 8.1 MAIN 1.3, MAIN 2, MAIN 3, TRAN 1 (only), TRAN 2(only), TRAN 2.4, LAW 1, NADB 1.2, NADB 2.1, NADB 3	1.4.1, 1.4.2, 1.4.5
Incident Management	ATMS 4(-4 1), EMER 7.1, EMER 8.2	1.2.4(- 1.2.4.3)
Individual Vehicle Routing	ATMS 4.11 NADB 2.3, EMER 3.2, IVHS 3.3	1.2.3.1

Input Stream Processing	ATMS 1.1, ATMS 7.1, ATMS 8.1, IVHS 3.1, NWS 1.1, NWS 2.1, ENV 1.1, ENV 2.1, NADB 1(only) NADB 2.1, NADB 2.2, EMER 8.1, TRAN 1 (only), TRAN 2(only)	1.1.1.1, 1.1.1.2, 1.1.3.6, 1.1.3.7, 1.2.4.1, 1.4.1
Integrated Modeling Manager	ATMS 3.1, ATMS 3.2, ATMS 3.3, ATMS 3.4, ATMS 4.6, ATMS 4.7, ATMS 4.8, ATMS 6.3, ATMS 7.2, ATMS 7.4, ATMS 8.2, ATMS 8.4, TRAN 2.2, TRAN 2.3	1.2.2.2, 1.2.2.3, 1.2.2.4, 1.2.2.5, 1.2.3.1, 1.2.3.2, 1.2.5
Inter-TMC Data Exchange	ATMS 11.1, ATMS 11.2	l/D1
Maintenance Management	ATMS 10.3, ATMS 10.4, ATMS 10.5, ATMS 10.7, ATMS 10.8, ATMS 10.9,	1.3.2.1
Origin-Destination Processing	ATMS 3.1, IVHS 3.2	1.2.2.1, 1.2.2.2

Output Stream Processing	ATMS 5.4, ATMS 6.4, ATMS 9.1, ATMS 9.2, IVHS 1.3, IVHS 2, IVHS 3.4, NADB 1.2, NADB 3, EMER 1.3, EMER 2, EMER 3.1, EMER 4, EMER 5, EMER 8.1, MAIN 1.3, MAIN 2, MAIN 3, LAW 1	1.4.2
Probe Vehicle Tracking	ATMS 4.12, EMER 7.2	1.2.2.4(P)
Signal and Control Optimization Models	ATMS 3.3, ATMS 3.4, ATMS 4.7, ATMS 4.8, ATMS 7.4, ATMS 8.4, TRAN 2.2, TRAN 2.3	1.2.2.2, 1.2.2.3, 1.2.2.4, 1.2.2.5, 1.2.3.1, 1.2.3.2, 1.2.5
Surveillance Image Processing	ATMS 1.1 (image only), ATMS 1.2, ATMS 1.3 ATMS 2.1, ATMS 2.2, ATMS 4.1, ATMS 4.2	1.1.3.7
MC Database Management System	All	1/DI
MC Hardware and Software Monitoring	ATMS 10.2, ATMS 10.3, ATMS 10.5, ATMS 10.7, ATMS 10.8,	1.3.2.3, 1.3.2.4, 1.3.2.5, 1.3.2.6

Traffic and Environmental Monitoring	ATMS 1.2, ATMS 1.4, ATMS 2.1,2.2, ATMS 4.1, ATMS 4.13, NWS 2.2, ENV 2.2 EMER 8.2	1.1.2, 1.1.3, 1.2.1.1, 1.2.1.2, 1.2.1.3, 1.2.1.4
Traffic Control	ATMS l.l(only Point Detector data), ATMS 3.1, ATMS 3.2, ATMS 3.3, ATMS 3.4, ATMS 3.5 ATMS 4.9, ATMS 5.3, ATMS 7.5, ATMS 8.5, ATMS 10.1, ATMS 10.2, ATMS 11.3, EMER 6, TRAN 2.4	1.1.1(P), 1.1.2(P), 1.2.2(P), 1.2.3(P), 1.2.5(P), 1.2.6(P)
raffic Simulation Models	ATMS 3.3, ATMS 3.4, ATMS 4.6, ATMS 4.7, ATMS 4.8, ATMS 6.3, ATMS 7.2, ATMS 7.4, ATMS 8.2, ATMS 8.4, TRAN 2.2, TRAN 2.3	1.2.2.2, 1.2.2.3, 1.2.2.4, 1.2.2.5, 1.2.3.1, 1.2.3.2, 1.2.5
Wide-Area Traffic hnagement System	ATMS 3.1, ATMS 3.3, ATMS 3.4, ATMS 5.1, ATMS 5.2 IVHS 3.3	1.2.1, 1.2.2, 1.2.3, 1.2.5, 1.2.6

Table C-2. Requirements to Support System Mapping

Requirement	Support Subsystem	Analysis Map from Task B
ATMS 1	Traffic and Environmental Monitoring	1.1.2, 1.1.3, 1.2.1.1, 1.2.1.2, 1.2.1.3, 1.2.1.4
	Surveillance Image Processing	1.1.3.7
	TMC Database Management System	1/DI
	Data Validation	1.1.2.2, 1.1.2.3
	Traffic Control	1.1.1(P), 1.1.2(P), 1.2.2(P), 1.2.3(P), 1.2.5(P), 1.2.6(P)
	I/O Manager	1.4.1, 1.4.2, 1.4.5
	Input Stream Processing	1.1.1.1, 1.1.1.2, 1.1.3.6 1.1.3.7, 1.2.4.1, 1.4.1
ATMS 2	Traffic and Environmental Monitoring	1.1.2, 1.1.3, 1.2.1.1, 1.2.1.2, 1.2.1.3, 1.2.1.4
	Surveillance Image Processing	1.1.3.7
	TMC Database Management System	1/DI
ATMS 3	TMC Database Management System	1/DI
	Wide-Area Traffic Management System	1.2.1, 1.2.2, 1.2.3, 1.2.: 1.2.6
	Traffic Control	1.1.1(P), 1.1.2(P), 1.2.2(P), 1.2.3(P), 1.2.5(P), 1.2.6(P)
	Origin-Destination Processing	1.2.2.1, 1.2.2.2
	Integrated Modeling Manager	1.2.2.2, 1.2.2.3, 1.2.2.4, 1.2.2.5, 1.2.3.1, 1.2.3.2, 1.2.5
	Signal and Control Optimization Models	1.2.2.2, 1.2.2.3, 1.2.2.4, 1.2.2.5, 1.2.3.1, 1.2.3.2, 1.2.5
	Dynamic Traffic Assignment	1.2.2.1(P)
	Traffic Simulation Models	1.2.2.2, 1.2.2.3, 1.2.2.4, 1.2.2.5, 1.2.3.1, 1.2.3.2, 1.2.5
ATMS 4	Traffic and Environmental Monitoring	1.1.2, 1.1.3, 1.2.1.1, 1.2.1.2, 1.2.1.3, 1.2.1.4
	Surveillance Image Processing	1.1.3.7
	Probe Vehicle Tracking	1.2.2.4(P)
	TMC Database Management System	l/D1
	Traffic Control	1.1.1(P), 1.1.2(P), 1.2.2(P), 1.2.3(P), 1.2.5(P), 1.2.6(P)
	Incident Management	1.2.4(- 1.2.4.3)

	Individual Vehicle Routing	1.2.3.1
	Integrated Modeling Manager	1.2.2.2, 1.2.2.3, 1.2.2.4 1.2.2.5, 1.2.3.1, 1.2.3.2 1.2.5
	Signal and Control Optimization Models	1.2.2.2, 1.2.2.3, 1.2.2.4 1.2.2.5, 1.2.3.1, 1.2.3.2 1.2.5
	Traffic Simulation Models	1.2.2.2, 1.2.2.3, 1.2.2.4 1.2.2.5, 1.2.3.1, 1.2.3.2 1.2.5
ATMS 5	TMC Database Management System	l/D1
	Wide-Area Traffic Management System	**1.2.1, 1.2.2, 1.2.3, 1.2.[illegible] 1.2.6**
	Traffic Control	**1.1.1(P), 1.1.2(P), 1.2.2(P), 1.2.3(P),** 1.2.5(P), 1.2.6(P)
	I/O Manager	1.4.1, 1.4.2, 1.4.5
	Output Stream Processing	1.4.2
ATMS 6	TMC Database Management System	l/D1
	Integrated Modeling Manager	1.2.2.2, 1.2.2.3, 1.2.2.4 1.2.2.5, 1.2.3.1, 1.2.3.2. 1.2.5
	Traffic Simulation Models	1.2.2.2, 1.2.2.3, 1.2.2.4 1.2.2.5 1.2.3.1, 1.2.3.2. 1.2.5
	I/O Manager	1.4.1, 1.4.2, 1.4.5
	Output Stream Processing	1.4.2
ATMS 7	TMC Database Management System	1/DI
	Traffic Control	1.1.1(P), 1.1.2(P), 1.2.2(P), 1.2.3(P), 1.2.5(P), 1.2.6(P)
	Event Planning and Scheduling	1.2.3.1, 1.2.3.2
	Integrated Modeling Manager	1.2.2.2, 1.2.2.3, 1.2.2.4, 1.2.2.5, 1.2.3.1, 1.2.3.2, 1.2.5
	Signal and Control Optimization Models	1.2.2.2, 1.2.2.3, 1.2.2.4, 1.2.2.5, 1.2.3.1, 1.2.3.2, 1.2.5
	Traffic Simulation Models	1.2.2.2, 1.2.2.3, 1.2.2.4, 1.2.2.5, 1.2.3.1, 1.2.3.2, 1.2.5
	I/O Manager	1.4.1, 1.4.2, 1.4.5
	Input Stream Processing	1.1.1.1, 1.1.1.2, 1.1.3.6, 1.1.3.7, 1.2.4.1, 1.4.1
TMS 8	TMC Database Management System	1/DI
	Traffic Control	1.1.1(P), 1.1.2(P), 1.2.2(P), 1.2.3(P), 1.2.5(P), 1.2.6(P)

APPENDIX D

ATMS ASSUMPTIONS

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ATMS ASSUMPTIONS

The following are our ATMS assumptions developed in an earlier report.

a. It is assumed that the ATIS, APTS, and CVO segments of IVHS will all have the capability to communicate with ATMS to provide and receive traffic-related information. These segments will have the capability to use this information to perform their functions of trip planning (suggested modes, schedules), route selection, vehicle scheduling, etc., appropriate to each segment. This assumption implies that these IVHS segments will not require trip planning, route selection, etc., from ATMS to meet their own objectives (although ATMS may have versions of these capabilities to meet traffic network management goals).

b. The ATMS role in routing is to assist ATIS/CVO entities in route determination and selection. More specifically, the ATMS role is not to determine routes for individual vehicles, but rather to ingest aggregated (or to aggregate) Origin-Destination (O-D) data pairs, to generate suggested routes for groups of vehicles sharing commonalties in O-D data, and to disseminate this information along with the traffic network status to IVHS. It is understood that ATIS will actually further compute/select particular routes for individual vehicles, however, ATMS must play an active role in routing to better manage the traffic network (i.e., traffic demand). This assumes a hybrid approach, combining the benefits of centralized and distributed routing.

C. Emergency and HAZMAT vehicle routing can be performed by ATMS. These are the only cases where ATMS performs individual vehicle routing. Thir assumption implies that route selection is done on a special-case basis (e.g., emergency vehicles).

d. It is assumed that advanced capability sensors will be available, within reasonable technology forecasts, appropriate to the needs of advanced traffic surveillance and control.

e. It is assumed that a sufficient number of private, commercial, and transit vehicles will be equipped as probes to provide adequate data to ATMS to support advanced traffic surveillance and control.

f. It is assumed that during the time frame of this version of ATMS (the year 2002) early versions of AVCS will be available, providing enhanced driver assistance through vehicle-to-roadway interactions, and that these interactions will not require dynamic interactions with ATMS or any special data types other than basic traffic and traffic infrastructure conditions.

g. It is assumed that the ATMS role in multi-modal trip planning is limited to information correlation and dissemination, and that ATMS will not perform the actual multi-modal trip planning and management functions. In this concept, ATMS would maintain information - primarily ATMS traffic data - and provide this information to ATIS/APTS elements that would determine actual multi-modal parameters and options.

h. Assets of the traffic network having primary or secondary surveillance functions are assumed to be internal (organic) to ATMS, not external entities. Examples include loop detectors, parking utilization sensors, Electronic Toll and Traffic Management (ETTM) components (assuming the ETTM entity has AVI from which traffic volumes can be derived), etc.

i. In-vehicle signing is assumed to be part of other IVHS elements (i.e., ATIS).

j. ATMS will support the development of various demand management strategies, which are mostly implemented by external organizations. Although the implementation of demand management strategies is done by external organizations, ATMS can support the analysis to determine effective strategies (e.g., congestion pricing, parking pricing, road pricing, impact fees, zoning restrictions, truck-free zones). Direct participation in the implementation of demand strategies is limited to aggregate routing information embedded in the dynamic network data, and control strategies for organic ATMS components (i.e., signals, CMS, ramp meters, etc.). This includes route diversion information in the case of incidents and congestion.

k. ATMS will provide data on violation rates, but not for individual vehicles. Individual vehicle violation determination is not a necessary function of ATMS, although ATMS does not preclude functionality for this purpose.

l. ATMS will provide integrated (i.e., freeways and surface street) traffic management at a regional (wide-area) level. To do this, ATMS must implement traffic management strategies across different traffic jurisdictions.

m. ATMS will exchange regional traffic data with adjacent ATMS entities through an external interface.

n. The ATMS role in incident management is limited to incident detection, initial incident notification to emergency units, and routing and coordination of emergency vehicles. Once emergency units arrive at the scene, they assume responsibility for coordinating the incident's resolution. It is assumed that ATMS may not actually manage the incident scene. ATMS does however, assume responsibility for managing traffic operations including CMS updates, alternate routing, and information dissemination.

0. The- ATMS role in parking management is limited to collecting and disseminating parking surveillance data. Garages equipped with appropriate sensors will transmit utilization levels to ATMS, where the data are collected and transmitted to ATIS. ATIS then uses this information to assist travelers in efficiently carrying out multi-modal (and single mode) trips requiring a modal transition near a parking facility. For example, a traveler wishing to park their car and board a subway system can use this information to go directly to subway stations where parking is currently available, and avoid stations where parking facilities are full.

ACRONYMS AND ABBREVIATIONS

AI	Artificial Intelligence
ANSI	American National Standards Institute
API	Application Program Interface
APP	Application Portability Profile
APTS	Advanced Public Transportation System
ASM	ATMS System Management
ATIS	Advanced Traveler Information System
ATMS	Advanced Traffic Management Systems
AVCS	Advanced Vehicle Control System
AVI	Automatic Vehicle Identification
AVL	Automatic Vehicle Location
CASE	Computer-Aided Software Engineering
CCTV	Closed-Circuit Television
CMS	Changeable Message Signs
COTS	Commercial-Off-the-Shelf
CRC	Cyclic Redundancy Checking
CUA	Common User Access
c v o	Commercial Vehicle Operations
DBMS	Database Management System
DOT	Department of Transportation
DTA	Dynamic Traffic Assignment
ERSI	Environmental Systems Research Institute
ETTM	Electronic Toll and Traffic Management
FHWA	Federal Highway Administration
GIS	Geographic Information System
GTRI	Georgia Tech Research Institute
GUI	Graphical User Interface
HAR	Highway Advisory Radio
HOV	High Occupancy Vehicle
IM	Incident Management
I/O	Input/Output
IPCP	Incident Prediction and Congestion Propagation
IPO	Input Process Output
IR	Infrared
ITMS	Inter-Jurisdictional Traffic Management Supervises
IVHS	Intelligent Vehicle Highway System

ACRONYMS AND ABBREVIATIONS (CONT'D)

LAN	Local Area Network
MOE	Measures of Effectiveness
MPO	Metropolitan Planning Organizations
MT0	Manage Traffic Operations
NIST	National Institute of Standards and Technology
O-D	Origin-Destination
OATS	Off-Line Analysis and Trend System
OJT	On-the-Job Training
ORNL	Oak Ridge National Laboratories
RDR	Requirements Discrepancy Report
SQL	Structured Query Language
TCS	Traffic Control System
TMC	Traffic Management Center
UPS	Uninterruptible Power Supply
UTCS	Urban Traffic Control System

SUPPORT SUBSYSTEM ACRONYMS

AACS	Analysis and Modeling ATMS Component Simulation Models Subsystem
ADTA	Analysis and Modeling Dynamic Traffic Assignment Subsystem
AHDA	Analysis and Modeling Historical Data Analysis Subsystem
AIMM	Analysis and Modeling Integrated Modeling Manager Subsystem
AODP	Analysis and Modeling Origin-Destination Processing Subsystem
ASCO	Analysis and Modeling Signal and Control Optimization Models Subsystem
ATSM	Analysis and Modeling Traffic Simulation Models Subsystem
CIOM	External Communications I/O Manager Subsystem
CISP	External Communications Input Stream Processing Subsystem
COSP	External Communications Output Stream Processing Subsystem
DDFM	Data Management Document and File Management
DDVA	Data Management Data Validation Subsystem
DIDE	Data Management Inter-TMC Data Exchange Subsystem
DTDB	Data Management TMC Database Subsystem
MSIP	Monitoring Surveillance Image Processing Subsystem
MTEM	Monitoring Traffic and Environmental Monitoring Subsystem
MVTR	Monitoring Vehicle Tracking Subsystem
SACS	System Management Automated Control Software Downloading Subsystem
SCIM	Traffic Management Configuration and Inventory Management Subsystem
SEPS	System Management Event Planning and Scheduling Subsystem
SMMS	Traffic Management Maintenance Management Subsystem
STHS	System Management TMC Hardware and Software Monitoring Subsystem
TIVR	Traffic Management Individual Vehicle Routing Subsystem
TIMS	Traffic Management Individual Management Subsystem
TTCS	Traffic Management Traffic Control System Subsystem
TWTM	Traffic Management Wide-Area Traffic Management Subsystem