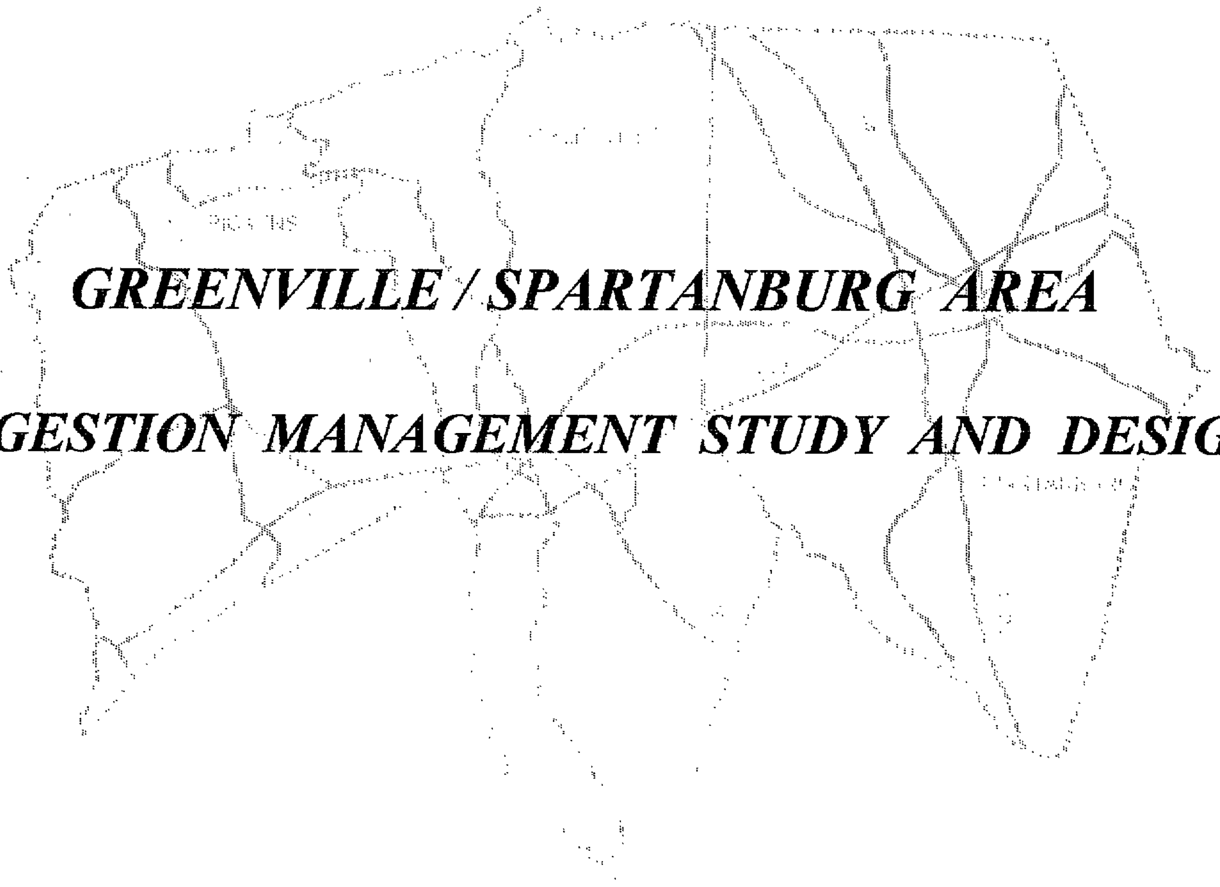
GREENVILLE / SPARTANBURG AREA

CONGESTION MANAGEMENT STUDY AND DESIGN



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Prepared For:
The South Carolina
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March 7, 1996

Mr. Richard B. Werts
Director of Traffic Engineering
South Carolina Department of Transportation
P.O. Box 191
Columbia, SC 29202

RE: Greenville/Spartanburg Congestion Management Study and Design Project

Dear Mr. Werts:

We are pleased to submit the Phase 2 Report for the Greenville/Spartanburg Congestion Management Study and Design Project.

This report summarizes conceptual design activities and study recommendations resulting from Phase 2 of the study.

This report concludes the Congestion Management Study and Design Project, which commenced in September 1993 and was funded through FHWA's ITS Early Deployment Program. The WSA team would like to thank you, your staff and all members of the Technical Steering Committee for the assistance and guidance provided throughout this challenging project.

We hope that the study will provide direction and support to SCDOT, and other local agencies, in their efforts towards incident management, congestion management and ITS implementation in the Greenville/ Spartanburg region of South Carolina.

Respectfully submitted,

WILBUR SMITH ASSOCIATES

David E. Castle

David E. Castle
Project Manager

DEC/db

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LIST OF EXHIBITS

Section 1
INTRODUCTION

This Report has been prepared during Phase 2 of the Greenville/Spartanburg Area Congestion Management Study and Design Project. It describes conceptual designs and summarizes study recommendations.

STUDY WORK PROGRAM

The Work Program was defined in two phases, and a total of nine tasks, as follows:

Phase 1:	Congestion Management Study		
	Task 1:	Inventory and Data Collection	
	Task 2:	Alternative Routes and Incident Management Strategies	
	Task 3:	Develop Conceptual ATMS System	
	Task 4:	Evaluate Driver Information Systems	
	Task 5:	Develop ATMS Organization	
	Task 6:	Review Legislation and Regulations	
	Task 7:	Prepare Preliminary Study Report	
Phase 2:	ATMS Conceptual Design		
	Task 8:	Prepare Conceptual Designs	
	Task 9:	Prepare Final Study Report	

STUDY REPORTS

During Phase 1 four documents were prepared and submitted to the Department for review and approval:

- Technical Memorandum on Incident Management Strategies . submitted January 4, 1994;

- Technical Memorandum on Conceptual ATMS System Functions - submitted May 17, 1994; and

- Technical Memorandum on ATMS Organization and Legislation Issues . submitted August 31, 1994.

- Preliminary Study Report submitted November 11, 1994.

During Phase 2 two additional documents were developed:

- Draft Phase 2 Report (Sections l-6) submitted June 14, 1995; and

- Draft Phase 2 Report (Sections 7 and 8) submitted November 30, 1995.

STEERING COMMITTEE MEETINGS

Following submittal of each study report a review meeting has been held with the project's Technical Steering Committee. This Committee of approximately 20 members, drawn from federal, state, county, and city agencies, has provided comments and input throughout the study. Additional Steering Committee meetings were held prior to project commencement and during the course of Task 5, Develop ATMS Organization. The eight meetings of the Committee were held in the Spartanburg County Planning and Development Department on:

- May 26, 1993;
- January 26, 1994;
- June 13, 1994;
- July 21, 1994;
- September 27, 1994;
- December 14, 1994;
- August 16, 1995; and
- December 21, 1995.

REPORT OBJECTIVES AND CONTENTS

The purpose of this report is to present the conceptual designs developed during Phase 2 of the study, and to summarize study recommendations.

In Section 9, Proposed Phase 2 Work Plan, of the Preliminary Study Report five aspects of the congestion management system were identified for development of conceptual designs, namely:

- Overview of regional ATMS/ATIS in Greenville/Spartanburg area.
- Backbone communications network to be installed during ongoing construction projects in the I-85 corridor;
- Freeway surveillance and ATIS for the couplet formed by the existing and newly constructed portions of I-85 north of the City of Spartanburg.
- Traffic surveillance and ATIS to facilitate travel to/from the downtown area of the City of Greenville.
- Freeway surveillance and ATIS in the vicinity of interstate construction/widening projects.

Each of the conceptual designs is presented in the sections which follow, starting with the overview of the system, which is intended to indicate the potential long-range objectives and scope of the proposed congestion management system. Cost estimates and a discussion of funding issues are then provided. In the final section, study recommendations are summarized.

The report is presented in the following sections:

- SECTION 1: INTRODUCTION
- SECTION 2: OVERVIEW OF REGIONAL CONGESTION MANAGEMENT SYSTEM
- SECTION 3: BACKBONE COMMUNICATIONS SYSTEMS
- SECTION 4: SPARTANBURG I-85 COUPLET
- SECTION 5: GREENVILLE DOWNTOWN ATMS/ATIS
- SECTION 6: ATIS SYSTEMS DURING IMPROVEMENT PROJECTS
- SECTION 7: COST ESTIMATES AND FUNDING
- SECTION 8: OTHER CONGESTION MANAGEMENT RECOMMENDATIONS

The conceptual designs presented in this report are intended to provide a starting point for more detailed studies or design activities which may occur in the future.

In developing conceptual designs for a regional Advanced Transportation Management System (ATMS), it is necessary to adopt a long term perspective and to identify system objectives and functionality which may take many years to accomplish. This is the viewpoint adopted in Section 2 of this Report. In contrast, when discussing specific projects which may provide the initial components of the ATMS, a shorter time horizon is used. This is done to ensure that benefits are received at each incremental step in the implementation of the overall system. For example, in Section 4 on the new Spartanburg I-85 Couplet, emphasis is given to the development of an incident detection system and means of advising motorists of potential diversion routes.

In presenting conceptual designs mention is made of alternative technologies which may be used to provide particular functional requirements. Alternative technologies should be reassessed during future design studies to ensure the latest technological advances, standards and policies are fully recognized at that time.

This reassessment will be necessary due to rapidly evolving communications technologies and the wide range of other ITS studies and operational tests currently underway throughout the country. FHWA's Architecture Development Program, referred to later in this Report, is one of many studies underway which should provide guidance and input to detailed design activities.

GLOSSARY OF TERMS

A number of abbreviations are used throughout this report. To assist the reader these abbreviations are listed below. Note that the abbreviation IVHS (Intelligent Vehicle-Highway Systems) has been replaced by ITS (Intelligent Transportation Systems). This change was deemed necessary to reflect the broad multimodal nature of the Federal government's program to apply advanced technologies to all surface transportation systems.

ATIS	-	Advanced Traveller Information System
ATMS	-	Advanced Transportation Management System
CCTV	-	Closed Circuit Television
CVO	-	Commercial Vehicle Operations
EMS	-	Emergency Medical Services
EMT	-	Emergency Medical Technician
GRATS	-	Greenville Area Transportation Study
HAR	-	Highway Advisory Radio
ITS	-	Intelligent Transportation Systems
IVHS	-	Intelligent Vehicle-Highway Systems
MAP	-	Motorist Assistance Patrol
MPO	-	Metropolitan Planning Organization
RWIS	-	Road Weather Information Systems
SCADA	-	Supervisory Control and Data Acquisition
SPATS	-	Spartanburg Area Transportation Study
TIP	-	Transportation Improvement Program
TOC	-	Traffic Operations Center
VMS	-	Variable Message Sign

Section 2
OVERVIEW OF REGIONAL CONGESTION MANAGEMENT SYSTEM

In this section the concepts proposed for the Greenville/Spartanburg Congestion Management System are described. The proposed system will have capabilities and features drawn from systems sometimes referred to as Advanced Traffic Management Systems (ATMS), Advanced Traveller Information Systems (ATIS), Advanced Rural Transportation systems (ARTS) and Commercial Vehicle Operations (CVO). For simplicity, the abbreviation ATMS will generally be used throughout this report, to refer to the integrated system.

This overview depicts the eventual long-term capabilities and scope of the system as currently envisioned. Such a system will be implemented in stages and will be developed at a pace determined by a variety of factors, including budgetary constraints, local priorities and the increase in traffic congestion on the region's highways. Implementation will also be influenced by the rate at which Intelligent Transportation System (ITS) concepts and technologies are proven and gain wide acceptance, among both transportation professionals and the travelling public. The proposed phased implementation of the system is illustrated in Exhibit 2-l.

An overview of potential system functions and scope is presented to provide a basis for the conceptual system design of the communications infrastructure contained in Section 3 of the Report.

SYSTEM OBJECTIVES

The overall objectives of the Greenville/Spartanburg ATMS may be broadly summarized as:

- reducing congestion;
- reducing accidents;
- improving incident management; and
- improving travel efficiency.

These objectives will be achieved by a wide variety of techniques and approaches, including Travel Demand Management (TDM), as well as by traffic monitoring and control strategies.

Geographic Scope

The initial focus of the Greenville/Spartanburg ATMS will be the rapidly developing corridor between the urban areas of Greenville and Spartanburg. While the principal route through the corridor is an interstate highway (I-85), a number of U.S. and State routes are also critical to transportation service in the corridor and in the urban areas.

As the system develops it is likely that the geographic area covered will expand. I-85 is not merely a convenient link between the cities of Greenville and Spartanburg for the use of local residents , it is part of a major transportation corridor of regional and national significance. It is also

Short Term Implementation

FOCUS

Traffic Management Team

Local Control Centers

Motorist Assistance Patrol

SPECIFIC PROJECTS

ATIS for I-85 Widening Projects

ATIS/ATMS for Downtown Greenville

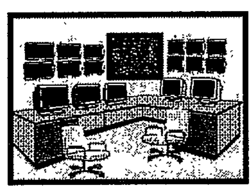
ATIS for Spartanburg I-85 Couplet

Medium Term Implementation

FOCUS

Integration of Local Projects into Regional System

Expansion of MAP and Other ATIS Services



SPECIFIC PROJECTS

Regional ATMS in Permanent TOC

Additional ATIS Projects

Adaptive Traffic Signal Control

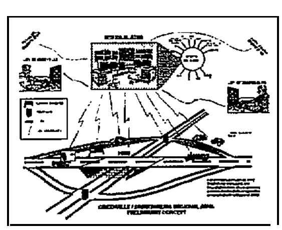
Region-wide Communications Network

Long Term Implementation

FOCUS

Full Range of AIMS, ATIS, ARTS and CVO Services

Links to Other Regional TOCs



SPECIFIC PROJECTS

Provision of ATIS Data Directly to Major Traffic Generators (Offices, Factories, Malls, etc.)

Support for In-vehicle ATIS Displays and Systems

THE PATH TO A REGIONAL ATMS FOR THE GREENVILLE/SPARTANBURG AREA Exhibit 2 crossed by other interstate highways, namely I-26 and I-385, which cater to predominately north-south inter-urban movements through the area.

The National Highway System In addition to interstate highways, the Greenville/Spartanburg corridor also contains, or is close to, a number of other routes contained in the National Highway System (NHS). The NHS embodies the commitment to a more flexible, balanced transportation system that Congress enacted in the ISTEA legislation of 1991. The ISTEA called for linking 'I--- all forms of transportation in a unified, interconnected manner --- economically efficient and environmentally sound --- the foundation for the Nation to compete in the global economy --- [to] move people and goods in an energy efficient manner."

In view of the importance attached to NHS routes by Congress and ISTEA, it is reasonable to assume that expansion of the ATMS will focus on improving traffic conditions and safety on NHS routes. In summary, in the long-term, the regional ATMS may be anticipated to primarily serve the following types of highway facilities in the region:

- interstate highways;
- other (non-interstate) NHS routes; and
- other arterials, of significance in an urban or metropolitan context.

An example of an arterial roadway, which is not on the NHS, but which is of major significance to the study area, is U.S. 29 which connects Greenville and Spartanburg, via Greer.

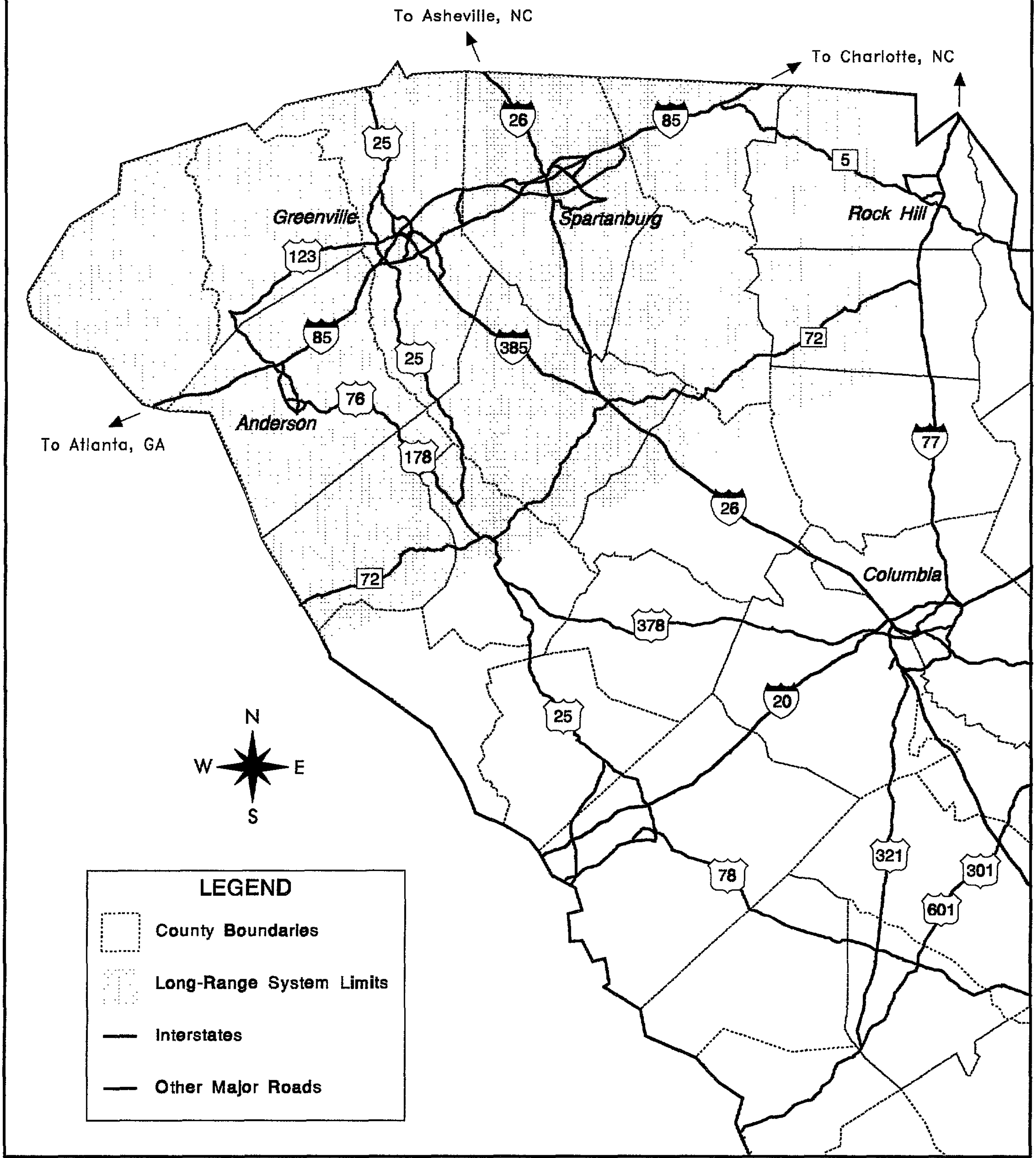
Long-term Regional Scope The geographic limits of the Greenville/Spartanburg Congestion Management Study are clearly defined. It covers the I-85 corridor between Greenville/Spartanburg. The western boundary is S.C. 153 which connects U.S. 123 in Pickens County to I-85 at Exit 40 in Anderson County. The Spartanburg/Cherokee county line is the eastern boundary. The study area extends approximately 12 miles north and south of the I-85 corridor.

The potential area which may eventually be covered by the Greenville/Spartanburg Regional ATMS has not been defined to-date. For the purpose of developing a long-range conceptual plan it is assumed that the system will eventually cover an area encompassing I-85 from the Georgia state line to the North Carolina state line and I-26 from the North Carolina state line to the area of Clinton where it intersects with I-385 and with U.S. 72 (a NHS route). The potential long-range geographic scope of the system is illustrated in Exhibit 2-2.

Functional Scope

The proposed initial functions and components of a regional ATMS may be grouped into four major categories:

The National Highway System, The Backbone of America's Intermodal Transportation Network, U.S. Department of Transportation, FHWA, December 1993.



POTENTIAL LONG-RANGE REGIONAL SCOPE OF THE GREENVILLE / SPARTANBURG ATMS

Wilbur Smith Associates

Exhibit 2-2

- Incident Management;
- Freeway Operations (ATIS and incident Management Support);
- Signal Systems; and
- Motorist Assistance Patrol.

Incident Management Proposed functions relating to incident management fall into two groups:

- Incident Management Planning; and
- Incident Management Support.

Recommendations relating to Incident Management Planning are described in Section 8 of this report.

Incident Management Support functions relate primarily to those activities performed by ATMS staff during the course of highway incidents. They are concerned with, but not limited to:

- Incident Verification (CCTV);
- Traveller Information Systems (HAR, VMS);
- Diversion Routes; and
- Communications with the Media.

ATMS staff will play an important role in coordinating the incident management response and dispatching appropriate personnel to the scene of the incident. It is important to note that it is not envisaged that ATMS staff receive "911" calls directly. These will continue to be handled by the existing 911 communications centers in Greenville and Spartanburg counties. The appropriate Highway Patrol or Fire Service officer at the incident scene will be responsible for actual on-site management of the incident as at present. ATMS staff would act **as** an available resource to those on the scene, for assistance as appropriate. ATMS facilities and staff would also be at the disposal of emergency services in the event of catastrophic emergencies (nuclear accidents) or natural disasters.

Freeway Operations Freeway operations functions include the control, monitoring and maintenance of system components, such as:

- Closed circuit television (CCTV);
- Variable Message Signs (VMS);
- Highway Advisory Radio (HAR);
- Vehicle detectors; and
- Communications equipment.

Functions associated with the dissemination of traveller information also fall into the category of freeway operations. Such functions are likely to evolve and assume increasing importance over time. Initially, functions in this area will focus on informing motorists of incidents, through conventional radio and TV media, variable message signs and highway advisory radio.

Then, provision of detailed traveller information will be provided by these means on a routine basis, plus additional channels such as cable television, monitors in major traffic generators (employment centers, shopping malls, airports), computer dial-up facilities etc. Finally, freeway operation functions will encompass support of ATIS systems using in-vehicle route guidance displays and equipment.

Freeway operations facilities should support Commercial Vehicle Operations (CVO) and should be linked to similar regional ATMS Centers in neighboring states and in other parts of South Carolina, such as potential centers in Atlanta, Charlotte and Columbia. CVO will provide services such as Commercial Vehicle Electronic Clearance, Automated Roadside Safety Inspection, On-board Safety Monitoring and Hazardous Material Incident Response.

An example of a specific CVO service would be 'Trailblazer." This is a deployment program funded by FHWA to institute roadside electronic verification of commercial vehicles for regulatory and safety purposes at weigh stations and mobile sites. It would create the infrastructure necessary to implement a nationwide electronic system. The proposed regional ATMS should allow for the integration of such services to ensure common infrastructure, such as communication facilities, are shared by all transportation related systems and services.

Signal Systems It is recommended that the proposed ATMS include a Central Distributed Traffic Control System for the region. The distributed system would have three control centers one in the City of Greenville, one in the City of Spartanburg and one at a regional Traffic Operations Center (TOC).

A Central Distributed Traffic Control System combines the strengths of a closed loop system (user friendly interface and storage of operating parameters in the local controller) with flexible communications polling and message types. It is recommended for the following reasons:

- Flexibility with potential to handle NEMA, Type 170 and future generation controllers;
- Ability to operate an adaptive traffic control strategy such as SCOOT in critical areas of the network, and conventional coordination in other areas;
- Supports multi-jurisdictional access and control capabilities from multiple centers, so that the Cities of Greenville and Spartanburg can retain responsibility for the operation of signals under their jurisdiction while being part of a region wide system the allocation of intersections to control centers for monitoring and control purposes would be determined solely by the system database and not limited or constrained by geographic location or specific communication channels.
- Capabilities for exchanging data, graphics and video between control centers and between neighboring regional ATMS centers.

Motorist Assistance Patrol The final category of functions proposed for the regional ATMS relates to the Motorist Assistance Patrol (MAP). MAP programs typically provide specially equipped vehicles to regularly patrol the interstate highway, to:

- assist disabled motorists;
- assist the Highway Patrol in tagging abandoned vehicles;
- detect incidents or other potential hazards (stranded motorist, debris, etc.); and
- assist with traffic control during incident management and clearance activities.

The regional ATMS could provide a base of operations and a communications center for MAP services in the Greenville/Spartanburg area. Recommendations on a MAP program are contained in Section 8 of this report.

Changing Emphasis in Functional Scope As previously mentioned, functions related to the dissemination of traveller information are likely to evolve and assume increasing importance over time. Indeed a mature ATMS is likely to utilize as much of its resources on data collection, data merging, data processing and on information dissemination as it will on controlling traffic signals and other devices directly visible to the motorist.

Traveller information services will assist a wide range of users including local residents, tourists and other long distance travellers, local industries and trucking operations. Services will be provided not only for motorists, but also for travellers using other modes of transportation including local and long distance bus services, rail and air.

The system's eventual role as a central clearing house for real-time information on the status of the region's transportation facilities will have an important bearing on the communications infrastructure necessary to support its operation in a flexible and efficient manner.

A TRANSPORTATION INFORMATION CENTER

A number of the principal sources of real-time and reference data and some of the means of disseminating information are summarized below. The potential of a regional ATMS should not be limited to the highway mode, and should encompass transit, rail and air transportation.

Sources of Transportation Data

Data relating to transportation will be provided to the ATMS by a wide range of automated and manual sources, including but not limited to:

- Vehicle Detectors;
- Driver's reports via cellular telephone;
- Information relayed from 911 centers;
- CCTV cameras;
- Commercial and private vehicles equipped with Automatic Vehicle Identification (AVI) type tags (transponders);

- In-vehicle navigation devices;
- Reports provided by trucking companies and their drivers;
- Reports provided by other transportation providers, e.g., transit operators, taxi companies etc.;
- Central databases on hazardous materials movements;
- Adjacent Regional ATMSs;
- Automated equipment status reports from traffic signal and other control or signing equipment;
- Road Weather Information Systems;
- Weather services; and
- Information on other modes, including adherence to schedules, delays, etc., on transit, rail and air services.

In the future it is likely that the majority of commercial vehicles will be equipped with transponders to automatically provide information currently obtained in roadside weigh stations. This information could be collected via the communications network of the ATMS and provided to the SC Department of Public Safety's Transport Police and other governmental agencies with need for this data. Alternatively, this information could be collected independently of the ATMS, with selected data, such as representative travel times, being passed to the ATMS via direct computer links. Safeguards would be in place to ensure confidential information gathered from commercial vehicles would not be available for purposes other than intended and agreed to by the commercial vehicle operators.

Information Dissemination

Information will be provided by a variety of means, dependent mainly on the location and circumstances of the end user.

- Drivers, en-route
  - VMS
  - HAR
  - Interactive monitors at Rest Areas and Welcome Centers
  - In-vehicle displays

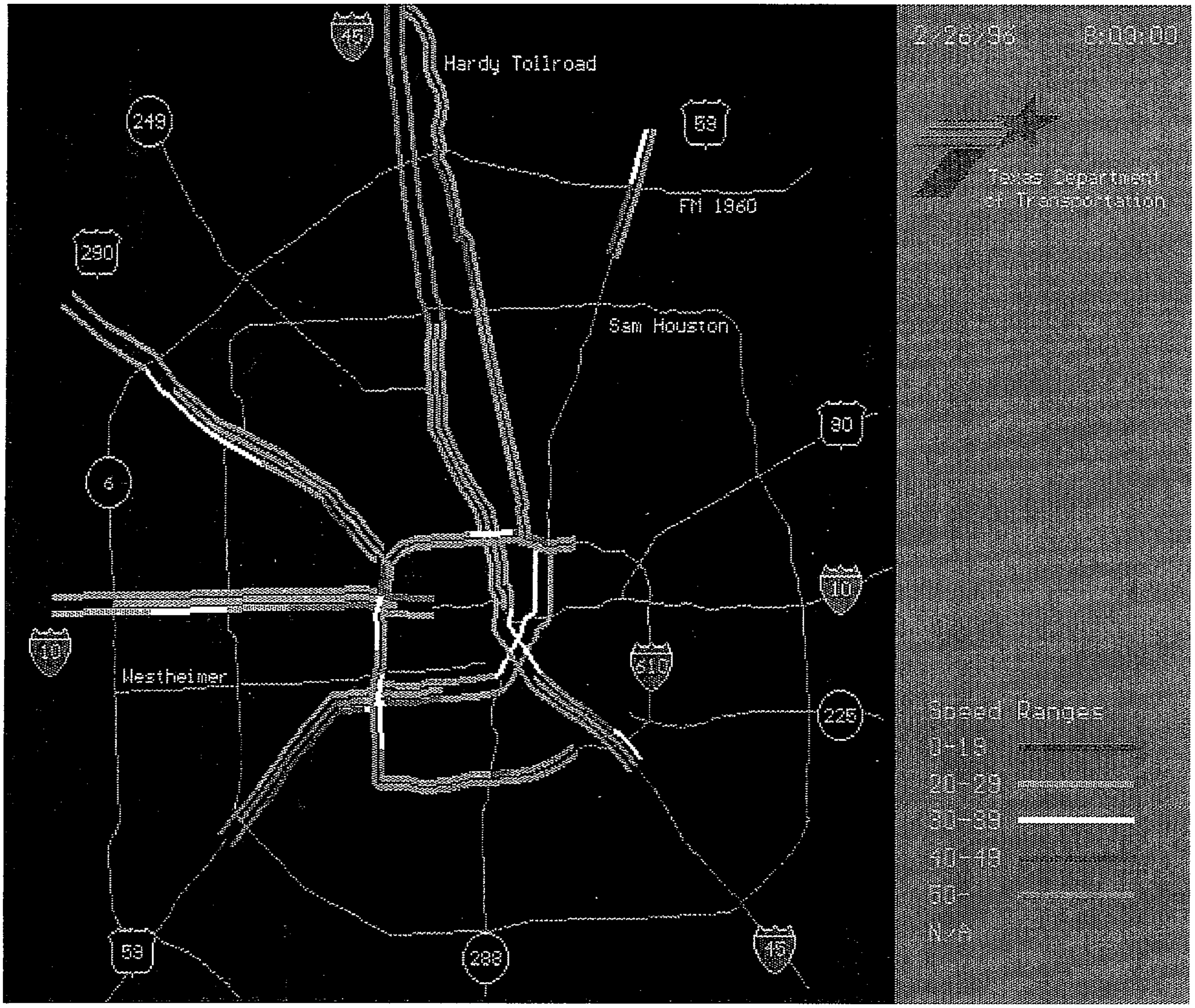
- Travellers, before trip commences
  - On-line bulletin boards accessed via a modem and computer
  - WEB pages, automatically updated, accessed via the Internet
    frequently updated, pre-recorded telephone messages
    dedicated cable television channel
    interactive monitors in kiosks at major traffic generators
  - Terminals networked to the ATMS, at major employment centers, trucking companies etc.
  - Commercial radio and television stations

- Transportation Service Providers and the Media
  up-to-date traffic condition reports automatically generated and faxed to subscribers
  terminals networked to the ATMS, to provide real-time status of traffic conditions, via text reports and graphic displays.

Some types of traveller information may be provided free-of-charge other types may only be available to subscribers who pay a fee for the service.

An example of the type of real-time traffic data currently available via Internet WEB pages is shown in Exhibit 2-3. The map, accessible at " http://herman.tamu.edu/traffic.html" , is generated by the City of Houston's Traffic Monitoring System. The map display shows current average speeds in both directions as well as on the HOV lane, using up to three color coded lines. If three lines are present for a roadway, the middle line represents the HOV lane. The two outer lines represent the freeway lanes in each direction. Speeds are in miles per hour. Each line is color coded to represent the current speed collected by the Traffic Monitoring System. Freeway links are marked as Not Available (gray line) if no information has been collected for 30 minutes. The map is updated every minute.

The monitoring system uses vehicles equipped with transponder tags as vehicle "probes," Transponder tag "readers" are placed at 1 to 5 mile intervals along freeways and HOV lanes. Each "reader" senses probe vehicles as they pass a reader station and transmits the data to a central computer. This information is used to calculate travel times of these probe vehicles between reader stations. From this travel time data, average speeds can be calculated for the roadway sections. This is the information shown on the Map display. The system recognizes tags issued by the Harris County Toll Road Authority. Other motorists can volunteer to be a traffic "probe," by requesting a free transponder.



Houston Real-Time Traffic Map
Accessible via the Internet

Exhibit 2-3

Section 3
BACKBONE COMMUNICATIONS SYSTEM

In order for the Greenville/Spartanburg Regional Advanced Transportation Management System (ATMS) to operate effectively, each component must be connected via communication links. With the exception of air path links, such as two-way radio communications, at least one end of a communications system involves the use of cables. Even cellular telephone communications typically utilize the cable plant of the telephone system for one end of a call. Therefore, a communications system utilizing cables must be provided throughout the area served by the ATMS.

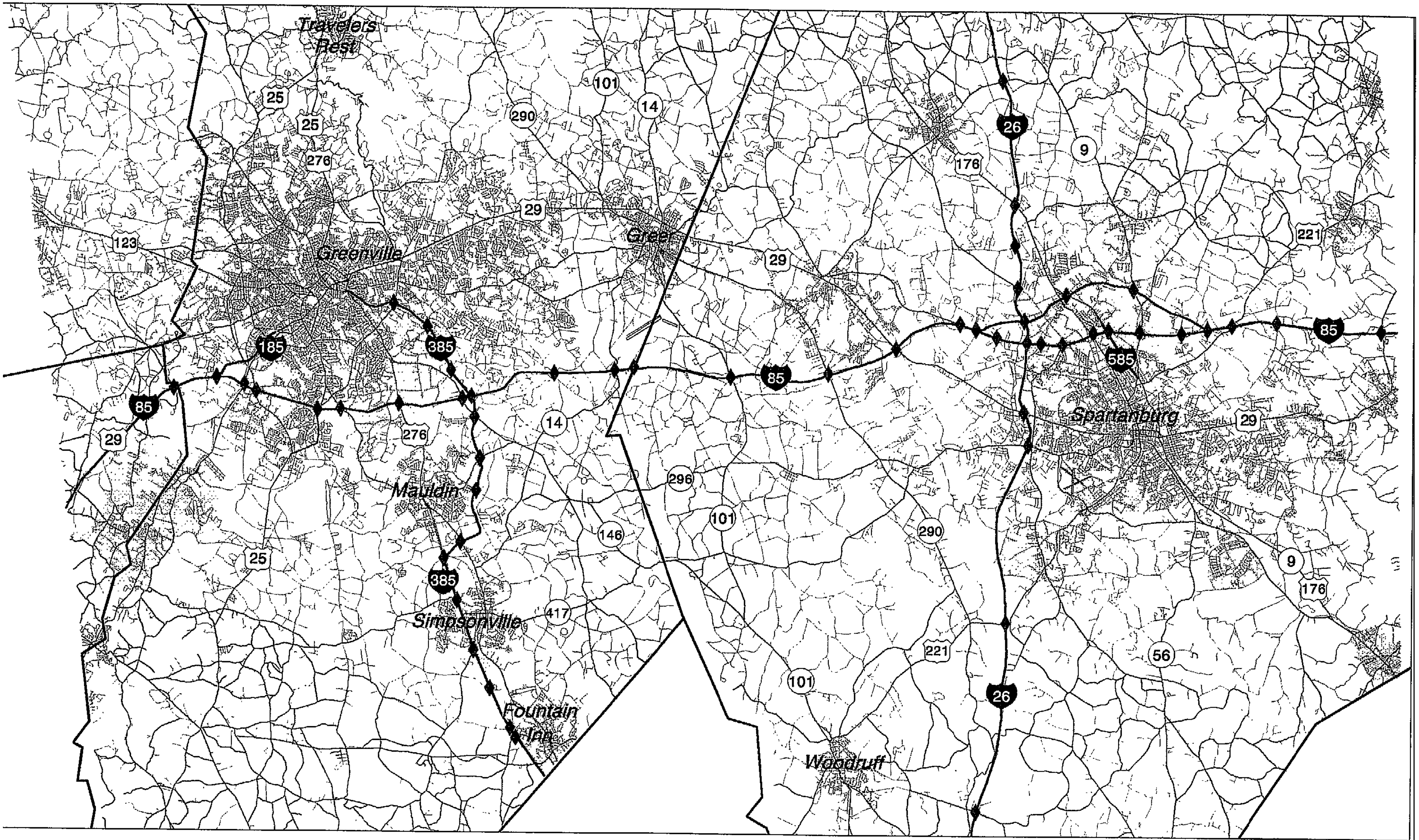
OBJECTIVES

The intent of this section is to describe, in conceptual terms, a communication system that can serve as the backbone of the total system. This backbone communications system will serve as the truck line throughout the entire corridor. It will permit individual elements of the system to be connected to the regional ATMS without installing a separate, individual communications link between each element and the ATMS Center(s). Each local element can be tied directly into the backbone system by the shortest practical route. Components which could be connected to the backbone communications system may include, but would not be limited to, elements of the following types of systems:

- Advanced Traveller Information Systems;
- Closed Circuit Television Systems;
- Highway Advisory Radio;
- Variable Message Signs;
- Vehicle Detection Systems;
- Traffic Signal Systems;
- Ramp Metering Systems;
- Commercial Vehicle Operations Systems;
- Traffic Operations Centers; and
- Other Regional ATMS Centers.

The backbone communications system is intended to provide communication facilities for ATMS projects implemented in the short term, as well as providing sufficient capacity and flexibility to meet future needs for the Greenville Spartanburg Regional ATMS. It is recommended that the backbone communications system follow the existing interstate network, with communication hubs being located at each interchange, as illustrated in Exhibit 3-l.

A conceptual design of a short segment of the backbone communications system is shown in schematic form in Exhibit 3-2.

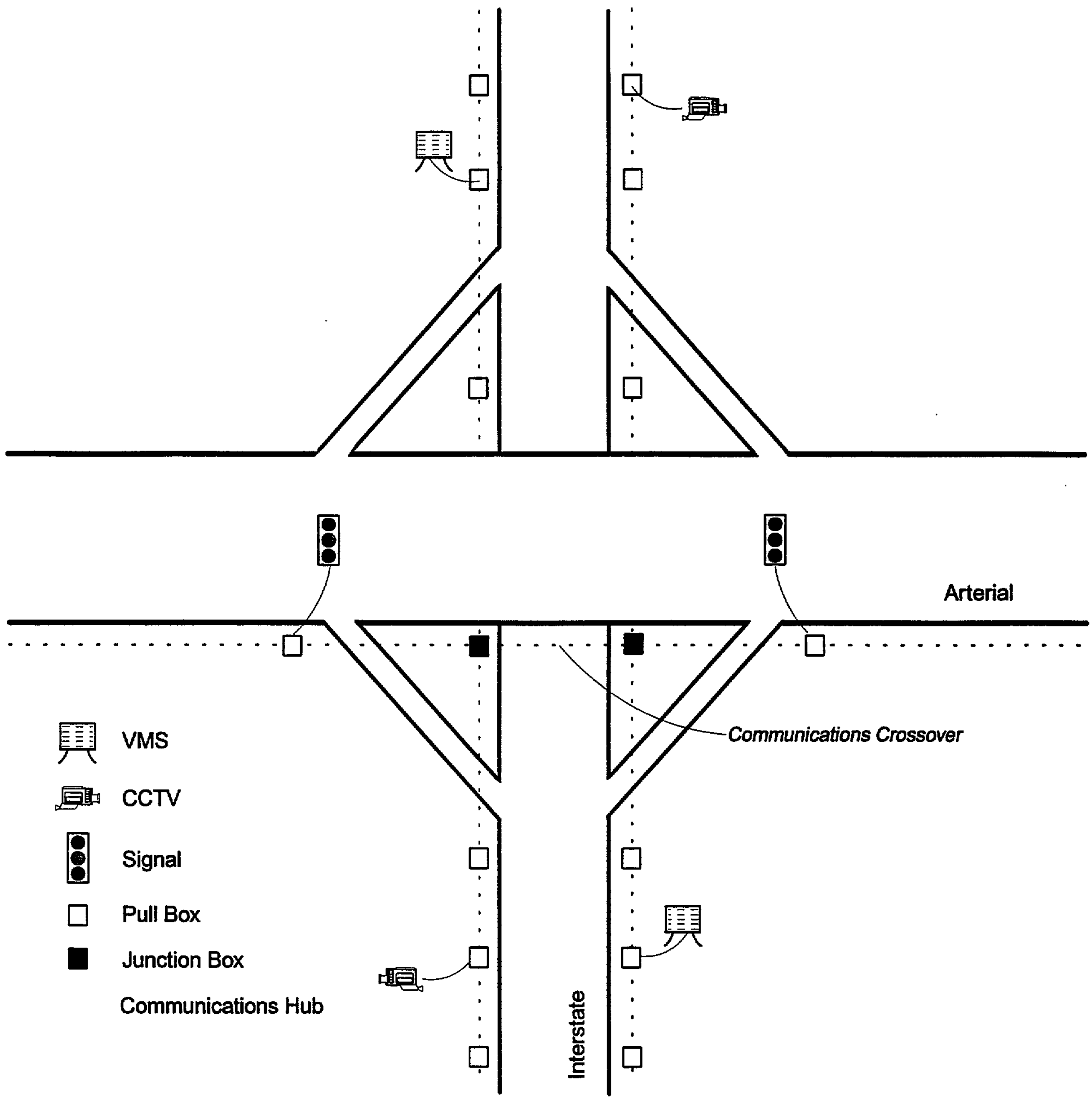


LEGEND

- Backbone Communications Network
- Potential Communications Hub
- County Boundary
- 85 Interstate Highway
- 29 US Highway
- 14 State Highway

BACKBONE COMMUNICATIONS NETWORK IN THE GREENVILLE / SPARTANBURG AREA

Exhibit 3-1



Backbone Communications System
Conceptual Design
Greenville / Spartanburg ATMS

Wilbur Smith Associates

Exhibit 3-2

PLANNED IMPROVEMENT PROJECTS

SCDOT is planning to improve interstate Highway 85 throughout the corridor. The interstate highway segments and the roadway improvements planned for a minimum of six lanes over the next five year period are:

- I-85 between SC 153 and US 276
  Status Under construction upgraded to 6 lane facility with collector/distributor roads. Project designed to accommodate 2 additional future lanes.

- I-85 between US 276 and Pelham Road
  Status Existing 6 lane facility currently in place.

- I-85 between Pelham Road to SC 129
  Status In preliminary engineering design phase (future 6 lane section).

- I-85 between SC 129 to US 221
  Status Under construction as a 6 lane facility. Scheduled for July, 1995 opening to traffic.

- I-385 between Greenville County line and Interchange with US 276
  Status In design phase as a 6 lane section, county line to RD. S-272; 8 lane section RD. S-272 to interchange I-385/US 276.

The backbone or major truck line of the communications system could be implemented in a very cost effective manner by constructing it in conjunction with, and as part of, these roadway improvement projects. When installed as part of a roadway construction project, the cost of installing conduit becomes rather insignificant, amounting basically to the cost of the materials involved.

The trunk line could be constructed as part of planned improvement projects in a variety of ways, ranging from the installation of conduit or duct banks ready to receive the future installation of communication links to the construction of the total proposed communications system or to some in-between level, appropriate to the need. The latter approach is recommended.

Each roadway improvement project for I-85, I-1 85, I-385 and other expressway and freeway facilities should include, at a minimum, the construction of conduit or duct banks for the backbone communications system.

PROPOSED CONSTRUCTION REQUIREMENTS

The party or parties responsible for the design of roadway improvements for I-85 and other limited access highways within the corridor must identify appropriate requirements for the backbone communications system in the construction plans and specifications. These requirements should, as a minimum, include:

- conduit/duct banks;
- pull boxes and junction boxes;
- communication links; and
- design considerations.

A brief discussion of each of these elements are presented in the following sections,

The planned improvements to some portions of the interstate highway and expressway systems may be completed prior to implementation of these designs. In such instances, the backbone communications system will have to be installed as a separate construction project.

Conduits

A minimum of two conduits should be installed in each conduit run or duct bank along limited access facilities. The inside dimension (diameter) of each of the conduits should be at least six inches. These conduits should be composed of polyvinyl chloride (PVC) and / or rigid galvanized steel (GS), as most appropriate for the proposed installation situation.

Conduit runs should be installed outside the shoulder area. This will permit the shoulder to be utilized for maintenance activities. It should also provide a protected area from typical construction activities. In this location, the most serious threat to the safety of conduit runs along limited access facilities should be the installation of Q type signs. It is recommended that conduit runs be installed on both sides of the limited access highways. This will provide system security by providing a second communications path between the ATMS Center and field equipment, as well as a measure of additional or reserve capacity.

Conduits should be installed at each interchange which would connect the mainline conduit runs or duct banks along either side of the limited access highway. These cross connections will be installed under the mainline roadways. Therefore, rigid galvanized steel should be utilized for these conduit runs. The minimum inside diameter of the conduit for these cross connections should also be six inches.

Pull Boxes/Junction Boxes

Pull boxes and junction boxes could be installed underground or above ground. However, due to the clear zone requirement of 30 feet from edge of mainline pavement, it is recommended that underground pull boxes and junction boxes be used. It should be noted that pull boxes or junction boxes used at interchanges should be installed above ground in a protected location. This will be necessary due to the cross connections and the potential communications hub expected at the interchanges.

Pull boxes or junction boxes should be installed every 1000 feet, on the average within the authorized area. This recommended spacing can be varied as needed to permit the installation of pull boxes or junction boxes **at** specifically predefined locations, for example, an interchange. If the location of any components are established prior to the installation of the conduit runs and pull boxes, the spacing could be modified to facilitate implementation of that element.

In rural areas, the distance between pull boxes or junction boxes can be extended from 1,000 feet to 3,000 feet. The need for ATMS devices lessens as the distance from the urban centers increase. The fiber optic cable specified for the backbone communications system must have sufficient tensile strength to be pulled 3,000 feet without subjecting the cable to damage.

Communication Links

A number of communication media could potentially be utilized as the backbone communications system, including:

- wire pair communications;
- coaxial cable communications; and
- fiber optics communications.

After reviewing communications media characteristics and potential future ATMS needs, a backbone communications system utilizing fiber optics communications is recommended. Major elements considered in this review included the capacity, transmission speed, flexibility and expansion capabilities of communications media.

Fiber optics cable offers a communications system which can be installed for voice, data, video and telemetry transmissions without regard to the type of information being transmitted by different elements in the network. Fiber optic cable is also immune to electromagnetic interferences; radio frequency interference; lighting effects: capacitance issues, and impedance matching problems and surges caused by power line faults.

DESIGN CONSIDERATIONS

Subject areas which need to be considered in the design of the backbone communications system are briefly described below.

Conduit

The polyvinyl chloride (PVC) conduit, which is to be installed for the mainline conduit runs or duct banks, should be required to meet Federal Specifications W-C-581 or ASTM D-1785. Rigid galvanized steel (GS), utilized as cross connectors between mainline conduit runs or duct banks, should be required to meet Federal Specification W-C-581 and American Standards Association Specification USAS C-80.1-1966. PVC and GS conduits should comply with the specifications noted or other appropriate specification approved by SCDOT and the local jurisdiction.

Innerduct Due to the planned incremental implementation of the Regional ATMS, the total backbone communications system, particularly the communications cables, will not be installed at the same time. This means that additional cable(s) will have to be pulled through a conduit or portion of a duct bank that is already occupied. In addition to the extra effort required and care which should be exercised in installing a new cable, the cable being pulled can very easily get entangled with the existing cable, resulting in a possible interruption of service.

To protect the operating cables and to facilitate the installation (pulling) of cables, it is recommended that innerducts be installed in each conduit run or duct bank in the backbone communications system. The innerducts will sectionalize the available conduit or duct space, thereby permitting additional cables to be installed without disturbing other cables or interfering with existing operations. Manufacturers recommend that cable being installed in each conduit or duct occupy less than 50 percent of the cross-sectional area of the conduit or duct.

Fiber Optic Cable

Distance and bandwidth are two major considerations as to the fiber to be used in a given application. The length of the longest link in the system is a major factor in the selection of fiber type and size. The amount of information the system will be required to carry (bandwidth) is another major consideration in determining the fiber size.

There are two major classifications of fiber, namely multimode and single-mode fibers. Typically, multimode fiber is better suited for short links and many connectors. Conversely, single-mode fiber is better suited for long distance applications.

In view of the foregoing considerations, single-mode fiber should be installed as the backbone communications system.

Communications Security

To protect against system downtime, equipment can be connected to additional fibers in the same cable. The redundant fibers would be utilized upon failure of the primary fibers. This level of redundancy is considered sufficient for minimizing downtime, except for the case of a cut cable, which should be relatively rare when properly installed and identified.

Redundant routing provides a higher level of security and should be considered when zero downtime is desired. In this instance, devices would be connected to fibers in different cable and using a different routing.

Splicing Methods

Field splicing of fiber optic cable is usually grouped into two major categories fusion splicing and mechanical splicing.

In fusion splicing, the fiber ends are placed under a high resolution monitor and aligned, using precision movement positioners. When aligned, the fiber ends are fused together by a high voltage electric arc. Fusion splicing devices are available which can automatically align the fibers and fuse the fiber ends. Mechanical splicing requires the fiber ends to be aligned to a common centerline which aligns the cores of the cable. The ends are inserted into an alignment tube and butted together. Typically, the fibers are held together by compression or friction.

Fusion splicing requires a larger initial investment in equipment than mechanical splicing. Conversely, the per splice consumable cost is high for mechanical splicing and practically zero for fusion splicing. In view of the anticipated decrease in the cost of fusion equipment coupled with a possible increase in the per splice consumable cost of mechanical splicing, consideration should be given to requiring fusion splicing in the backbone communications system.

Communication Hubs

Connections between ATMS elements, situated outside the limited access facility right of way, and the backbone communications system should be restricted to communication hubs. Along limited access facility these hubs would be located at interchange locations. The interchange area will provide easy access for installation and maintenance. In most instances, the intersecting route will be part of the system and ATMS devices will be installed along it.

Cross connections between conduit runs are proposed for each interchange. This will provide additional capacity, flexibility and redundancy routing, if required, at the interchange area. Junction boxes would be installed to facilitate terminations and splices for required cable branches. In this manner, each interchange could operate as a communications hub site.

Equipment should be provided at each hub, as required, to permit concentration of communications from each element to the Regional ATMS Center. For example, surveillance cameras at a number of remote sites would be transmitted to the hub via different communication links. Equipment at the hub would permit the ATMS Center to select **a** camera(s) for viewing at any particular time. This would reduce the amount of information required to be transmitted simultaneously to the center, thereby reducing communications demand.

A schematic of a typical communications hub equipment cabinet is shown in Exhibit 3-3.

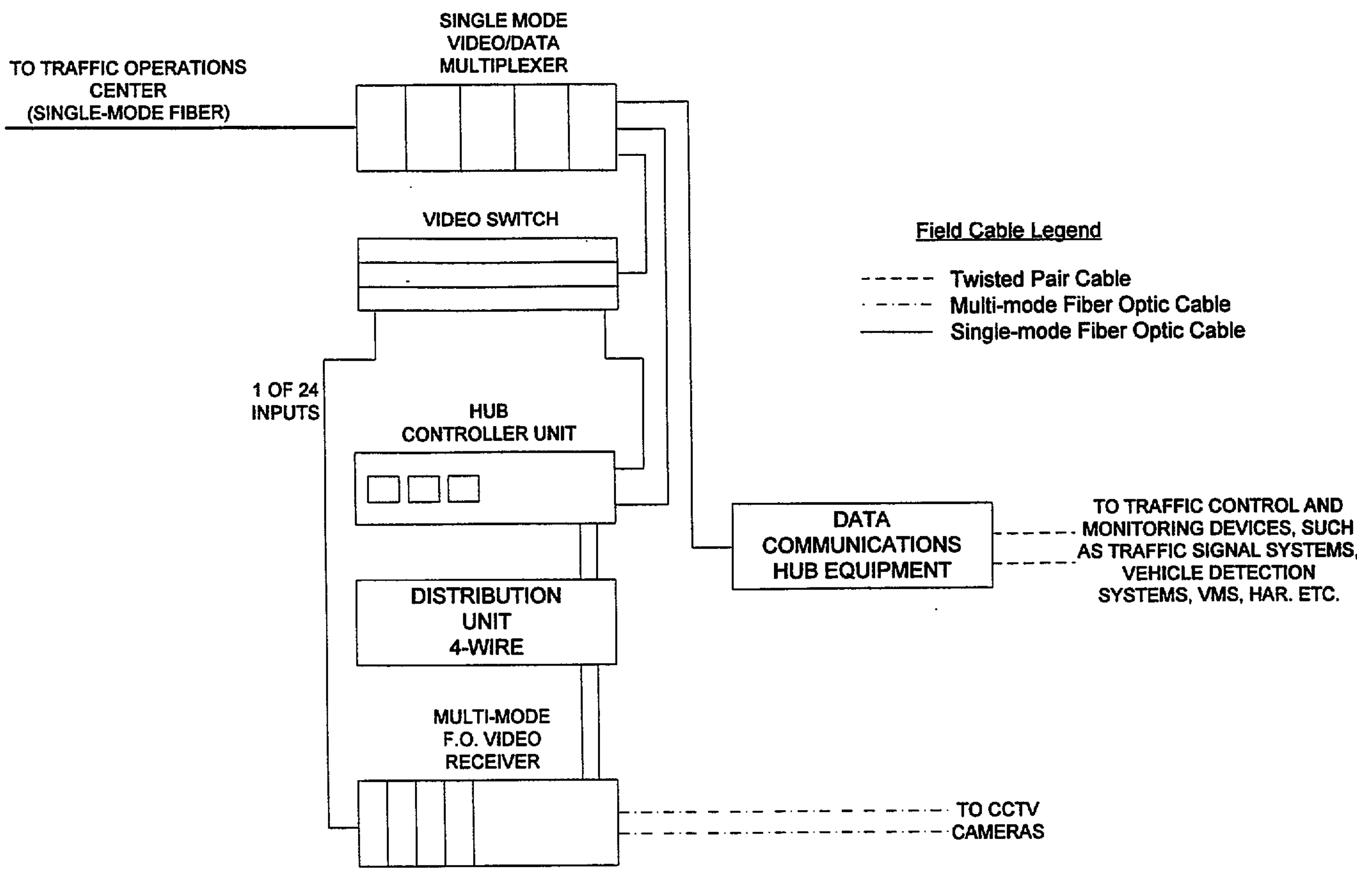


Exhibit 3-3
SCHEMATIC OF COMMUNICATIONS HUB

Section 4
SPARTANBURG I-85 COUPLET

SCDOT has recently completed a new section of I-85 north of Spartanburg which replaces an existing segment of the interstate. The new section was opened to traffic in August 1995. For purposes of distinguishing between the new and old segments, the new 9.5 mile segment will be referred to as "I-85 Bypass." It is understood that the old segment will retain its interstate classification. In this report the old segment is referred to as "I-85 Business."

Now that I-85 Bypass is open to traffic, improvements to I-85 Business will be made to upgrade this facility. This will result in two parallel interstate segments which will allow one to act as a convenient and high quality diversion route when serious incidents block travel lanes and reduce capacity on the other.

OBJECTIVES

The most concise way of describing the objectives of this subtask is to conceptualize methods for utilizing the two I-85 segments to their maximum capability as diversion routes for the other.

With modem technology, their usefulness as co-diversion routes can be greatly enhanced. By forewarning motorists of impending restrictions to traffic flow on either of the highways, the motorists can readily divert to the other.

In its simplest implementation, the warnings would only be indicated prior to the bifurcation points at both the north end and at the south end. In more complex implementations, the warnings would also be provided prior to roadways which intersect both highways so that the diversion could take place after motorists, traveling in either direction, have already committed themselves to one or the other of the highways.

These enhancements to I-85 Bypass and I-85 Business could take the form of:

- Automatic detection of incidents[1];
- Automatic estimation of incident severity;
- Visual confirmation of incidents and their severity;
- Semi-Automatic determination of recommended diversion strategies;
- Semi-automatic generation of diversion information;

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1 With anticipated construction events on I-85 Business in the next few years, "incidents" should be read to include construction events, both scheduled and unscheduled.

- Automatic notification of the South Carolina Highway Patrol (SCHP) of events and actions;
- Semi-automatic monitoring of the incident's clearance status; and
- Semi-automatic return of diversion information to normal after incident is cleared.

STATEMENT OF THE PROBLEM

There are two distinct reasons for considering the diversion of traffic on all or part of the two roadways from one to the other[2]

- An incident (accident, stalled car, enforcement activity) on either road may occur, which disrupts one or more lanes of traffic; and
- A construction or maintenance event occurs which affects one or more lanes of either roadway in either direction.

In either instance, the worst case scenario must include the possibility of the complete closure of both directions of flow on either I-85 Bypass or I-85 Business.

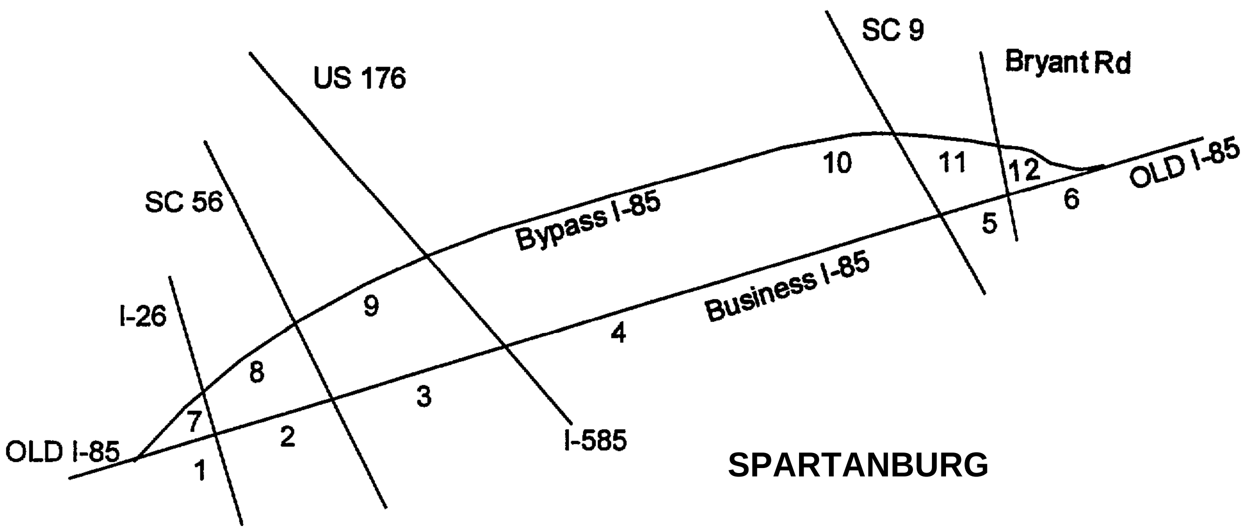
Impact of Incident Location

The location of the problem can lead to a subsidiary set of scenarios:

- If the incident or construction event is <u>before</u> the first linking roadway, the diversion indicator would occur prior to the bifurcation point;
- If the incident or construction event is after the first linking point, diversion would be established:
  - prior to the bifurcation point; and/or
  - prior to the first linking point above the incident/event.

Five roadways cut across the two parallel I-85 segments. These roadways, one of which is an interstate (I-26) provide potential links between the segments and so become potential elements in diversion routes. Exhibits 4-l to 4-4 illustrate various incident diversion points and concepts. The four exhibits indicate diversion routes if all possibilities for locations of incidents were considered. In this "highest cost" scenario, one could envisage Variable Message Signs at each of the diversion points on both freeways and in both directions. In this way, the only motorists who couldn't react to a message would be those who are already on the link on which the incident occurs; i.e., they would not know about the incident until after all of their options were behind them.

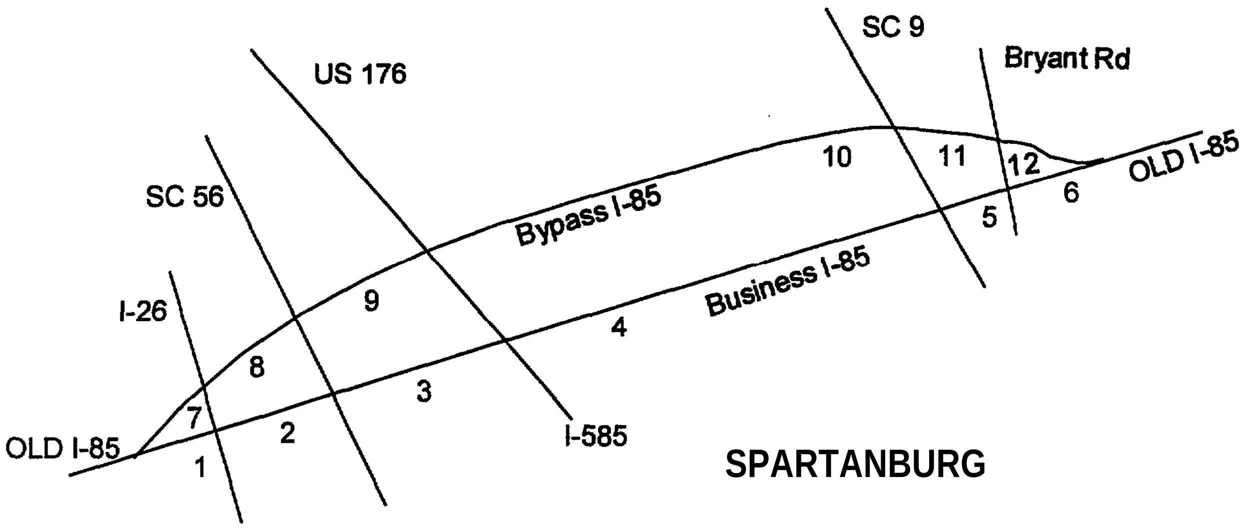
[2] Throughout this discussion, the same logic applies to both directions of traffic flow.



Northbound Business I-85 Traffic - Incident Routes for Incidents at #:

For Incident at	Diversion if Destination is Business I-85	Diversion if Destination is not Business I-85
1	Bypass I-85 to I-26; S. to Business I-85	Use Bypass I-85 all the way
2	I-26 to Bypass I-85; to SC-56; S. to Business I-85	Use Bypass I-85 all the **way**
3	SC-56 to Bypass I-85; to US-176; S. to Business I-85	Use Bypass I-85 all the **way**
4	US-176 to Bypass I-85; to SC-9 S. to Business I-85	Use Bypass I-85 all the way
5	SC-9 to Bypass I-85; to Bryant Rd; S. to Business I-85	Use Bypass I-85 all the way
6	Bryant Rd to Bypass I-85; to Old I-85.	Use Bypass I-85 all the way

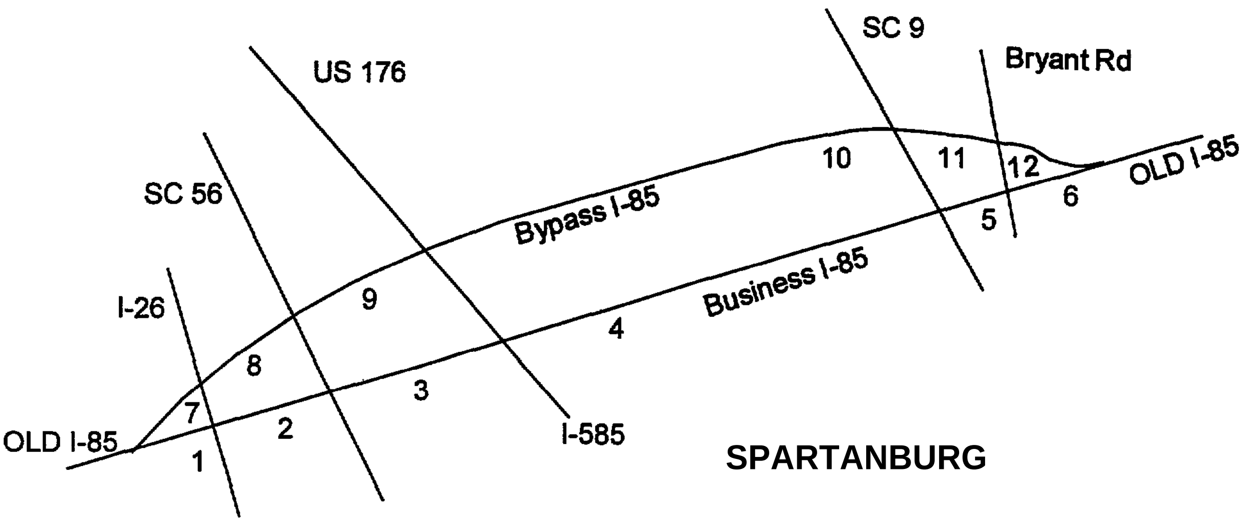
Exhibit 4-1: Incident Diversion Locations (Case 1)



Northbound Bypass I-85 Traffic - Incident Routes for Incidents at #:

For Incident at	Diversion if Destination is Bypass I-85	Diversion if Destination is not Bypass I-85
7	Business I-85 to I-26; N. to Bypass I-85	Use Business I-85 all the way
8	I-26 to Business I-85; to SC-56; N. to Bypass I-85	Use Business I-85 all the way
9	SC-56 to Business I-85; to US-176; N. to Bypass I-85	Use Business I-85 all the way
10	US-176 to Business I-85; to SC-9 N. to Bypass I-85	Use Business I-85 all the way
11	SC-9 to Business I-65; to Bryant Rd; N. to Bypass I-85	Use Business I-85 all the way
12	Bryant Rd to Business I-85; on to Old I-85.	Use Business I-85 all the way

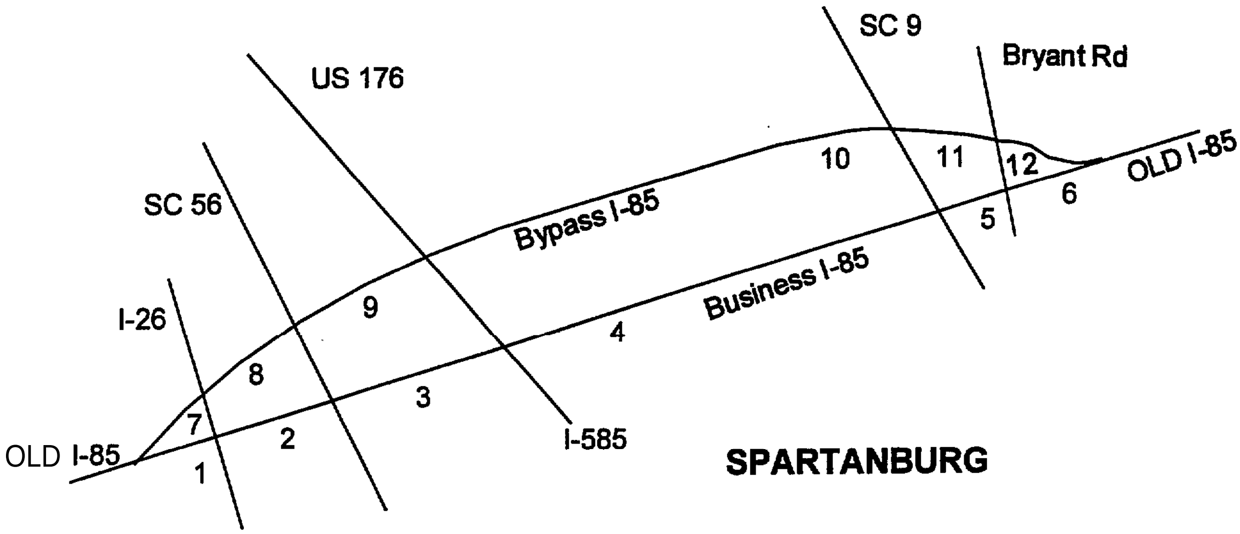
Exhibit 4-2: Incident Diversion Locations (Case 2)



Southbound Business I-85 Traffic - Incident Routes for Incidents at #:

For **Incident at**	**Diversion if Destination is Business I-85**	**Diversion if Destination is not Business I-85**
6	Bypass I-85 to Bryant Rd; S. to Business I-85	Use Bypass I-85 all the way
5	Bryant Rd to Bypass I-85; to SC-9; S. to Business I-85	Use Bypass I-85 all the way
4	SC-9 to Bypass I-85; to US-176; S. to Business I-85	Use Bypass I-85 all the way
3	US-176 to Bypass I-85; to SC-56 S. to Business I-85	Use Bypass I-85 all the way
2	SC-56 to Bypass I-85; to I-26; S. to Business I-85	Use Bypass I-85 all the way
1	I-26 to Bypass I-85; on to Old I-85.	Use Bypass I-85 all the **way**

Exhibit 4-3: Incident Diversion Locations (Case 3)



Southbound Bypass I-85 Traffic - Incident Routes for Incidents at #:

For Incident at	Diversion if Destination is Business I-85	Diversion if Destination is not Bypass I-85
12	Business I-85 to Bryant Rd; N. to Bypass I-85	Use Business I-85 all the way
11	Bryant Rd to Business I-85; to SC-9; N. to Bypass I-85	Use Business I-85 all the way
10	SC-9 to Business I-85; to US-176; N. to Bypass I-85	Use Business I-85 all the way
9	US-176 to Business I-85; to SC-56; N. to Bypass I-85;	Use Business I-85 all the way
8	SC-56 to Business I-85; to I-26; N. to Bypass I-85	Use Business I-85 all the way
7	I-26 to Business I-85; on to Old I-85	Use Business I-85 all the way

Exhibit 4-4: Incident Diversion Locations (Case 4)

Level of Implementation

Three levels of diversion implementation may be considered, namely Full, Mid-range and Basic.

Although full implementation involving all five linking routes might be the "ideal" situation, it is the most expensive and its benefit to cost ratio would probably be low.

A more cost effective scenario (mid-range implementation) would be to choose only 2 of the 5 intersecting roadways to serve as recommended diversion routes. In practice all of the routes would serve as diversion routes for those familiar with the area. The recommended routes, which would appear on the VMS system, would be for those who are not familiar with the area and have no concept of the "best" way to escape a long traffic delay. In this case, US-176 and SC-9 would most likely serve as the logical roads to recommend for diversion.

In its most basic and simplest form, the only formal diversion would occur prior to the bifurcation of I-85 into the Business route and the Bypass Route. Although sensors would be required over both routes, diversion signs would only be needed prior to the decision point is reached at either end. Once again local drivers would doubtless use linking roads to access the other segment of I-85 to avoid an incident, but these would not be identified on VMS.

Complexity of Incident Management Strategies

Referring back to Exhibits 4-l through 4-4, note that a complex incident management strategy is required before recommendations are made to the motorists. The wording on the signs should be developed so that the percentage of drivers who heed the signs can be estimated. For example, a sign which says "minor congestion ahead, exit at US 176" would not have the impact of a sign which says, "Freeway closed ahead; all traffic must exit at US 176."

Thus, the incident management strategy must be capable of combining the information about the capacity of each of the freeway links; the capacity of the closest diversion roadway; and a good estimate of the demand on the restricted freeway; on the diversion roadway and on the recommended freeway links. These factors will all be variable as a function of the time of day, day of week; as a function of the weather; and as a function of maintenance/construction activity on all of the roadways and freeways involved.

It is recommended, therefore, that the central computing system must be capable of accessing and maintaining an appropriate database and that the system be capable of measuring and archiving, for incident management purposes, the demand on all of the links. This data, for a given day will most likely be valid for the corresponding day next year with a certain predictable inflation factor based on other historical data. It should be noted that this concept is identical in structure to the concept required for the collection, archiving and use of street traffic flow data in order to develop timing plans for ATMS systems.

SOLUTIONS TO THE PROBLEM

Some of the processes involved in reducing delays which result from incidents are discussed below, under the following headings:

- Monitoring of Incidents
- Monitoring of Construction Activities
- Communicating with the Road User
- Functions of the Central Site
- Functions of the Dispatcher

A more detailed discussion of specific technologies is provided later in this Section,

Monitoring of Incidents

Detection Automatic incident detection is still in its infancy. Many concepts have been considered and are being evaluated in many projects and in many States. The basic "California Algorithms", which were based on measuring occupancy at an upstream detector station and at a downstream detector station and determining from those measures whether something is obstructing traffic flow between them was the earliest and most tested of the various algorithms. The California algorithms have been heavily criticized because of their high false alarm rate. It is, however, not yet proven that new algorithms, especially those based on speed, will provide any better results.

In any case, since the detectors themselves can only measure speed (or occupancy or presence) they can not, *per se,* detect an incident. A thorough discussion of the state-of-the-art in incident detection equipment and algorithms will be provided later in this section.

Initial Verification An approximate estimate of the severity of an incident can be determined by monitoring the average speed or occupancy across all lanes both upstream and downstream of the incident. The difference in the average values of either speed or occupancy can provide this estimate. Again, it is intuitively obvious that if the incident completely closes off the 'roadway, the speed will be zero upstream of the incident and will be undefined downstream (i.e., there will be no vehicles to measure.) Incidents with lesser severity, for example one that only closes down one lane, will produce low average speeds upstream and high average speeds downstream. By categorizing the speed differences into 4 different groups, the incident severity can estimated as minor, minimal, major or catastrophic.

This technique can be used to prioritize incident severities which occur simultaneously, so as to provide a means of incident response resource allocation. It does not provide the same level of confidence as other methods of verifying incidents and determining their severity.

High Level Verification and Severity Evaluation Following the initial detection of an incident, the current State of the Art is to use Closed Circuit Television (CCTV) to verify that an incident does exist. The viewer can, within a short period of observation, determine a measure of the severity and make an assessment of what aid needs to be called in to handle the situation.

Depending on the time-of-day, the Traffic Operation Center (TOC) dispatcher may also receive one or more cellular calls which might give a better picture of the incidents severity. The value of this information depends, for the most part, on the ability of the caller to comprehend what he is able to see and to remain emotionally uninvolved so that he can give a clear and accurate assessment.

Finally, at some point, enforcement personnel will arrive. At this point, except for peripheral support, the TOC dispatchers role is to provide information to motorists who are approaching the incident or who are already trapped in the resulting traffic jam. The support he can give is to ascertain from on-site enforcement personnel what they believe the situation to be and to use that information, in combination with data in the system's database, to generate information and recommendations to the motoring public, via VMS and other components of ATIS.

Monitoring of Construction Events

Construction on the I-85 business segment will be on-going for the next several years. These construction activities will reduce the capacity of this segment at various times and at various places. These construction events will affect the operation of the couplet as follows:

- Should an incident occur on the bypass, the instructions provided to the motorist will need to be dependent on the capacity remaining in the construction zone(s) along I-85 Business; and
- The location of the construction zone(s) will also have to be considered in these instructions.

Advance Information on Planned Construction Activity Construction activities, normally carefully scheduled and monitored by the Construction Engineering Inspection Team, should be known of far enough in advance so that their effect on the couplet's operation can be predicted in advance and the necessary planning be put into effect so that the dispatcher can make his decisions based on his advanced knowledge of the construction zone's remaining traffic capacity.

This advance knowledge will also provide the dispatcher with sufficient information so that he can modify his motorist information strategy by alerting motorists who might be thinking of using the business roadway to use the bypass because of the construction conditions on the business road. Once more, the dispatcher can use the capacity reduction information in his diversion strategy.

Construction activities, regardless of how well planned, are highly subject to variable conditions often beyond the control of the Contractor. Weather conditions, absence of key material or personnel and/or the consequences of delays from the previous day can seriously handicap the ability to predict accurately real construction events. Therefore, other means must be brought into play to verify construction events.

Real Time (CCTV) Monitoring of Construction Events Fortunately, the CCTV system needed for verification and evaluation of incidents can also be used for evaluating, in real time, construction activities. It will be a function of the dispatcher to:

- use his CCTV system to determine if the actual events are generally following the planned schedule of construction activities. Based on this evaluation, the dispatcher can modify his diversion strategies based on what exists;
- scan the construction zone(s) on a regular basis to determine any new construction activities not previously predicted or noticed; and
- scan the construction zone(s) on a regular basis to determine if there are any non-construction related incidents which require care.

Communicating with the Road User

Two commonly used methods of communicating with travellers are discussed below. Both methods are aimed at drivers who are already enroute and involve roadside infrastructure.

As discussed in Section 6 of the Preliminary Study Report[3] a wide variety of means for disseminating traveller information are potentially available. These means, which may be used in combination with the methods discussed below, include conventional radio and TV media, computer dial-up facilities, monitors in major traffic generators, etc.

Variable Message Signs This discussion will consider the differences between fixed VMS and movable VMS. A fixed VMS is one which is set in place and remains at that location. Such signs are designed for a roadway not likely to have on-going construction which will affect the routes through the area. The size and the amount of information which can be displayed is fixed by the purpose of the sign, its location and the amount of information a driver can assimilate when passing it at high speed, i.e., 55 and 65 mph.

Portable signs, now used heavily by the construction Industry, are not nearly as large as the fixed VMS signs because of their portability requirements. Generally, such portable signs are programmed at the sign by the Contractor. They are designed to be turned on or off either manually or as a function of the time of day. There is no reason why such signs cannot be communicated with by radio. Spread spectrum radio, which avoids FCC licensing problems, would be suitable for this application. Because of the limited sign size, the amount of information which can be displayed on a portable VMS is also limited.

Highway Advisory Radio Highway Advisory Radio (HAR) is the second method for communicating with motorists. It is somewhat less successful than VMS as a means of

3 Greenville/Spartanburg Area Congestion Management Study and Design, Preliminary Study Report, Section 6, Proposed Regional ATMS Concepts, prepared by Wilbur Smith Associates, November 1994.

communication with the driver. Motorists tend not to switch to the necessary frequency band, even if they see some notification that they should do so. In addition, motorist unfamiliarity with HAR is such that they are often beyond the HAR message point by the time they determine how to find the HAR frequency on their radio.

The best usage of HAR for the I-85 Couplet may be to use it at the north end and the south end of the couplet as a general message area, especially when there are incident or construction events. In this usage, a very visible sign would alert motorist to tune to a given HAR frequency. This sign would be illuminated only when there is some occurrence on the couplet that requires alerting the motorist to a condition.

Function of the Central Site

The Central site will serve as the command post for the incident management function. The Central Site is designed to provide information and support to the Incident Management Team which must ultimately make the on-site decisions necessary to save lives, reduce property loss, maintain traffic flow and ensure proper adherence to legal issues.

The Central Site's function is as follows:

- Provide the central information clearing house for detecting, managing and clearing the incident.
- Provide the command and control center for the detection of the incidents, for assisting in the management of the incident, for diverting traffic around the incident, and for clearing the incident.

The Central Site will contain:

- Communication components to:
  - Communicate to and from CCTV cameras;
  - Communicate to and from VMS system;
  - Communicate to and from HAR system;
  - Communicate to and from Construction Management forces;
  - Communicate with SCHP;
  - Communicate with local Disaster Management agency; and
  - Communicate with commercial broadcast stations (radio and TV).
- CCTV controls and monitors:
  - CCTV monitors to view the area as seen by the CCTV cameras; and
  - CCTV controls to point, zoom, focus (etc.).
- VMS control devices for generating messages, imposing pre-generated messages, monitoring the messages displayed;

- Computers to:
  - Perform incident detection algorithm computing functions;
  - Perform CCTV control functions (for detected incidents and construction events);
  - Perform Semi-Automatic Incident Diversion recommendation function; and
  - Perform incident logging function.

Functions of the Dispatcher

The dispatcher's role in incident management is to:

- Be alert for alarms from the Semi-Automatic Incident Detection System;
- Monitor construction schedules for the day;
- Use the CCTV to scan I-85 Business construction zone(s) to verify construction activities;
- Use the CCTV to scan I-85 Business zones where automatic incident detection is not operational (due to construction) to detect incidents as early as possible;
- Ensure that the current conditions are entered properly into the Semi-Automatic Incident Diversion System;
- Respond to the recommendations of the Semi-Automatic Incident Diversion System;
- Use judgment and experience to override the recommendations of the Semi-Automatic Incident Diversion System;
- Monitor the clearance of the incident via CCTV, direct contact with the incident management team, the SCHP, and related elements of the system;
- Enter changes to the existing scenario into the Semi-Automatic Incident Diversion System and monitor its response;
- Monitor variable message signs and HAR to ensure that they are performing their role in the scenario properly;
- Inform the Semi-Automatic Incident Management System (SAIMS) of the end of the incident;
- Based on recommendations of the SAIMS, ensure that all activities associated with the system have been terminated; and
- Ensure that all logs associated with the incident are properly prepared, stored in computer memory and/or printed and properly approved and authenticated.

CONCEPTUAL DESIGN

Conceptually, the ideal system would make provisions for signs and diversion points at each of the possible connectors in the system. More practically, however, it would probably be more cost effective to initially include diversion signs and diversion points at the north end and the south end of the couplet only - the “Basic” level of implementation referred to earlier. This “Basic” concept will be used throughout the following conceptual design discussion.

All research on incident detection up to the present time has indicated that 0.5 mile spacing of detectors (regardless of the type) is the most cost effective method of accomplishing incident detection. A wider spacing between detectors results in a longer response time and a higher probability of missing an incident. Closer spacing leads to higher capital costs and more difficult maintenance problems. Thus, detector spacing of 0.5 mile will be used in this discussion.

CCTV camera locations should be, on the average, 1 mile apart and they should be capable of viewing both directions of the roadway. The one mile spacing provides excellent visibility and provides some overlap between the view as seen by two adjacent cameras. Locating cameras, however, is also a function of the topography of the land on which the road is built and the number of turns and bends in the road. Finally, the CCTV coverage should favor the viewing of interchanges. Therefore, after an initial conceptual placement of cameras based on an average spacing, additional fine tuning of the locations (including adding camera sites) is required.

A number of communication paths will be required by the proposed system, as summarized in Exhibit 4-5.

Exhibit 4-5
DATA RATES FOR SYSTEM COMPONENTS

Device	Direction	Message	Data Rate
Detector	To Central	Speed/occupancy/presence	Quite Low
Detector	From Central	N/A	N/A
Signs	To Central	An indication if the message is displayed and if it is displayed correctly	Quite Low
Signs	From Central	The message to be displayed. This can either be the message itself or it can be a code which instructs the sign controller what to display. It might include both features.	Quite Low

Exhibit 4-5 (Cont)
DATA RATES FOR SYSTEM COMPONENTS

Device	Direction	Message	Data Rate
CCTV	To Central	The Video Signal	High
CCTV	From Central	Pan, Zoom and Tilt	Quite Low
HAR	To Central	**None**	**N/A**
HAR	From Central	Message to be broadcast	Middle

The location of the central site (for dispatcher and for central computations and logging purposes) should be as close to the couplet as possible to ensure reliable communications at the lowest cost. However, with modern communications systems, there is essentially no limitation on the location of the central site.

Key Components

The I-85 couplet's proposed ATIS will consist of many hardware, software and human components. Each must work well with the other.

It is difficult to say which of the many elements is the most important. Certainly, the dispatcher or system operator, is the key element in making the system work. He must evaluate incoming information, some of which may be "noisy" or otherwise suspect; enter some of the data into some type of computerized system which will provide him with additional information; and make instantaneous judgments based on the mass of data available to him.

The incident detection system must have reliable hardware and, just as crucial, effective algorithms for converting the detector data into a form which the dispatcher can readily use to deduce the probability and significance of an incident.

The computer and its database must be able to absorb and display historical data which can be compared against current data and from which diversion recommendations can be deduced.

The system must have some means of communicating its information to the motorist. The information must be clear, concise and understandable in the few seconds that the motorist might have to make the correct decision as to which route to follow.

Finally, the dispatcher must be able to communicate with law enforcement and emergency assistance personnel so that he can be fully "on top" of the situation and can properly respond to events as they unfold as the incident is being processed.

With the emphasis given above to the dispatcher and to communications it is clear that the human interface with the system will be a key factor in the final design of the system. In fact, in one major ITS implementation in Florida, it has been stated that the number of dispatchers required can be reduced from three to one per shift by making the system much more user-friendly.

The Incident Detection Algorithms

It is the function of an incident detection algorithm, located either in a computer at or near the roadway or in the central computer site, to provide the first indication that there is a problem on the freeway system. Where the algorithm's computations are done affects system communication requirements.

A discussion of candidate incident detection algorithms is provided in Appendix A as background to the conceptual or functional design of the incident detection subsystem.

Detection Devices

The three principle detection devices available are:

- Loop detectors & amplifiers
- Radar detectors
- Video Image detectors.

Loop Detection Devices Loop detection is a well known technology. It is widely used for traffic actuated controller operation and traffic responsive traffic control system. A brief discussion of practical aspects of the use of loop detection in incident detection is given below.

Loops for incident detection purposes are invariably installed in each lane of the freeway. In this way, reasonably accurate volumes and occupancies for each lane are collected. In many non-incident detection applications, loops are installed crossing several lanes because the end usage only requires an indication of presence on the approach lanes.

It would be possible to install a loop across all lanes for incident detection purposes as well. The resulting occupancy would be an average. The results would not be accurate. However, as indicated in Connecticut's experience[4], where speed detectors are placed at the side of the road and measure the speed of all of the vehicles on the road, a similar "averaging" effect is achieved. According to the reference, this still results in sufficient accuracy for incident detection purposes. It is not obvious why the same conclusions could not be drawn from using a loop which monitors several lanes and using either the occupancy resulting from this or converting it to speed by the standard volume/occupancy to speed conversion equation.

The system loops should be located every 0.5 mile. They should not be mounted in "pairs"; they should be mounted as individual sensors stations. Instead of detector station "pairs"; there

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4 Mauretz, M. R. and Stoeckert, W. W., "Speed Based Traffic Monitoring: Connecticut's Experience with Radar Detectors," pp *447-453, Proceedings of the /VHS American 1994 Annual Meeting,* April 1994.

will be a continuum of detector stations along a roadway with the downstream detector for one pair being the upstream detector station for the next pair. Thus there will be full coverage with no gaps anywhere along the roadway. The loops can be standard 6 ft x 6 ft loops. Since loop reliability is always a major problem, the loops should be imbedded in the roadway as far as practical.

The loop lead in length can be a concern. However, current loop detector amplifiers operate with extremely long lengths with negligible problems except for decreased sensitivity as the lead-in length increases. Sensitivity (or accuracy of counts) is not an issue in the incident detection equation.

Because of the well-known status of loop detection, no further discussion of it will be given here. Algorithms based on speed have been received with some degree of enthusiasm. Devices to measure speed directly are not as well known as the loop device. Thus, more discussion will be provided here about radar speed measuring devices.

Radar Detection Devices Radar detectors measure speed directly. They operate on the Doppler shift principal. The theory of operation and a discussion of characteristics relevant to implementation, such as spacing, mounting height etc., are provided in Appendix B. The principal characteristics are summarized below, and illustrated in Exhibit 4-6.

Mounting Considerations The following characteristics impact mounting of radar detection devices:

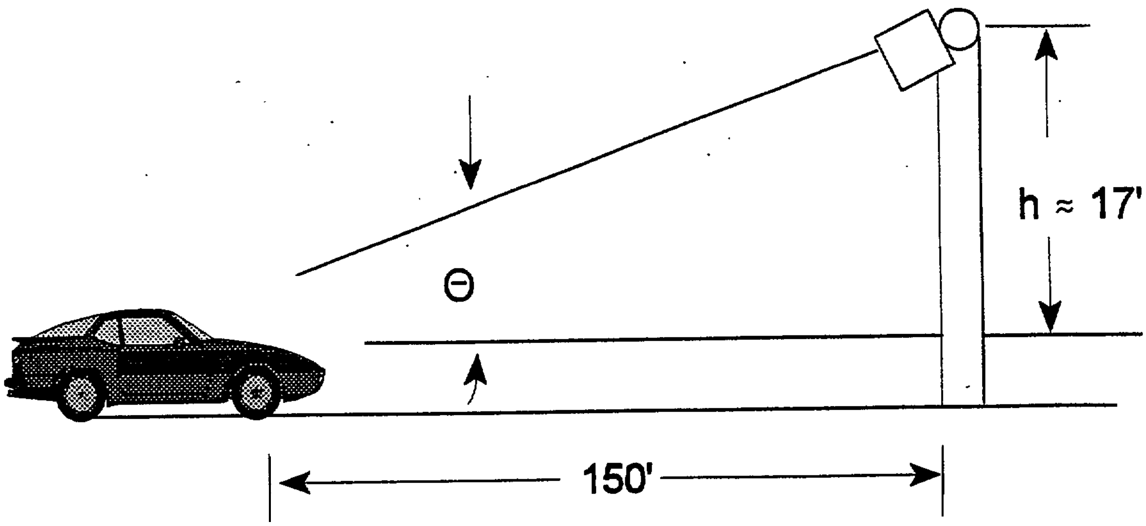
- should be mounted over the roadway, one for each lane of the road;
- can measure speed of vehicles going away from it or approaching it;
- mounting height of 17 to 20 feet is typical, from a sign or overpass bridge; and
- exact spacing of detectors is not critical any spacing in the range of 0.5 to 1 .O miles should be satisfactory.

Design Considerations In designing a radar detection system for a freeway care must be taken to avoid interference between detectors in adjacent lanes or between detectors pointing towards each other through the use of sufficiently different frequencies or other means.

Video Image Detection

Video image detection utilizes a TV camera and complex pattern recognition algorithms to analyze each picture from the camera and deduce from the moving objects the state of traffic flowing on the roadway.

The cost of such techniques are quite high because the camera, the computer and the algorithms needed are all expensive.



Radar Geometry

Exhibit 4-6

The functionality of these devices for the general incident detection process has not yet been proven. However, a number of operational tests are currently underway to examine the effectiveness of video image detection. The device can be used effectively under certain conditions and at certain locations where other types of traffic flow detection cannot or will not operate effectively. While use of video image detection is not assumed in the remainder of this section, its potential role should be re-examined during the design activity to reflect the latest developments in this rapid developing application of video technology.

CCTV Subsystem

A conceptual plan of the system-wide application of CCTV for the I-85 couplet is necessary to support the installation of a dedicated communications network. .The deployment of CCN functions also provides the impetus to fully integrate the various components of an ATIS system.

The implementation of CCTV is a key element in upgrading Incident Management along I-85. Until the I-85 control center operation has the capability to instantaneously verify a suspected incident, to visually assess the required response needs and to monitor the associated trafftc impacts along both the mainline and potential diversion routes, the optimal benefits of automated incident detection cannot be achieved.

Background & General Design Considerations The primary purpose of CCTV is to view as many mainline freeway lanes as possible in order to verify changes in traffic flow conditions and to identify the reasons for such changes. The use of CCTV cameras at strategic intervals along freeways allows the effectiveness of various traffic management strategies to be monitored. CCTV provides aid in confirmation of incidents and allows the various incident response agencies to assess the type of assistance needed to bring the freeway back to normal operation.

CCTV is typically located such that full coverage is provided along freeways for incident management purposes. Depending on mounting height, CCTV can provide up to one mile visibility in all directions. Color cameras are currently the most popular, with improved imaging technologies allowing for satisfactory low-light performance as well. Most cameras have automatic and manual iris controls that carry out this function. CCTV video cameras have adjustments that consist of pan, tilt and zoom functions, all of which are controlled from the traffic management center, either manually or through assigned pre-set views.

A CCTV camera surveillance site, as a minimum, consists of the following basic elements:

- a video camera with appropriate accessories:
- an equipment cabinet to house the video electronics as well as the communication interface equipment;
- power supplies and power signal conditioning as required;
- cabling, connectors, panels and termination equipment; and

- lightning protection system.

Implicit in the CCTV location concept is the fact that, to the extent possible, all equipment cabinets, mounting devices, prime power sources, communication links and other equipment be shared with other components of the such as the VMS and detector subsystems.

General Guidelines - Guidelines for determining CCTV camera site selection were developed and are used by the California Department of Transportation (CALTRANS). However, they are not absolute, and camera placement is determined on a project specific basis after a thorough case analysis. The CALTRANS guidelines are:

1. Establish a clear view of high accident concentration locations. Coverage of weaving and merging areas near ramps and interchanges is critical. The number of cameras required should increase in areas where there is a high rate of incidents.

2. Maximize coverage and visibility of traffic.

3. Provide ready access for maintenance.

4. Provide for visibility of messages on existing and/or planned VMS.
   If feasible, while meeting the primary purpose of CCTV (viewing traffic), placing cameras to allow visual verification of the message being displayed is desirable.

5. Provide overview of traffic flow conditions to gauge motorists' reactions to message.

6. Allow no more than 3.2 km (2 miles) between cameras with good visibility and when warranted by traffic volumes and accidents as just previously discussed.

7. Minimize susceptibility to vandalism.

8. Consider electrical power and communication accessibility.

9. Be sensitive to surrounding neighborhoods (prevent unwarranted views; e.g., provide pan stops).

10. Consider mounting conditions (height, steadiness, etc.).
    - Maintenance personnel prefer lower pole heights for equipment and safety, which can be accessed with small panel trucks. High heights required large personnel hoists.

    - If higher heights are necessary, side access is preferred.

    - Higher poles are not as steady.

    - Most of the time, using higher poles above a roadway does not improve view, especially around the interchanges when it is necessary to see <u>under</u> the structures.

11. Towers are not advisable, if residential areas are in the immediate vicinity, unless a way of screening the camera and tower from the residents' view is possible (see item 9, above).

12. Where sound walls are adjacent to the edge of the pavement, the cameras should be accessed from behind the sound wall. As a last resort, a section of sound wall should be removed to provide maintenance vehicle access.

13. Avoid placement of poles; cabinets, pull boxes, splice vaults, etc., in high speed gore areas.

14. Keep in mind the potential for shared use with other agencies.

15. Maintain some uniformity of locations, at least within sections, so that the operators don't have to make too many adjustments when moving from one camera to another (operator friendliness).

Conceptual Location of CCTVs on the I-85 Couplet In order to meet the guidelines established above, it has been ascertained that a camera density of approximately 1.5 cameras per freeway mile would provide good coverage. Note that this coverage provides for two cameras to see most areas and that additional cameras are provided to see under bridges and around curves and hills where such coverage is more difficult to obtain.

Assuming that the two roadways, I-85 Bypass and I-85 Business, are each 9 miles in length, the total number of cameras is estimated at 27 (2 x 9 x 1.5).

The final design of this couplet will eventually determine the exact camera locations. Involved in the locating of the cameras and beyond the guidelines listed above are the following considerations. Each camera will be specified to have a usable range of at least one mile. This criteria will provide complete surveillance of the coverage area from each camera with plenty of room for overlap. Typically, the operator could view an incident from at least two adjacent cameras.

Cameras, for the most part; should be located on either shoulder along the I-85 Business and Bypass corridor with accessibility to power and communication facilities shared with other components of the regional ATMS.

Should individual signs of the VMS be installed at each of the interchanges, the sign structures can be used as a foundation on which to place the cameras. This reduces the overall cost of the project. However, the downside of this cost-saving concept is that the Control Center operator will not to able to read the VMS signs to visually verify the message being displayed. This may not be a critical issue, especially if the VMS system includes self-monitoring features.

Mounting of CCTV Cameras on the I-85 Couplet Typically, the cameras should not be mounted lower than 20 ft. or higher than 40 ft. The supporting argument was discussed in the general design considerations. However, there are Interchanges with exceptionally high bridges which must be carefully analyzed to determine the effectiveness of utilizing a very high pole for the CCTV camera. This procedure would allow the operator to view the vehicular traffic on the high bridges. This may, optionally, be replaced by a pole mounted on the bridge itself. However, the vibration of the bridge must be carefully considered.

Deflection Requirements The CCTV camera supporting structures must not deflect more than 1.5 inches in any direction with up to 30 mph wind speeds. This deflection must be measured at the top of the support structure at the location where the pan and tilt drive unit is attached to the pole in order to verify this requirement. In addition, camera mounting structures must not be attached directly to a bridge because it is probable that the deflection of the mounting structure when heavy equipment uses the bridge will be greater than the 1.5 inches specified above.

Pole Mounted Cameras - Cameras may be mounted on poles which provide a self standing structure or mounted on a pole attached to or designed into the frame of a VMS or static sign structure. The designer should also specify a pan and tilt unit and 'zoom" capability, in order to provide a wide area of viewing.

The motion picture and TV industries have developed devices to stabilize their cameras. These stabilizing devices are very expensive ($10,000) and not currently appropriate for highway surveillance systems. It is anticipated that such devices will come down in price in the future and may find a place in the Transportation industry.

Cameras Mounted on VMS Signs Where CCTV cameras will be mounted on a proposed VMS sign, consideration should be given in the design to housing the CCTV camera and auxiliary equipment in the same cabinet. The associated cabling for these units should be routed inside the support structure for the CCTV cameras. Furthermore, the specifications must indicate that the support structure not be subject to harmonic vibrations within the range of the environmental conditions specified.

Need for Field Surveys During the final design phase of the CCTV system, a detailed field survey will be required to determine the recommended camera height at each location, to define the coverage area and to finalize the selected overlapping schemes for improved viewing by the Control Center operator.

A cost saving factor is to group the remote camera video signals into a hub to be switched and transmitted to the Control Center Site instead of individually transmitting separate video for each camera site. Each Hub equipment cabinet shall include a video monitor for the maintenance personnel and for troubleshooting purposes.

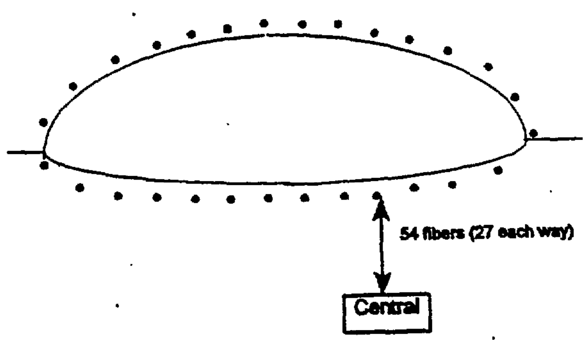
Typical Communication Scenarios Irrespective of the number of cameras that are on the highways, staffing considerations will limit the number of monitors in the I-85 couplet control center to a relatively small number, possibly as low as 3 or 4. For any given incident, the operator can see the incident from two views on two of the monitors and can view the effect of the incident on one or two additional monitors. It is highly unlikely that conditions on the couplet would warrant additional monitoring.

Because of the wide bandwidth requirements of the CCTV system, it is most likely that in the final (overall) I-85 system, fiber optic based communications will be the most effective. For the initial I-85 couplet, there may be other alternatives that can be considered.

With these assumptions in mind, the communication requirements of the CCTV subsystem can be discussed. Four scenarios will be postulated and their pros and cons considered.

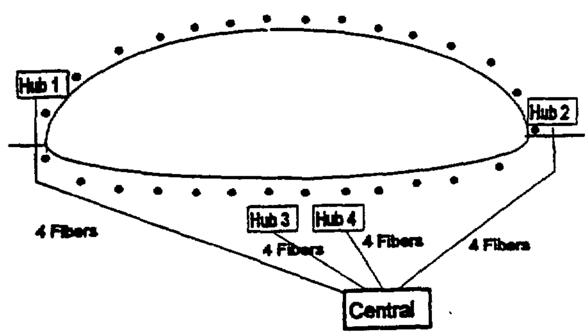
Scenario #1

In this scenario, an individual cable would be run from each camera position to the central site. In addition, there would be (perhaps) the same number of fibers going back to the camera sites. Thus, some 54 fibers would be required for the video, alone.



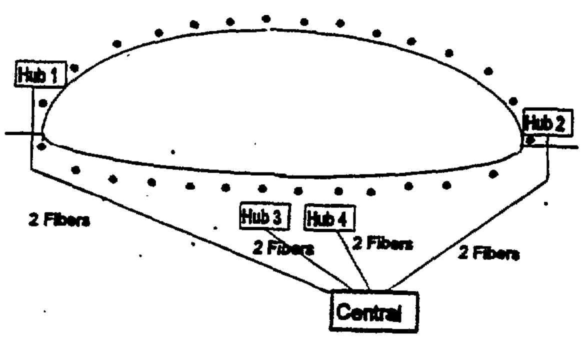
Scenario #2

Run individual fibers from each camera to **a** local hub. The local hub includes a communication "switch" which allows the operator to select which camera's data is to be returned to central. The operator can select any of up to 4 views from any camera and bring them all back to central at the same time for display on 4 terminals. In this case, there would be 7 cables leading into each hub from 7 cameras. There would be seven fibers going back to each camera from each hub. There would be 4 fibers running from each hub to the central site and 4 fibers going back to each hub.



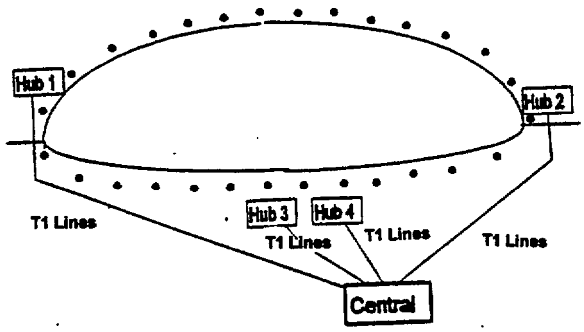
Scenario #3

Run fibers from cameras to various "hubs." The hubs serve as concentrators to "multiplex" the video signals from several cameras (and related equipment) on to a single fiber. The number of such devices is limited to practical considerations. The concentrated data from several devices is then transmitted to the central site for display. Note that the number of fibers from hub to central has been reduced to two.



Scenario #4

Return the data to central over leased T1 lines. Pictorially, this scenario looks the same as Scenario 3 except that the two fiber lines from each hub are replaced by T1 lines, leased from the telephone company. The main advantage that is approach would have would be to utilize leased lines until such time as the complete I-85 system is developed and the final location for the central site is defined. One Tl line is needed for each camera so that if it is required to bring back 4 camera views from each hub, then 4 T1 lines are required. One T1 line is capable of 386 Kbits/second data rate. A video picture appears somewhat "washed out" and jerky with this low data rate. However, it provides adequate performance for most cases.



Preliminary Recommendations for CCTV Communications Any recommendations for a communications network to support CCTV operations on the I-85 couplet must be regarded as tentative at this stage. Final decisions should be made as part of design activities for the project. These decisions will be influenced by a number of factors including:

- status of construction of a backbone communication network; and
- recommendations or guidelines resulting from FHWA's ITS Architecture Development Program.

Decisions on the nature and extent of ITS implementation will be made primarily by state, regional and local agencies, service providers, fleet operators and consumers. To ensure nationwide compatibility of ITS implementation USDOT is developing a common ITS framework a system architecture. The architecture development program is due to be complete by mid-1996.

Of the four scenarios described above two in particular may warrant further consideration depending upon the status of the factors mentioned above:

- Utilize the hub concept with the T1 lines. The hubs will be needed in any future system expansion and/or concept and so will have a role in the ultimate system. The use of T1 lines, though somewhat expensive, will minimize the capital outlay needed to connect the field to the central site until the backbone communications system is constructed; and

- Utilize fiber optic cables with individual fibers to the Traffic Operations Center. If conduit for the backbone communications system is available the use of fiber optic cables is preferred. The use of individual fibers to central avoids costly compression/switching devices in the field at this stage. As the regional ATMS expands and new functions are added, such devices may be integrated into the system to increase the capacity and usefulness of the installed cable plant.

VMS Subsystem

A conceptual plan of the system-wide application of VMS for the I-85 couplet is necessary to support the installation of a dedicated communications background. Obviously, without being able to communicate effectively with the motorists, the system is valueless. Therefore, it must be considered a "given" that VMS subsystems will be used.

Background & General Design Considerations An earlier discussion has indicated that potentially there could be VMS signs prior to each diversion point along the two roadways of the couplet. In addition, VMS signs could be placed at the interchange entrance ramps to inform motorists that they should divert to another route before committing to the freeway entrance.

However, for purposes of the conceptual design of the project, it is assumed that the primary purpose of the system is advise motorists approaching Spartanburg from either direction on I-85 to divert to the other roadway if their planned roadway is partially or completely closed. Therefore, we will consider two VMS signs at either end of couplet.

VMS Considerations There is a great deal of research and practical applications of VMS signs at this time. Current (mid 1995) results of this work leans toward the LED type of sign as gaining favor over the fiber optic sign. However, because the state-of-the-art is changing so rapidly, it is recommended that the selection of the type of sign be made at the latest possible date prior to the system's final design.

The type of sign selected has no effect on the communication subsystem, the CCJV subsystem, or the dispatcher's operation at the central site. Thus, delaying a decision on VMS sign type will not alter the design or concepts of the other subsystems.

VMS Data Rates The VMS subsystem, like the detector subsystem, has very low data rate requirements. The signs can be implemented in 3 ways:

- Provide a series of "canned" messages in the sign. The central system then only has to send to the sign the number of the message to be displayed; i.e., 1 byte plus overhead;
- Only provide the ability to download a message from central as it is needed.
- Provide the option of selecting a "canned" message or downloading a new message.

Undoubtedly the last method of implementation is the one of most interest. It provides the most flexibility and allows the "canned" messages to act as backup in the case of a communication problem.

Another option to consider is the ability to "upload" the data that is being displayed on the sign. In some systems, great care is taken to ensure that a CCTV subsystem camera can view each sign so that the dispatcher can be assured that the sign is displaying the appropriate information.

In either case, however, the data rate is very slow and has very little impact on the design of the communication system.

VMS Recommendations It is recommended that for the I-85 Couplet ATIS implementation, two signs be.installed at the north and south end of the couplet facing oncoming traffic. These signs must be designed so that the messages are clear and concise. Signs must be designed which experience has proven will cause a certain percentage of drivers to divert. When an incident ahead is minor, it may only be necessary for 10 percent of the motorists to divert to an alternate route as opposed to 100 percent when the incident is very severe.

The signs should provide information about here the incident is and the severity. Knowing where the incident is might not help the out-of-state trucker or tourist, but it will greatly help the local population, familiar with the alternate routes, in selecting the best route to bypass the condition.

Central System Requirements for the Couplet

The equipment needed at the central site to support the couplet includes:

- A PC type computer to handle the communication requirements. It is anticipated that keeping this computer separate from the operator's computer will make the operator's task much easier. The communication requirements include:
  - the transmission of sign information, the confirmation that the sign is displaying the right information;
  - the transmission of camera control information; and
  - the receipt of detector data.

It is also recommended that this computer do the incident detection algorithm computations.

- A PC type computer to handle all of the operator interface requirements. This includes displaying information to a screen, the ability to generate sign messages; the ability to modify, if necessary, incident detection algorithms or constants; the display of incident severity, etc.

- A PC type of computer suitable as a database manager. There will be a substantial amount of data shared between the computers. One computer committed to database management, at the current price of computers, is a reasonable requirement.

- All three computers to be interconnected via a LAN. The LAN can be fairly unsophisticated because the system is quite simple. LANTASTIK or lower levels of NOVELL LAN's can be readily used.

- One monitor for each of the computers. Except for the main operator's monitor, they can be monochrome. The main operator's monitor should be color and should be Windows based for ease of operation.

- Four CCTV monitors.

- A "camera steering console, " switched automatically to the cameras to be viewed by the operator, which permits the operator to manual pan, tilt and zoom each camera.

- The communications equipment for the central to field communications.

- A video recorder (perhaps two) so that the operator can log an event on video tape for later playback and analysis.

- Adequate storage and office space for maps, print out of log data, meetings to review incident handling procedures, etc.

Section 5
GREENVILLE DOWNTOWN
ATIS/ATMS

A Greenville sports arena is planned for a site in downtown Greenville. As shown in Exhibit 5-1, the site is bounded by Academy Street, Beattie Place, and Church Street. The arena will seat 17,000. Approximately 600 of the 6,000 parking spaces needed to serve the arena will be provided on site. This deficit of on-site parking will require arena visitors to park in existing public parking lots. As shown in Exhibit 5-1, these are located primarily across Church Street in an area approximately seven blocks long and five blocks wide.

The scattered locations of parking spaces will present a challenge in directing arena visitors to the nearest available parking. Because the existing facilities are all located across Church Street, a major arterial in downtown Greenville, pedestrians crossing Church Street will need to be accommodated. Heavy traffic volumes immediately after, and for some time before, each event will also require efficient traffic operations to minimize traffic congestion impacts. These developments provide the impetus for the implementation of an ATIS/ATMS in the downtown area of Greenville.

DOWNTOWN ATIS AND ATMS OBJECTIVES

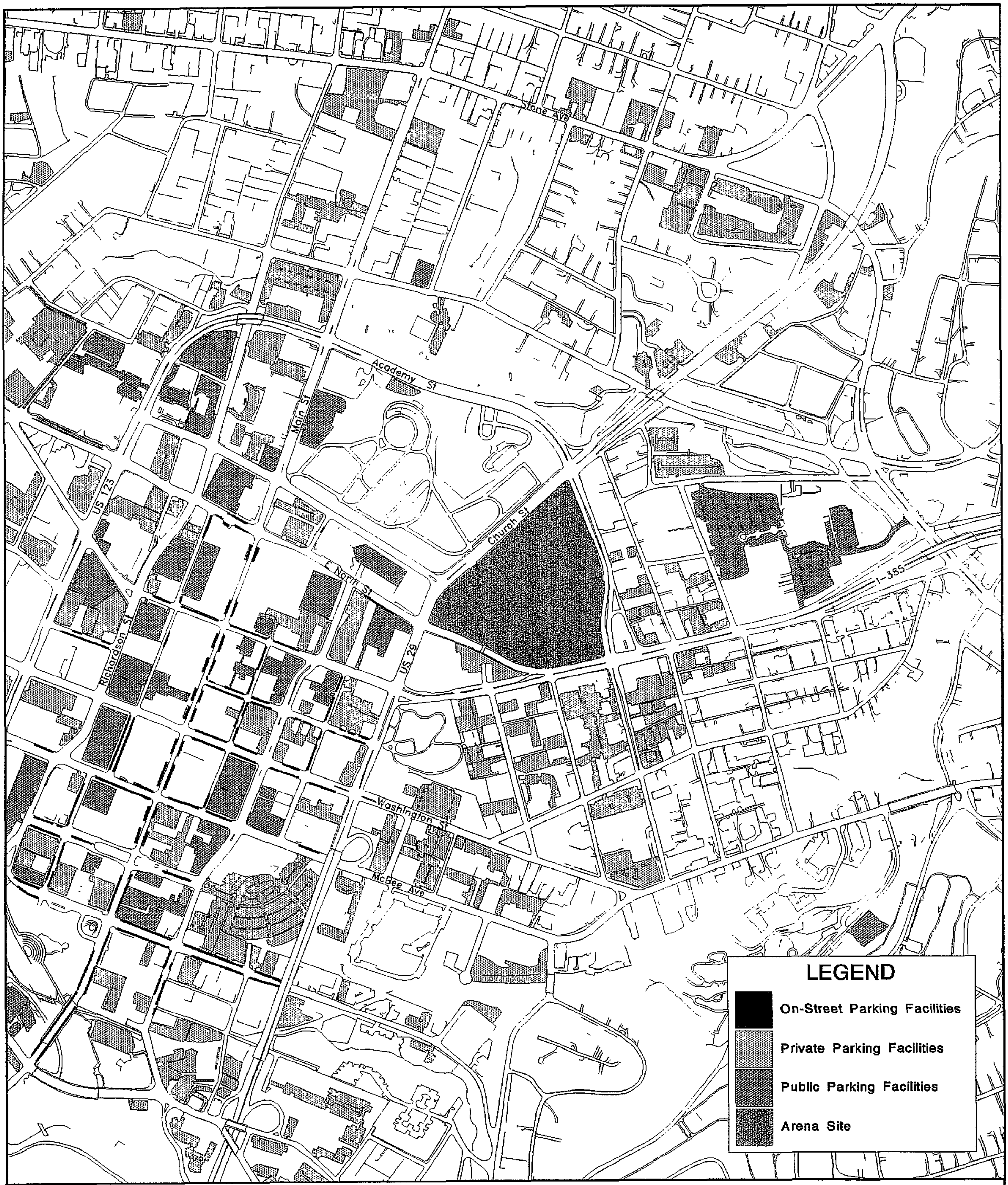
As a result of the situation summarized above, the objectives of an ATIS/ATMS for the Greenville Downtown area would be to:

- advise drivers on interstate highways of approach routes to the arena;
- advise drivers on approach routes of the location of available parking; and
- aid in control of event traffic by allowing imposition of special signal timing plans on the City of Greenville's existing closed loop systems.

The special timing plans designed for arena events will need to make provision for the higher level of pedestrian activity anticipated, as well as heavy, highly directional, traffic volumes. While of particular value during arena events, the Downtown ATIS/ATMS will also assist traffic management functions during normal peak and off-peak traffic conditions.

EXISTING ADVANCED TRAFFIC MANAGEMENT SYSTEMS

Existing usage of signal systems and other components of ATMS in the City of Greenville and surrounding areas is summarized below.



ARENA SITE AND MUNICIPAL PARKING FACILITIES

GREENVILLE, SOUTH CAROLINA

Wilbur Smith Associates

Exhibit 5-1

Traffic Signal Systems

The only existing ATMS in the vicinity of the arena site is the City of Greenville's downtown signal system. The system is made up of four closed loop systems which are operated by four separate masters.

Currently, the four systems operate independently of each other and are referred to as:

- Northwest System;
- CBD North System;
- CCBD South System; and
- Academy/Pendleton System.

Signals within these four systems are shown in Exhibit 5-2.

Three of these systems are all monitored by the same central computer. The Northwest system is on a computer with two other systems, which reach into the downtown area. These are the Stone Avenue System and the Augusta Road System. Portions of the Stone Avenue and Augusta Road Systems are also shown in Exhibit 5-2.

Highway Advisory Radio (HAR) and Variable Message Signs (VMS)

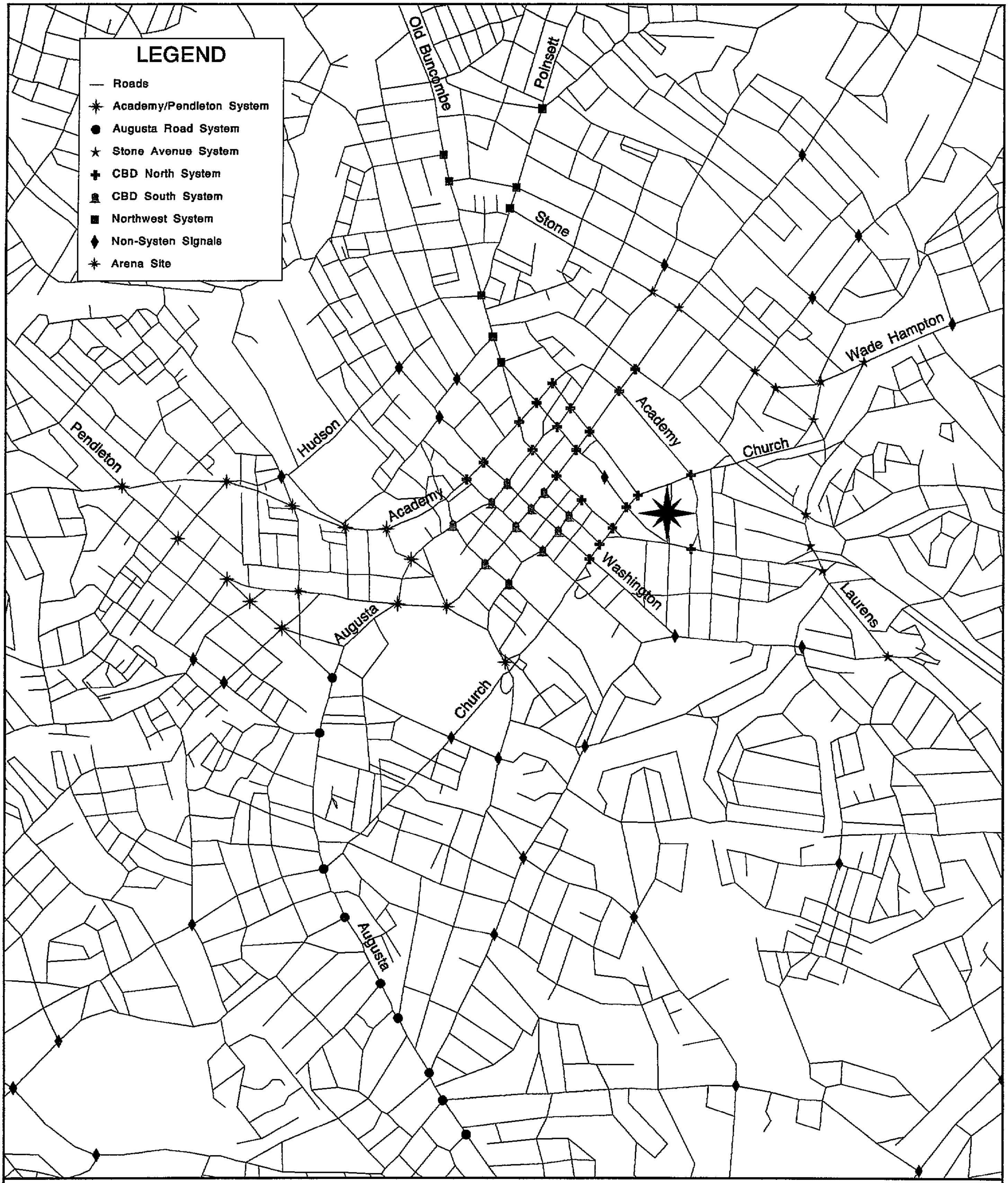
HAR and VMS have been used in Greenville during the reconstruction of I-65 in recent years. However, these methods of conveying information to the driver are not currently used in "normal" conditions in Greenville. School flashers which operate by time-of-day and traffic signal railroad preemption which operates by signals from approaching trains are as close to variable message systems as are used in the area under normal conditions.

The HAR which is being provided during I-85 reconstruction has been provided by the contractor, and the equipment may become the property of the South Carolina Department of Transportation (SCDOT) after construction is complete. Messages can be changed via phone from remote locations.

There are two stations in the I-85 HAR system. One is located at SC 153 for northbound traffic, and the other is located at US 276 for southbound traffic. One station uses the frequency of 1500 on the AM dial while the other uses 600.

GREENVILLE DOWNTOWN ATIS AND ATMS CONCEPTS

Since the scope of this study does not include preliminary design of ATIS and ATMS components, the following discussion is only conceptual. The concepts presented are intended to be used as guides in more detailed planning efforts in the future and as a basis for developing a preliminary cost estimate.



DOWNTOWN SIGNAL SYSTEMS

Greenville, South Carolina

Wilbur Smith Associates

Exhibit 5-2

ATIS/ATMS concepts are discussed under three headings, namely:

- Interstate Driver Information;
- Parking Information VMS; and
- Event Traffic Control Systems.

Interstate Driver Information

Advice to drivers on the interstate highways concerning approach routes to the arena and downtown Greenville could take several forms including:

- Fixed signs;
- Variable Message Signs; and
- Highway Advisory Radio.

Fixed Signs The first of these forms of communication, fixed signs, would be installed by SCDOT. This form of communication would not, however, be considered part of a dynamic ATIS, as the information conveyed would be static.

Variable Message Signs VMS are a potential component of an ATIS, due to their ability to change messages to reflect current conditions. However, the cost of installation and operation of VMS on the interstate highway, specifically for arena traffic may not to be justified since:

- information that does not change, such as directions to the arena, can be provided more cost-effectively on fixed signs; and

- the type and quantity of changeable information needed on interstate approaches to the arena can be provided more efficiently through the use of a medium such as HAR. HAR can also provide drivers with longer and more detailed messages than can be provided by VMS. For normal freeway operating speeds and typical VMS legibility, motorists have about 8 seconds to read a message on a VMS. Consequently, the message must be short. In contrast, a single HAR message can be broadcast over an extended distance such as one mile, allowing messages of up to one minute in length.

Highway Advisory Radio HAR is a means of providing highway and traffic-related messages to drivers via standard AM radio receivers in vehicles. In cases where VMS are not used, instructions about the station on which to set the radio can be given on fixed signs, which can be equipped with flashing beacons to indicate when information is available.

Each HAR station must be licensed for operations. These stations can either be fixed or mobile. For arena information, a fixed site would be preferable. Messages can be live or prerecorded on magnetic tape, synthesized voice systems, or digital voice systems.

Some caution must be issued in a discussion of the use of HAR. In some locations, it simply does not work. However, HAR has been used on I-85 during reconstruction of that route.

In addition, the Federal Communications Commission (FCC) is considering changing its policy of reserving certain frequencies for HAR. That change would allow more powerful commercial radio to have access to those frequencies and could adversely affect the usefulness of HAR. The FCC changes and their impacts would have to be studied carefully before an HAR system could be depended on for long-term use.

An HAR system on the interstate highways for downtown and arena information would require fixed signs, perhaps with flashing beacons, at:

- I-85 northbound south of I-185
- I-85 southbound north of I-385
- I-385 northbound south of I-85

Two separate stations would be needed for northbound and southbound traffic. In fact, the stations currently being used during I-85 construction would be ideally located to provide arena approach information. An additional station closer to the arena could provide information to drivers approaching on non-interstate routes such as Poinsett Highway, Academy Street, Laurens Road, and North Church Street/Wade Hampton Boulevard.

Parking Information VMS

After drivers leave the interstate and approach the arena on arterial streets, they will be travelling at lower speeds. Those lower speeds will allow drivers longer times to read and react to messages on VMS than would be allowed on the interstate. As drivers get closer to the arena, more site specific and up-to-the-minute information, such as can be supplied by VMS, is needed.

The primary objectives of the VMS on approach arterials will be to convey information about the location of available parking. Conveying that information will require:

- VMS on approach routes such as Church Street west, Church Street east, and the I-385 Spur. Two portable VMS would allow some flexibility to communicate to drivers on other routes such as Buncombe/Rutherford and Academy, as needed;
- a mechanism for conveying the occupancy level of the larger garages and lots to a central control center. This mechanism could vary from calls from garage attendants and lot observers to automatic systems for the garages and closed circuit television for the lots;
- a central control center which receives information from the parking garages and lots, determines the appropriate message to be displayed on each route and sends the signal to the VMS as to which message to display; and
- communication among these system components.

Information for Visitors Leaving the Arena

Visitors to the arena who are unfamiliar with downtown Greenville may benefit from guidance on the best routes home. Information could be provided via arena scoreboard facilities, monitors located within the arena or downtown car parks and/or a downtown HAR station.

Event Traffic Control Systems

ATMS requirements for the arena should take advantage of the existing closed loop systems operated by the City of Greenville. Special event signal plans should be prepared for:

- Church Street;
- East North Street;
- Beattie Place;
- Stone Avenue/I-385 Interchange;
- Academy Street; and
- Buncombe/Rutherford.

The signals which would be involved on the roadways listed above are part of four systems:

- CBD North System;
- Academy/Pendleton System;
- Northwest System; and
- Stone Avenue System.

As discussed previously, the first three of the above systems are monitored by the same central computer. However, the Stone Avenue system is monitored by another central computer.

Additional heavy inbound and heavy outbound patterns may need to be added to the existing Laurens Road System.

The requirements for a system which could impose event timing patterns on existing signal systems and monitor traffic flow are:

- additional detectors in the vicinity of the arena;

- software and hardware to allow signals under the control of various masters to work together for purposes of implementing event timing plans;

- closed circuit cameras to verify traffic conditions in the vicinity of the arena -these could possibly be mounted on the arena or the auditorium focusing on East North/Academy, Academy/Church, Church/East North and Church/Beattie;

- communication among detectors, central, and system masters/intersection controllers; and

- central control facilities.

A number of traffic operations issues will also need to be addressed and resolved before requirements for event related traffic signal controls can be finalized. These issues include the relative importance of having the Stone Avenue/I-385 Interchange in the arena ATMS. That importance must be weighed against the effort and long-term operations required to either switch the entire Stone Avenue system to the downtown central or switch the interchange signals to the CBD North System. This would likely require switching Laurens/Washington and Laurens/Ackley from the Stone Avenue System to the Laurens Road System. The configuration of existing systems and the need for flexibility in the assignment of controllers to subsystems is anticipated to be addressed in a separate study.[1]

Further study of projected traffic operations before and after arena events to determine if additional ATMS functions such as variable lane use control will be needed. It is understood that the arena developer is undertaking site impact studies, which will include projections of traffic volume and flow conditions before and after arena events.

CONTROL CENTER FACILITIES

A central control facility will need to be large enough to house monitors for the closed circuit cameras, a central computer for coordination of various signal systems for events, a printer and various support equipment such as a desk for radio, telephone, and other equipment and supplies. Space will, therefore, be one concern in locating the central control center.

An additional concern will be the accessibility to a communications network. The City of Greenville is currently working with communications companies to determine what, if any, projects can be undertaken by these companies to aid in provision of fiber optic communication for public service uses.

One company is examining the possibility of providing the City access to a fiber optic line between City Hall (Broad/Main), Municipal Court (Academy/Main), and the Law Enforcement Center (LEC) (East North/McGee). This line would go by the arena site.

With this line in place, central control for the downtown ATMS could be housed at City Hall or at the arena without installation of fiber optic cable past where "free access" will be available, However, housing the central at either of these locations will result in certain inefficiencies for City of Greenville Traffic Engineering personnel who will operate the ATMS. It is understood that a 10 x 12' office area in the Ensignia Parking Garage between Church Street and Main Street may be available. This represents another alternative location for the control center.

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[1] Greenville Signal System Strategic Plan Study, Commissioned by Greenville County Planning Commission (commenced May 22,1995).

City Traffic Engineering is located on Hudson Street between Welbom Street and Maybeny Street approximately nine blocks from City Hall and approximately 17 blocks from the arena. Besides the time spent in travel back and forth to a control center location away from Traffic Engineering offices, a remote location would not allow work directly with the ATMS and the City Signal Systems without additional communications work.

Working directly with both systems would be possible if the signal system monitoring computers were relocated to a new facility which could also house the arena ATMS control center. That would eliminate the problem of the systems being physically separated but would not eliminate the problem of travel back and forth between the Traffic Engineering offices and a remote, combined control center.

Other factors which must also be considered include:

- the cost of installing a sufficient communications network from City Hall to Traffic Engineering if all central control facilities were located there; and

- the long-term usefulness of Traffic Engineering as a control center as long as it is in a flood zone.

The issues mentioned above, while real, are not insurmountable. As ongoing studies are completed and a long-range strategy for traffic signal systems in Greenville is developed the integration of arena related facilities (VMS, HAR, CCTV, event timing plans) into the City of Greenville traffic control systems should be readily achievable. Such facilities would then have the potential of providing benefits to road users at all times and not be limited to periods immediately before and after arena events.

Section 6
ATIS SYSTEMS DURING IMPROVEMENT PROJECTS

As mentioned in Section 3 of this Report, major improvement projects are planned for sections of I-85 in the Study Area for a number of years to come. These projects will create needed additional capacity and enhance safety in the corridor. They will also provide an opportunity for the construction of key elements of the ATMS backbone communications system in a highly cost-effective manner.

However, the process of implementing major improvement projects in a heavily travelled corridor, such as I-85, is not a painless experience for road users.

OBJECTIVES

During major improvement projects on limited access facilities driving conditions may be degraded as a result of a number of factors, including:

- number and/or width of travel lanes may be reduced;
- paved shoulder may be eliminated or reduced in width;
- uneven roadway surface;
- loss of familiar landmarks, signs, pavement markings etc.;
- temporary lane markings; and
- temporary lane alignments which may have to guide the driver around work zones, or in the extreme case, guide drivers onto the opposite roadway or travel lanes.

Such degraded driving conditions can lead to a lowering of capacity and corresponding increase in the potential for congestion. Such conditions can also lead to an increased risk of accidents, as drivers negotiate their way through essentially "unfamiliar" territory.

SCDOT have a set of standard procedures and practices to be followed by contractors to minimize the risk of accidents involving drivers and construction/maintenance workers at work sites. Can advanced technology be used to further improve traffic operations and safety in work zones?

CONCEPTUAL DESIGNS

Conceptually an ATIS for a major roadway improvement project has many similarities to an ATIS for other corridor applications, such as discussed for the I-85 couplet in Section 4 of this Report. However, the means of implementation are likely to be constrained by the special circumstances found in a construction zone.

Similarities with Other ATIS

As with any ATIS for limited access highways, an ATIS for a major improvement project should be viewed as a key component of Incident Management. Accordingly it shares a number of requirements with other ATIS, including:

- need for accurate detection of incidents;
- ability to verify incident location and severity;
- means to facilitate incident response; and
- ability to provide accurate and timely information to travellers.

The ability to provide rapid and efficient response is always crucial to successful incident management. The reasons are obvious when personal injuries are involved. Even where injuries are not involved the speed of response is also very important in reducing traffic congestion caused by reduced capacity at the incident site.

The importance of a quick response to an incident within the work zone of a major improvement project is magnified by the constraints, frequently encountered, which further limit available capacity until the incident is cleared. These constraints may include:

- absence of a paved shoulder
  - emergency vehicles have no paved shoulder to use to approach the incident if travel lanes are filled by queuing traffic;
  - no paved shoulder is available to "store" damaged vehicles until they can be removed;
  - no paved shoulder is available to park emergency response vehicles;
  - no paved shoulder is available to act as a temporary travel lane if other lanes are blocked;

- reduced width of travel lanes;
  - less roadway capacity is available at the incident site, thus increasing incident clearance time.

Special Considerations

Although the objectives may be similar to other ATIS, the means of implementation of an ATIS within a major improvement project must reflect the special circumstances to be found in a work zone. Chief among these are the temporary nature of the project and the ever changing layout of the work site and roadway.

The special circumstances inherent in a major improvement project favor ATIS components and technologies which are flexible, portable and inexpensive. They should also preferably be reusable either within the permanent ATIS infrastructure at that site or at another temporary ATIS project at another location.

POTENTIAL ATIS COMPONENTS IN AN IMPROVEMENT PROJECT

Alternative technologies for various components of ATIS have been discussed in earlier sections of this Report. Technologies which may be most appropriate for application within an Improvement Project ATIS may include:

- incident detection
  - radar detectors
  - video image processing
- verification
  - CCTV
- communications
  - radio
  - telephone lines
- traveller information
  - portable VMS
  - HAR

Control Center Facilities

Control Center facilities for an ATIS implemented in connection with a interstate highway improvement project are likely to be, by their nature, rather basic and temporary. The facilities, which could be installed in a trailer at the Contractor's work site, could be as simple as a single CCTV monitor, microcomputer, communications equipment and a telephone.

If it is considered necessary to monitor traffic operations through the work zone after the Contractors normal working hours, then arrangements could be made to switch central monitoring and control functions to a facility already manned 24-hours a day such as the Highway Patrol or emergency communications centers. Monitoring of peak traffic flows through the work zone which occurs outside daylight hours, such as the evening peak in winter time, may be warranted due to the increased risk of incidents during such circumstances.

Low Technology Approaches

Not all options for improving traffic flow through major improvement projects or traveller awareness of potential delays need involve advanced technology. Two options which may warrant consideration are:

- increased MAP patrols; and
- tow-trucks on standby.

If a Motorist Assistance Patrol (MAP) service is operated in the vicinity of a major improvement project, then the frequency of patrols could be increased in the work zone area during peak travel periods to minimize the time before a stranded motorist or lane blocking incident is detected.

Similarly, valuable time may be saved by placing a tow-truck on standby near the improvement project. This may be done during peak periods or for longer periods as judged appropriate. Such arrangements would need to be coordinated with the Highway Patrol, who are currently responsible for calling tow trucks to remove vehicles from interstate highways in South Carolina.

Section 7
COST ESTIMATES AND FUNDING

Cost estimates are presented for two initial projects which may be viewed as the first steps towards development of a regional ATMS for the Greenville/Spartanburg area. The projects relate to the Spartanburg I-85 Couplet (see Section 4) and the Greenville Downtown ATMS (see Section 5).

Potential funding sources for implementation of recommendations developed during this study are then discussed.

COST ESTIMATES

Due to funding limitations cost estimates have been developed for initial implementation of two local ATMS projects. If successful, these projects may be expanded over time and form the basis of a region-wide system of traffic and incident management.

Design Options and Assumptions Conceptual designs for these projects have been developed, as described earlier in this report. At the conceptual design level many design options are not determined. They will be defined during detailed design efforts, which are beyond the scope of this study. A summary of design assumptions is therefore included with each cost estimate.

Since design details are not known at this time, cost estimates are provided for a number of options. This is done to provide a likely range of costs and to provide preliminary information for a comparison of technical options inherent in detailed design tasks.

Engineering and Inspection The cost estimates include an allowance for preparation of Plans, Specifications and Estimates (PS&E) at 12 percent of construction costs and for Construction Engineering Inspection (CEI) at 15 percent of construction costs.

SPARTANBURG I-85 COUPLET COST ESTIMATES

Estimates for the Spartanburg I-85 Couplet ATMS focus on initial components which would constitute a Basic system, as defined in Section 4 of this Report. Attention is given to this level of system implementation, rather than the Mid-Range or Full Levels of Implementation due to anticipated budget limitations in coming years.

Estimates are provided for three major types of components, namely:

- VMS System;
- CCTV System; and
- Incident Detection System

These systems, while providing distinct functional capabilities, need not be independent of each other and may share many system resources, such as central computers and communications media.

VMS SYSTEM COST ESTIMATES

It is assumed that due to budget constraints the system is initially limited to two VMS signs. It is also assumed that other measures would have to be taken to keep costs down while at the same time providing a system which is truly helpful to the motoring public and which can serve as a building block for future expansion without the waste of any manpower or equipment. Four approaches to implementation are examined:

- Scenario 1 - Local central with portable signs;
- Scenario 2 - Downtown central with portable signs;
- Scenario 3 - Local central with permanent signs; and
- Scenario 4 - Downtown central with permanent signs.

Cost estimates are presented for each approach. The incremental costs of expanding the system are then discussed.

Two schematic diagrams are provided to illustrate these scenarios:

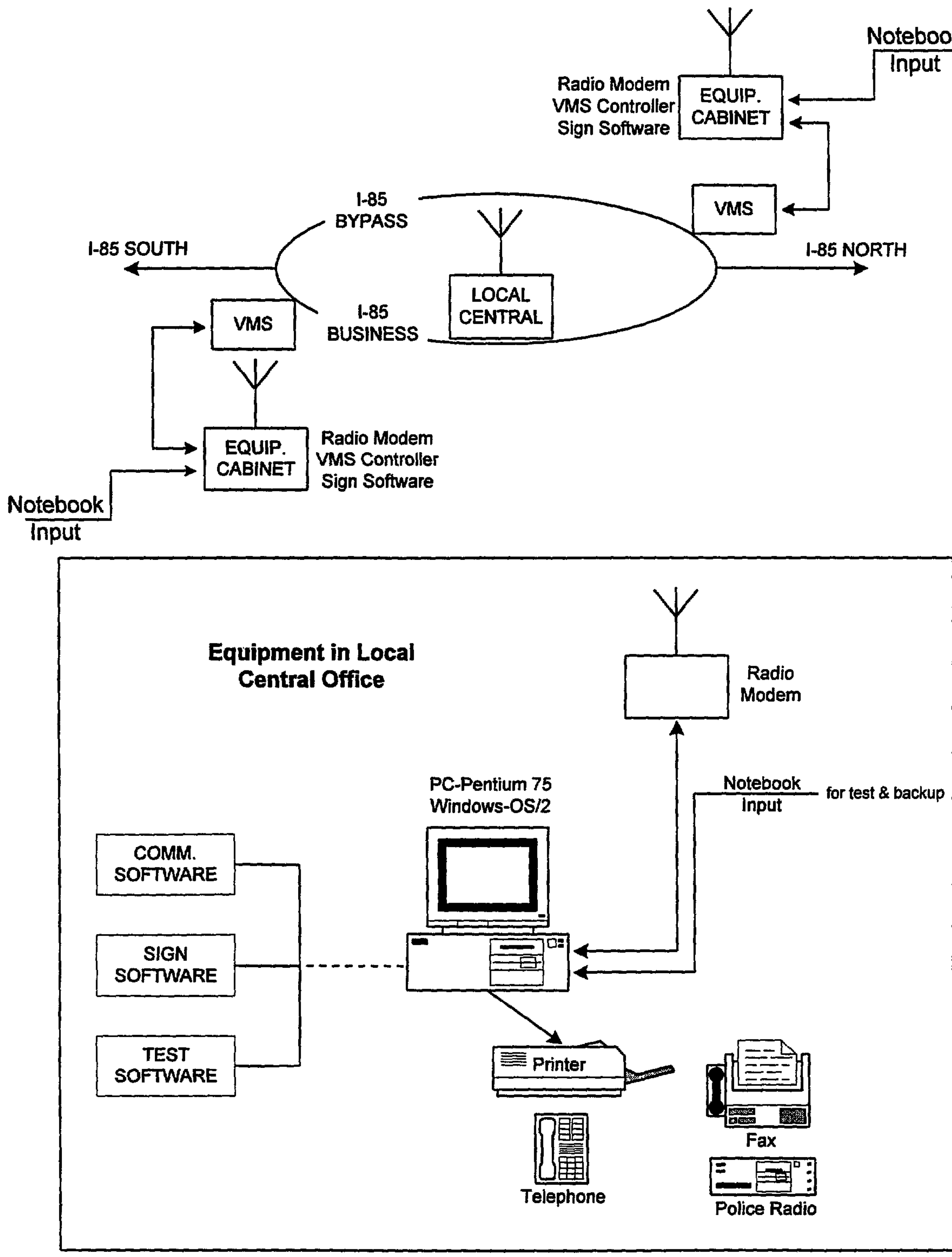
- Exhibit 7-l - VMS Scenarios 1 and 3 with "Local" central office; and
- Exhibit 7-2 - VMS Scenarios 2 and 4 with Downtown central office.

VMS Scenario 1

In this scenario central equipment and functions are assumed to be located close to the l-85 couplet. For the purpose of this estimate it is assumed a trailer would be used to house the central system.

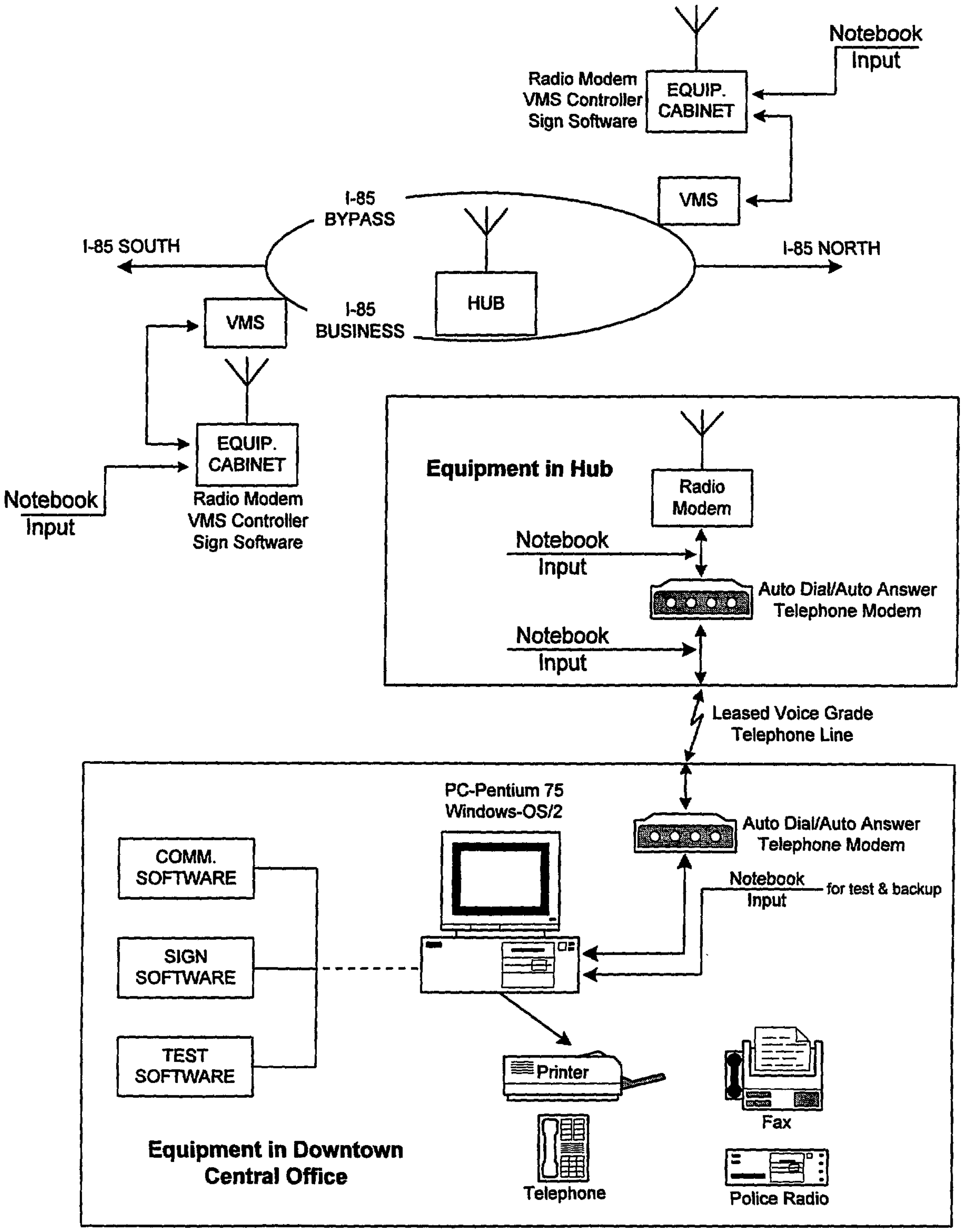
System Concept The concept for this scenario is as follows:

- Provide a trailer located somewhere between the two roadways (l-85 Bypass and l-85 Business) and roughly at the midpoint of the pair.
- Provide two modest signs at either end of the pair. These signs, similar to portable signs used in construction projects, would display a short message such as "divert to Business 85". Other information could be displayed, of course.
- The trailer (central) would have telephone and radio contact with the Highway Patrol and with other emergency operations. Through this information, an operator would be have the ability to create messages or to select "canned" messages applicable to the situation at hand.



VMS Scenarios 1 and 3 with "Local" Central Office
I-85 Couplet

Exhibit 7-1



VMS Scenarios 2 and 4 with Downtown Central Office
I-85 Couplet

Exhibit 7-2

The Central Site The trailer would be equipped with at least the following items:

- A central sign control computer;
- Software for the sign control system;
- A central radio. In the current state of the art, and for temporary purposes, a spread spectrum radio in the 900 to 920 MHZ region would be adequate; and
- Outside of the trailer, an antenna would be mounted. Perhaps the lowest cost implementation for the antenna would be to mount it on a standard high mast lighting pole. A height of 50 to 65 feet would suffice.

For cost estimate purposes radio communication is assumed between the central site and remote sign locations. Alternatives, such as use of the cellular phone network, should be considered for data transmission at the detailed design stage.

Remote Sites The following equipment would be located at each VMS location:

- The variable message sign;
- The sign controller (something like a 170 controller);
- The controller software;
- A radio antenna mounted on the sign. It should be 20 to 30 feet above the ground. The antenna would be of the Yagi type, similar to a standard household TV antenna except much smaller. It would be about l/5 the size of a household antenna; and
- The radio receiver, preferably mounted in the sign - or as close to the antenna as possible. The coaxial cable from the radio to the antenna causes signal strength loss which reduces the range of the radio substantially.

Test and Maintenance Equipment The Contractor will need specialized equipment for installation purposes. The cost of these items might be lumped into the sign cost. If sign maintenance is done by a third party, then the first two items would be supplied by the maintenance organization. The notebook computer and its software would be supplied by the sign vendor.

- 1 Time Domain Reflectometer;
- 1 Oscilloscope;
- 1 Digital Voltmeter; and
- 1 Notebook Computer, supplied by the sign manufacturer to perform sign diagnostics through the sign controller.

Local agencies may already have some of the required test and maintenance equipment. If this is the case, costs for maintenance equipment may be lower than shown.

Flexibility and Expandability This configuration would readily be expandable to additional VMS anywhere in the couplet. The radio system concept “polls” each sign on a regular basis but a sign responds only when it receives its own address. Thus, messages are addressed to an individual sign and the addressed sign displays the message as soon as it is received. The communication between the signs and the central site will include feedback data which ensures the central site that the sign has received the message and the message that it displays is the message it was given.

The radio could either be a type requiring an FCC license or it could be of the spread spectrum type. In either case, the single central radio can be the master control device for many remote signs. It does not seem unreasonable to expect, because of the low data rate required by VMS communication requirements, that up to 50 remote signs could be controlled by one channel. Although a path analysis would be required for each remote site to ensure that adequate signal strength would be available at all times, experience with radios of the type used in this application finds that a range of 5 or 6 miles can be accommodated with a high measure of communication reliability.

VMS Scenario 1 Cost Estimate A cost estimate for Scenario 1, based on the concepts and assumptions described above, is shown in Exhibit 7-3.

In reviewing the cost estimate it is important to recognize those operational costs not included in the estimates. These costs include:

- Property on which the signs and control center are placed;
- Costs of maintenance after acceptance;
- Costs of staffing after acceptance;
- Costs of telephones and radios for maintaining contact with police/emergency agencies; and
- Costs of electrical power.

VMS Scenario 2

Distinct operational benefits are likely to result if the central system is located within an existing agency. This scenario is based on this premise and assumes that the central office is located further away from the couplet than in Scenario 1. A downtown location is assumed.

Desirable attributes for the downtown central office site include:

- It is associated with some other public service entity;
- That perhaps members of the other entity could assist in routine monitoring of the system to ensure it is operating properly and, in case of need, can man the system in order to assist in the resolution of a severe incident on the couplet; and
- Typically, this other public service entity might be:
  - The highway patrol;
  - State, County or City agency;
  - A private organization hired by the State to operate the system;
  - 911 or a similar emergency management organization; or
  - Combinations of the above.

Exhibit 73
Cost Estimate for VMS Scenario 1
Local Central with Portable Signs

ITEM	COST
Construction (Furnish and Install)	
Central	
■ Trailer 1 @ $15,000	$15,000
■ Central sign control computer; 1 @ $4,000	4,000
■ Software for the sign control system: 1 @ $10,000	10,000
■ Central radio; 1 @ $4,000	4,000
■ High Mast Lighting Pole for the Antenna; 1 @ $ 15,000	15,000
. ■ Central antenna and coax cable lead in; 1 @ $1,000	1,000
■ Power & Telephone Connections to trailer; 1 LS @ $1,000	1,000
■ Training and Documentation; 1 LS @ $4,000	4.000
	$54,000
Remote Sites (Two\	
■ Small, portable variable message sign; 2 @ $50,000	100,000
■ Sign controller; 2 @ $8,000	16,000
■ Controller software (included above)	
■ Notebook computer (for local control of the sign); 1 @ $3,000	3,000
■ Radio antenna mounted on the sign; 2 @ $500	1,000
■ Radio transmitter/receiver; 2 @ $4,000	8.000
	$128,000
Test and Maintenance Equipment	
■ 1 Time Domain Reflectometer @ $8,000	8,000
■ 1 oscilloscope @ $8,000	8,000
■ 1 digital voltmeter @$200	200
	$16,200
Total Construction Costs	**$198,200**
Engineering & Inspection Costs	
PS&E Costs (at 12% of the construction costs)	$23,800
CEI costs (at 15% of the construction costs)	29,700
Total Engineering & Inspection Costs	**$53,500**
Total Project Costs	**$251,700**

System Concept The only difference between this concept and the one described above is that the central site would be remote from the couplet. When this type of configuration arises, it is necessary to think in terms of a "hub". A hub is an unmanned site which serves as **a** way station for the transfer of messages between the central site and the remote sites. Typically, a "hub" might be an equipment cabinet or it might be a small building.

The Central Site Characteristics of the central office are summarized below:

- The central site control room would have sufficient space for the following equipment:
  - A central sign control computer.
  - Software for the sign control system.
  - A leased voice grade telephone line connecting the central site to a "hub" located in the area of the couplet.

- The central site would have telephone and radio contact with the Highway Patrol and with other emergency operations; and

- The central would communicate with the intermediary "hub" instead of directly to the signs. The primary reason for this is that radios of the kind used for this purpose would probably not provide the radio range to communicate directly with each sign. In addition, the "hub" concept provides a valuable resource for other portions of an ITS, i.e., cameras and detectors.

The Hub Site In this scenario the hub could be a conventional traffic control cabinet. It would contain the central site radio as discussed in Scenario 1, above. The computers would not be located there, but would be located at the central site. Communication between the central site and the hub would be over a standard leased voice grade telephone line. The communication data rate for at least the first two signs would not require more than this type of communication service. When CCTV is added, the data rate becomes substantially higher and the communication concepts tend to become more complex.

The hub would contain a dial up modem. The central site would dial the hub and, after communication handshaking is established, would transmit data via the modem, through the radio and then on to the particular sign being addressed.

The Remote Sites The remote sites would be identical to those discussed in VMS Scenario I, above.

Test and Maintenance Equipment The test and maintenance equipment would be identical to that discussed in VMS Scenario 1, above.

Flexibility and Expandability The system would provide the same degree of flexibility and expandability as in VMS Scenario 1.

<u>VMS Scenario 2 Cost Estimates</u> A cost estimate for Scenario 2 is shown in Exhibit 74. As with Scenario 1 these cost estimates do not include operational costs related to staff, power, telephones etc. They also do not include rent for office space.

VMS Scenario 3

The projects depicted by the above two scenarios would be very limited; the variable message signs themselves would be very limiting. Large permanent VMS could be installed at either end of the couplet to provide a wide range of motorist information. Such signs are more costly then the portable signs assumed in Scenarios 1 and 2.

A large VMS, capable of displaying 3 lines of 24 characters per line, would cost in the order of $100,000 each. In addition, the sign structure might cost from $ 50,000 to $ 100,000 depending on the type of sign and structure used. The lower end of this range is assumed for estimation purposes.

There would be no additional costs for computers, software, etc. There will be additional costs in the area of PS&E and CEI. For instance, sign bridges often require a soil analysis during the PS&E phase to ensure structural integrity.

Scenario 3 assumes use of two permanent VMS signs and use of a local (trailer) central office site. A cost estimate for Scenario 3 is shown in Exhibit 7-5.

VMS Scenario 4

This scenario combines the permanent VMS signs used in VMS Scenario 3 with the more remote (downtown) central office location of VMS Scenario 2. A cost estimate for Scenario 4 is shown in Exhibit 7-6.

Summary of VMS Scenario Costs

A comparison of costs for the four scenarios is given in Exhibit 7-7.

Exhibit 7-4
Cost Estimate for VMS Scenario 2
Downtown Central with Portable Signs

ITEM	COST
Construction (Furnish & Install)	
Central	
- Central sign control computer; 1 @ $4,000	$4,000
■ Software for the sign control system; 1 @ $10,000	10,000
■ Training and Documentation; 1 LS @ $4,000	4,000
■ Refurbish and existing room in existing building; LS @ $4,000	4,000
	$22,000
Hub (One)	
- Equipment cabinet; 1 @ $2,000	2,000
■ Central radio; 1 @ $4,000	4,000
■ High Mast Lighting Pole for the Antenna; 1 @ $15,000	15,000
■ Central antenna and coax cable lead in; 1 @ $1,000	1,000
■ Power & Telephone Connections to cabinet; 1 LS @ $1,000	1,000
	$23,000
Remote Sites (Two)	
Same configuration and costs as provided in Scenario 1	$126,000
Test and Maintenance Equipment	
Same as provided for Scenario 1	$16,200
Total Construction Costs	**$189,200**
Engineering & Inspection Costs	
PS&E Costs (at 12% of the construction costs)	$22,700
CEI Costs (at 15% of the construction costs)	$28,400
Total Engineering & Inspection Costs	**$51,100**
TOTAL PROJECT COSTS	**$240,300**

Exhibit 7- 5
Cost Estimate for VMS Scenario 3
Local Central with Permanent Signs

ITEM	**COST**
Construction (Furnish and Install)	
Central	
■ Trailer 1 @ $15,000	$15,000
■ Central sign control computer; 1 @ $4,000	4,000
■ Software for the sign control system; 1 @ $10,000	10,000
■ Central radio; 1 @ $4,000	4,000
■ High Mast Lighting Pole for the Antenna; 1 @ $15,000	15,000
- Central antenna and coax cable lead in; 1 @ $1,000	1,000
■ Power & Telephone Connections to trailer; 1 LS @ $1,000	1,000
- Training and Documentation; 1 LS @ $4,000	4,000
	$54,000
Remote Sites (Two)	
■ Large, permanent variable message sign; 2 @ $150,000	$300,000
■ Sign controller; 2 @ $8,000	16,000
■ Controller software (included above)	
- Notebook computer (for local control of the sign): 1 @ $3,000	3,000
- Radio antenna mounted on the sign; 2 @ $500	1,000
- Radio transmitter/receiver; 2 @ 34,000	8,000
	$328,000
Test and Maintenance Eauipment	
■ 1 Time Domain Reflectometer @ $8,000	$8,000
■ 1 oscilloscope @ $8,000	8,000
■ 1 digital voltmeter @ $200	
	$16,200
Total Construction Costs	**$398,200**
Engineering & Inspection Costs	
PS&E Costs (at 12% of the construction costs)	647,800
CEI Costs (at 15% of the construction costs)	59,700
Total Engineering & Inspection Costs	**$107,500**
Total Project Costs	**$505,700**

Exhibit 7- 6
Cost Estimate for VMS Scenario 4
Downtown Central with Permanent Signs

ITEM	COST
Construction (Furnish and Install)	
Central	
- Central sign control computer; 1@ $4,000	$4,000
■ Software for the sign control system; 1 @ $10,000	10,000
■ Training and Documentation; 1 LS @ $4,000	4,000
■ Refurbish and existing room in existing building; LS @ $4,000	4,000
	$22,000
Hub (One)	
■ Equipment cabinet; 1 @ $2,000	$2,000
■ Central radio; 1 @ $4,000	4,000
- High Mast Lighting Pole for the Antenna; 1 @ $15,000	15,000
■ Central antenna and coax cable lead in; 1 @ $1,000	1,000
■ Power & Telephone Connections to cabinet; 1 LS @ $1,000	1.000
	$23,000
Remote Site (Two)	
Same configuration and costs as provided in VMS Scenario 3	$328,000
Test and Maintenance Equipment	
Same configuration and costs as provided in VMS Scenario 3	$16,200
Total Construction Costs	**$389,200**
Engineering & Inspection Costs	
PS&E Costs (at 12% of the construction costs)	$46,700
CEI Costs (at 15% of the construction costs)	58.400
Total Engineering & Inspection Costs	**$105,100**
Total Project Costs	**$494,300**

Exhibit 7-7
Comparison of VMS Scenario Costs

Scenario	Description	Project Cost
1	Local central (trailer) with portable signs	$251,700
2	Downtown central with portable signs	$240,300
3	Local central (trailer) with permanent signs	$505,700
4	Downtown central with permanent signs	$494,300

Costs are similar whether the central system is located locally to the I-85 couplet in a trailer, or located in an existing office of a suitable agency in the downtown area of Spartanburg. The costs associated with a trailer in Scenarios 1 and 3 are offset to some extent by the need for a field equipment hub in Scenarios 2 and 4. The location of the central system should therefore be based on operational and other issues. As noted earlier, the center should ideally be located within existing offices of an agency related to its traffic management/safety functions. This would facilitate part-time or "as needed" operational staff, as appropriate for the initial small-scale system.

The major cost components in the proposed VMS system scenarios are the signs themselves, ranging from $50,000 each for portable signs to $150,000 each for permanent signs (including supports). Using radio, communication costs are not a major factor in total project costs. This permits a VMS system to be installed prior to the establishment of a fiber optic backbone communications network, if necessary. When such a network is implemented, only a small portion of the investment in the initial VMS system will become redundant.

VMS System Expansion The VMS system concepts described above allow for system expansion. Portable signs installed with Scenarios 1 or 2 could be replaced with permanent signs at a later date to form Scenarios 3 or 4. Additional signs could be easily added. The initial implementation provides all central equipment and software required for an expanded system of signs. To add a sign it is only necessary to furnish and install the VMS and remote radio.

The cost estimates for the addition of one portable sign and one permanent sign are shown in Exhibit 7-8 and 7-9, respectively.

CCTV SYSTEM COST ESTIMATES

In developing cost estimates for a Closed Circuit Television (CCTV) system for the I-65 couplet, it is again assumed that budget constraints severely limit the scale of initial implementation. For cost estimate purposes it is assumed that two remote CCTV cameras are installed initially.

Exhibit 7- 9
Cost Estimate for Additional Portable VMS Sign

ITEM	COST
Construction (Furnish and Install)	
■ Small portable sign; 1 @ $50,000	$50,000
■ The sign controller; 1 @ $8,000	8,000
■ Controller software (included above)	
■ Radio antenna mounted on the sign; 1 @ $500	500
■ Radio transmitter/receiver; 1 @ $4,000	4,000
Construction cost per portable sign	**$62,500**
Engineering and Inspection Costs	
PS&E Costs (at 12% of the construction costs)	$7,500
CEI Costs (at 15% of the construction costs)	9,400
Engineering and Inspection Cost per Portable Sign	$16,900
Total Cost for Each Additional Portable Sign	**$79,400**

Exhibit 7- 9
Cost Estimate for Additional Permanent VMS Sign

ITEM	COST
Construction (Furnish and Install)	
■ Large, permanent sign; 1 @ $150,000	$150,000
■ The sign controller; 1 @ $8,000	8,000
■ Controller software (included above)	
■ Radio antenna mounted on the sign; 1 @ $500	500
■ Radio transmitter/receiver; 1 @ $4,000	4,000
Construction cost per large permanent sign	**$162,500**
Engineering and Inspection Costs	
PS&E Costs (at 12% of the construction costs)	$19,500
CEI Costs (at 15% of the construction costs)	24,400
Engineering and Inspection Costs	**$43,900**
Total Cost for Each Additional Large Permanent Sign	**$206,400**

In discussing CCTV concepts it is assumed that the CCTV system will be installed in conjunction with or following installation of a VMS system. Where components are required by both systems the costs are shown in the cost estimate for the VMS system.

Communication Options A high performance telephone channel leased from the telephone company, called **a** T1 channel, can provide an adequate, but not spectacular transmission medium for video signals. Radio, in theory, can be used. Unfortunately there are not adequate available channels to permit such an operation. Installation of fiber optic cable, is, of course, a real possibility providing high quality and abundant expansion capacity. However, the installation costs are quite high.

Costs are estimated for leased T1 lines and user-owned fiber optic cable. The impact of a local or downtown control center is also examined, yielding a total of five scenarios:

- Scenario 1 - Local central with leased T1 lines;
- Scenario 2 - Downtown central with leased T1 lines;
- Scenario 3 - Local central with user-owned fiber;
- Scenario 4 - Downtown central with user-owned fiber; and
- Scenario 5 - Downtown central with combination leased/user owned lines.

Two schematic diagrams are provided to illustrate these scenarios:

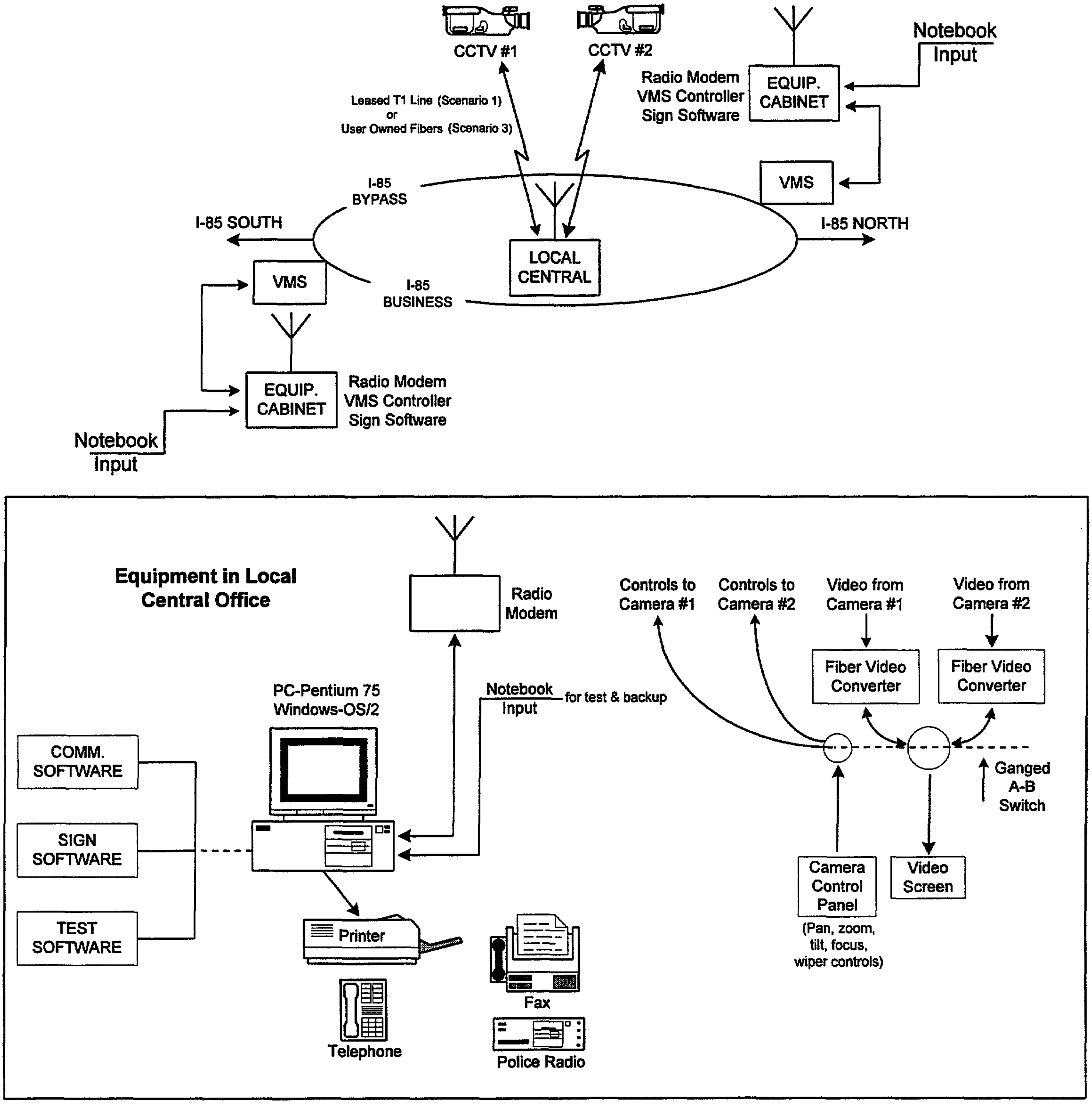
- Exhibit 7-10 - CCTV Scenarios 1 and 3 with "Local" central office; and
- Exhibit 7-l 1 - CCTV Scenarios 2,4 and 5 with Downtown central office.

CCTV Scenario 1

In this scenario central equipment and functions are assumed to be located close to the I-85 couplet, in the same location (trailer) as the central VMS system in VMS Scenario 1. Communications between central and remote equipment is achieved through leased T1 lines.

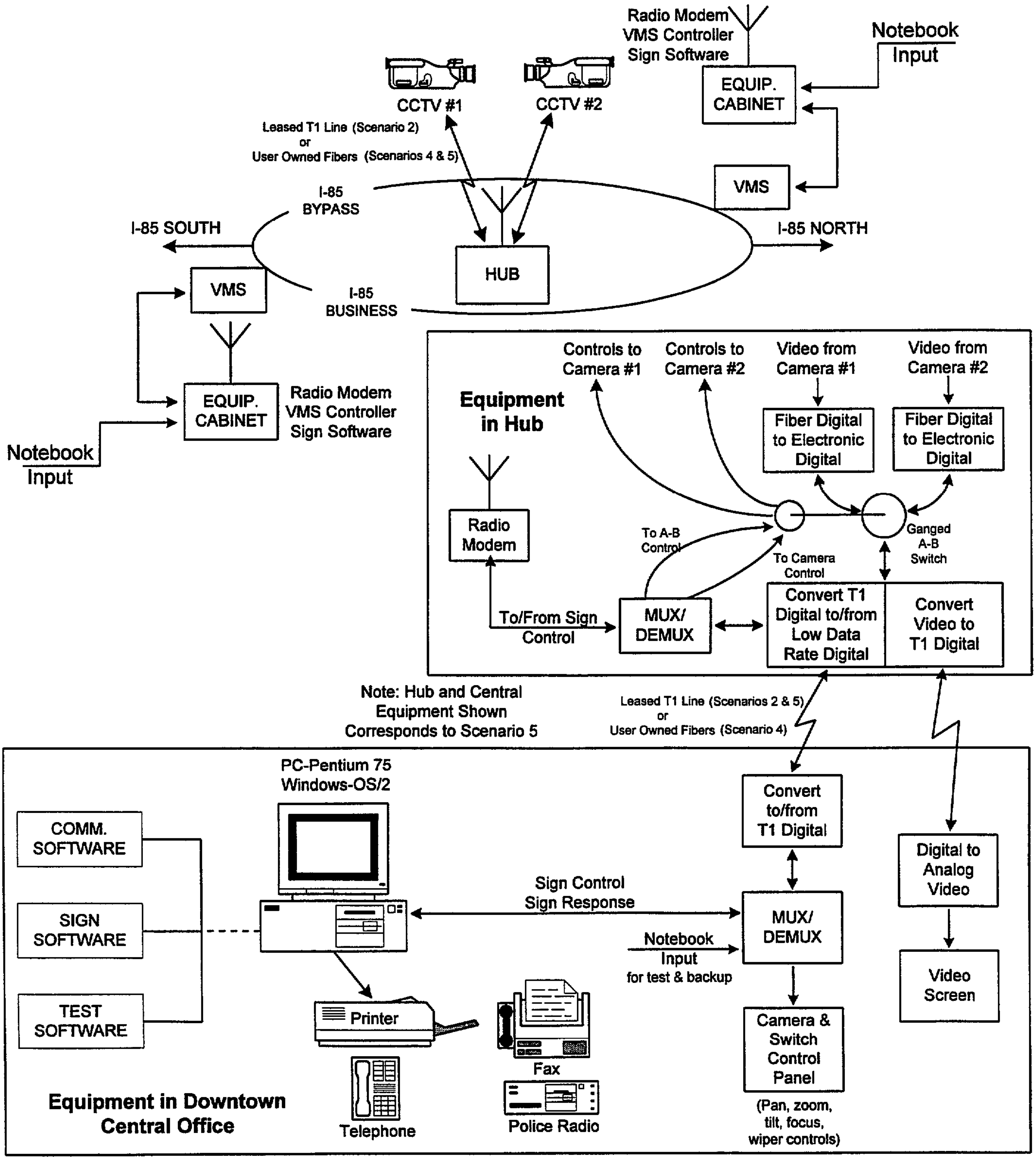
System Concept The concept for this scenario is as follows:

- Provide a trailer located somewhere between the two roadways and roughly at the midpoint of the pair. This is the same trailer as assumed in VMS Scenarios 1 and 3.
- For an initial implementation, provide two remote CCTV cameras. They should be located at the most critical points of the couplet. Potential sites may include the interchanges of I-85 and I-26 and of I-85 and I-585. These cameras will provide 360 coverage at each site. Depending on the height of the camera, it can be envisioned that the useful visible range would be about 1 mile in all directions.
- The cameras have full Pan, Tilt and Zoom capability controlled from the central control facility.
- The trailer (central) would have telephone and radio contact with the Highway Patrol and with other emergency operations. The operator would have only limited capability



CCTV Scenarios 1 and 3 with "Local" Central Office
I-85 Couplet

Exhibit 7-10



CCTV Scenarios 2, 4 and 5 with Downtown Central Office
I-85 Couplet

Exhibit 7-11

for determining if an incident existed (because of his limited view from two cameras). However, these two cameras would provide information at critical points and at critical times.

- The central would be equipped with two monitors and two camera control panels. In future expansion of the system, cameras could be added without adding additional monitors. Normal operation of such centers allows the operators to switch camera views from one monitor to another. When there are more cameras than monitors, obviously some of the information is not displayed.

The Central Site The trailer would have sufficient room for the following equipment in addition to VMS system components:

- Two monitors;
- Two camera control panels: and
- Communication equipment adequate for video transmission.

Remote Sites At each of the CCTV camera sites the following equipment would be installed:

- Color CCTV camera;
- A pole for mounting the camera. A height of 40 to 60 feet is recommended;
- The camera communication and control cabinet at the base of the pole; and
- Communication electronics adequate for video transmission.

Test and Maintenance Equipment The Contractor will need specialized equipment for installation and maintenance purposes. The cost of these items might be lumped into the CCTV costs. If CCTV maintenance is performed by a third party, these items would be supplied by the maintenance organization:

- 1 oscilloscope; and
- 1 digital voltmeter.

Leased T1 Lines A T1 line can be leased from the telephone company for approximately $1,050 per month. A single T1 line can carry 1.54 Mbps in both directions. A data rate this small provides limited quality video. Modern communication packing procedures can push more data over a communication channel than using older, conventional techniques. When all of these techniques are used, a single Tl line provides a picture which is adequate though somewhat degraded. There tends to be a “jerkiness” to **a** moving picture, especially when the camera is being panned. The telephone company will gladly lease two or more T1 lines to provide better video coverage. The cost, of course, for each additional T1 line is the same **as** the cost of the first one.

The camera control signals (pan, tilt, zoom) require a very low data rate. The bandwidth of the T1 line from central to camera is much larger than needed for camera control signal requirements, but there is little that can be done to better utilize this empty channel.

There is normally an initial connection charge for a T1 line. This is typically about $1,200. The Present Worth of leasing a line under these conditions, considering a system life of 15 years and an interest rate of 8%, is approximately $107,900. Adding to this the cost of the installation results in a total cost of a T1 line leased for 15 years equivalent to $109,100.

<u>CCTV Scenario 1 Cost Estimates</u> A cost estimate for Scenario 1 based on the concepts and assumptions described above, is shown in Exhibit 7-12.

In reviewing the cost estimates it is important to recognize those operational costs (other than leased T1 lines) not included in the estimates. These costs include:

- Property on which the CCTV cameras and control center are placed;
- Costs of maintenance after acceptance;
- Costs of staffing after acceptance;
- Costs of telephones and radios for maintaining contact with police/emergency agencies; and
- Costs of electrical power.

CCTV Scenario 2

In this scenario the control center is assumed to be located in the downtown area of Spartanburg. This scenario parallels the VMS Scenario 2. The communications network includes an equipment hub located near the couplet.

<u>Central Site</u> The central site is assumed to be located somewhere in the City of Spartanburg, preferably shared with an existing agency. The central site control room would require space, in addition to that required for the VMS system, for two TV monitors, keyboard sized camera control panel, and communication equipment. The communication equipment requirements are quite small; perhaps requiring the space of a 2 drawer filing cabinet.

In place of the leased, voice grade line from the central to the hub (required for the VMS system), a Tl line would be required between the central site and the hub. This T1 line would be shared by the two TV cameras; i.e., the operator would select which camera to view. If two T1 lines were used, of course, both camera views could be seen simultaneously. In general, there would be little advantage to having both camera views display at central at the same time. The operator is able to switch from one view to the other view very rapidly so that there is little operational downside to this approach.

Exhibit 7-12
Cost Estimate for CCTV Scenario 1
Local Central and Leased T1 Lines

ITEM	COST
Construction (Furnish and Install)	
Central	
■ Trailer - Assume already available	$0
- Monitors; 2 @ $1,000	2,000
■ Camera control panels; 2 @ 1,000	2,000
■ Training and Documentation; 1 LS @ 4,000	4,000
	$8,000
Remote Sites (Two)	
■ CCTV Cameras; 2 @ $5,000	$10,000
■ Mounting pole; 2 @ $15,000	30,000
- Electrical Service; 2 @ $500	1,000
	$41,000
Communications	
■ Digital Video Communication equipment; both ends; 2 @ $10,000	$20,000
■ T1 lease lines, connection charge; 2 @ $1,200	2,400
	$22,400
Test and Maintenance Equipment	
■ 1 oscilloscope @ $8,000	$8,000
■ 1 digital voltmeter @ $200	200
	$8,200
Total Construction Costs	**$79,600**
Engineering and Inspection Costs	
PS&E Costs (at 12% of construction costs)	$9,600
CEI Costs (at 15% of construction costs)	11,900
Total for Engineering and Inspection	**$21,500**
Total Capital Costs (Excludes Leased T1 Lines)	**$101,100**
Communications Media	
2 T1 leased lines for 15 years, Remote Site to Central 2 @ $107,900 (present worth)	$215,800
Total Project Costs, Including Leased Tl Lines (present value)	**$316,900**

The Hub Site - The hub could be a small building or a large equipment cabinet. Because of the probability that the system will be expanded in the future, it is recommended that the hub be a small building dimensioned perhaps 12 feet by 12 feet. Leasing a room in an existing building would also be a possibility or, as before, a small construction trailer could be used.

If the VMS and the CCTV are treated as a single "system," an additional multiplexer would be required so that the VMS data to and from the central site to the hub could be added to the video data and sent over the same T1 line as the CCTV signals. The cost of the extra multiplexer would be in place of the costs of a standard telephone line.

The Remote Sites - The remote CCTV sites would be the same as in CCTV Scenario 1.

Test and Maintenance Equipment - The same equipment would be required as in CCTV Scenario 1.

CCTV Scenario 2 Cost Estimates - A cost estimate for Scenario 2 is shown in Exhibit 7-13.

CCTV Scenario 3

In this scenario, communications to CCTV cameras is achieved through installation of user-owned fiber-optic cable. Other aspects of the scenario are similar to Scenario 1, with the control center assumed to be local to the couplet.

User-Owned Fiber - The installation of fiber can be done overhead or underground. The cost is about equivalent to the cost of installing a copper wire communication system.

The installation of conduit underground along with pullboxes every 800 feet costs approximately $4.00 per foot. The cost of under pavement installation is approximately $11.00 per foot. A typical semi-rural installation might involve 2 percent of the installation under pavement and a small amount under concrete and/or jack and bore. The $4.00 per foot cost is a reasonable average. The cost of pullboxes is approximately $250. The cost of the fiber is approximately $2.00 per foot. The cost of sundry devices associated with fiber installation is approximately $0.50 per foot.

For fiber installation the cost of a Time Domain Reflectometer is added to Test and Maintenance Equipment costs for this scenario.

CCTV Scenario 3 Cost Estimates - A cost estimate for the scenario is shown in Exhibit 7-14.

Exhibit 7-13
Cost Estimate for CCTV Scenario 2
Downtown Central and Leased T1 Lines

ITEM	COST
Construction (Furnish and Install)	
Central	
- Monitors; 2 @ $1,000	$2,000
■ Camera control panels; 2 @ $1,000	2,000
■ Training and Documentation; 1 LS @ $4,000	4,000
	$8,000
Hub	
■ Assume no additional costs for the hub	$0
Remote Sites (Two)	
- Color CCTV Cameras; 2 @ $5,000	$10,000
■ Mounting pole; 2 @ $ 15,000	30,000
- Electrical Service; 2 @ $500	1,000
	$41,000
Communications	
- Digital Video Communication equipment; both ends; 2 @ $10,000	$20,000
■ Multiplexing equipment to combine video and sign signals	10,000
■ T1 leased lines, connection charge; 3 @ $1,200	3,600
	$33,600
Test and Maintenance Equipment	
■ 1 oscilloscope @ $8,000	$8,000
■ 1 digital voltmeter @ $200	200
	$8,200
Total Construction Costs	**$90,800**
Engineering and Inspection Costs	
PS&E Costs (at 12% of construction costs)	$10,900
CEI Costs (at 15% of construction costs)	13,600
Total for Engineering and Inspection	**$24,500**
Total Capital Costs (Excludes Leased Tl Lines)	**$115,300**
Communications Media	
2 T1 leased lines for 15 years, Remote Site to Hub 2 @ $107,900 (present worth)	$215,800
1 T1 leased line for 15 years, Hub to Central @ $107,900 (present worth)	107,900
	$323,700
Total Project Costs, Including Leased T1 Lines (present value)	$439,000

Exhibit 7-14
Cost Estimate for CCTV Scenario 3
Local Central and User-owned Fiber Optic Cable

ITEM	COST
Construction (Furnish and Install)	
Central	
■ Trailer - Assume already available	**0**
■ Monitors; 2 @ $1,000	2,000
■ Camera control panels; 2 @ 1,000	2,000
■ Training and Documentation; 1 LS @ $4,000	4,000
	$8,000
Remote Sites (Two)	
■ Color CCTV Cameras; 2 @ $5,000	$10,000
- Mounting pole; 2 @ $15,000	30,000
■ Electrical Service; 2 @ $500	1,000
	$41,000
Communications	
- Digital Video Communication equipment at both ends; 2 @ $10,000	$20,000
Communications Media (User-Owned Lines)	
■ Conduit Installation; 42,240 feet x $4.00	$169,000
■ Pull boxes; 42,240/800 = 53 pullboxes x $250	13,300
■ Fiber; 42,240 x $2.00	84,500
■ Sundry fiber equipment; 42,240 x $0.50	21,100
	$287,900
Test and Maintenance Equipment	
- 1 Time Domain Reflectometer @ $8,000	$8,000
■ 1 oscilloscope @ $8,000	8,000
- 1 digital voltmeter @ $200	200
	$16,200
Total Construction Costs	**$373,100**
Engineering and Inspection Costs	
PS&E costs (at 12% of construction costs)	$44,800
CEI costs (at 15% of construction costs)	56,000
Total for Engineering and Inspection	**$100,800**
Total Project Costs	**$473,900**

CCN Scenario 4

In this scenario user-owned fiber optic lines are assumed to interconnect CCTV cameras, a local hub and **a** downtown central office.

For the purpose of estimating costs it is assumed that the hub is five miles from the central office location. It is further assumed that conduit would be underground for 50 percent of this distance, under pavement for 25 percent and overhead (joint use) for 25 percent. Using cost estimates for conduit installation underground, under pavement and overhead of $4, $11 and $3 per foot respectively, yields a composite unit cost of $5.50 per foot.

A cost estimate for CCTV Scenario 4 is shown in Exhibit 7-15.

CCTV Scenario 5

A communications network combining Scenarios 3 and 4 can be envisaged, in which user-owned fiber is installed between the remote cameras and the field hub, while a leased T1 line connects the hub with the downtown central office. This combination is the premise for Scenario 5.

This scenario would contribute to the development of a backbone communications network along the I-85 corridor. At the same time it would lease communications capacity between the field hub and a central office in downtown Spartanburg. This approach is consistent with the long-term version of the Greenville-Spartanburg ATMS systems and a regional Traffic Operations Center. When a regional TOC is implemented, control of the I-85 couplet traffic management systems would migrate to the new facility without significant waste of the initial investment in communication facilities.

A cost estimate for CCTV Scenario 5 is shown in Exhibit 7-18.

Summary of CCTV Scenario Costs

A comparison of CCTV Scenario costs is given in Exhibit 7-17. Capital costs are compared, as are total project costs, which include the present value of leasing T1 communication lines for a period of 15 years.

In contrast to the VMS system discussed earlier, communication costs are the major factor in the CCTV system. These costs may be borne initially if a user-owned fiber optic network is installed or be paid over time if leased T1 lines are used. In the long-term use of a use-owned fiber optic communications network provides significant cost and other advantages. Additional components and functions may be added to the system with only incremental costs. Every effort should be made to take advantage of planned roadway construction projects to install conduit for the communications network at a fraction of the cost normally required.

Exhibit 7-15
Cost Estimate for CCTV Scenario 4
Downtown Central and User-owned Fiber Optic Cable

ITEM	COST
Construction (Furnish and Install)	
Central	
■ Monitors; 2 @ $1,000	2,000
■ Camera control panels; 2 @ 1,000	2,000
■ Training and Documentation; 1 LS @ $4,000	4,000
	$8,000
Hub	
■ Assume no additional costs for the hub	$0
Remote Sites (Two)	
■ Color CCTV Cameras; 2 @ $5,000	$10,000
■ Mounting pole; 2 @ $15,000	30,000
■ Electrical Service; 2 @ $500	1,000
	$41,000
Communications	
■ Digital Video Communication equipment at both ends; 2 @ $10,000	$20,000
■ Multiplexing equipment to combine video and sign signals	10,000
	$30,000
Communications Media (User-Owned Lines)	
Cameras to Hub	
■ Conduit Installation; 42,240 feet x $4.00	$169,000
■ Pull boxes; 42,240/800 = 53 pullboxes x $250	13,300
■ Fiber; 42,240 x $2.00	84,500
■ Sundry fiber equipment; 42,240 x $0.50	21,100
	$287,900
Hub to Central	
■ Conduit Installation; 26,400 feet at $5.50	$145,200
■ Pull boxes and aerial junction boxes; 33 x $250	8,300
■ Fiber; 26,400 x $2.00	52,800
■ Sundry fiber equipment; 26,400 x $0.50	13,200
	$219,500
Test and Maintenance Equipment	
Same as CCTV Scenario 3	$16,200
Total Construction Costs	**$602,600**
Engineering and Inspection Costs	
PS&E costs (at 12% of construction costs)	$72,300
CEI costs (at 15% of construction costs)	90,400
Total for Engineering and Inspection	**$162,700**
Total Project Costs	**$765,300**

Exhibit 7-16
Cost Estimate for CCTV Scenario 5
Downtown Central and Combination of User-owned
Fiber Optic Cable and Leased T1 Lines

ITEM	COST
Construction (Furnish and Install)	
Central	
■ Monitors; 2 @ $ 1,000	$2,000
■ Camera control panels; 2 @ 1,000	2,000
■ Training and Documentation; 1 LS @	4,000
	$8,000
Hub	
■ Assume no additional costs for the hub	$0
Remote Sites (Two)	
■ CCTV Cameras; 2 @ $ 5,000	$10,000
■ Mounting pole; 2 @ $ 15,000	30,000
■ Electrical Service; 2 @ $ 500	1,000
	$41,000
Communications	
■ Digital Video Communication equipment at both ends; 2 @ $10,000	$20,000
■ Multiplexing equipment to combine video and sign signals	10,000
■ T1 leased lines, connection charge; @ $1,200	1,200
	$31,200
Communications Media (User-owned Lines) - Cameras to Hub	
■ Conduit Installation; 42,240 feet x $4.00	$169,000
■ Pull boxes; 42,240/800 = 53 pullboxes x $250	13,300
■ Fiber; 42,240 x $2.00	84,500
■ Sundry fiber equipment; 42,240 x $0.50	21,100
	$287,900
Test and Maintenance Equipment	
Same as CCTV Scenario 3	$16,200
Total Construction Costs	$384,300
Engineering and Inspection Costs	
PS&E Costs (at 12% of construction costs)	$46,100
CEI Costs (at 15% of construction costs)	57,600
Total for Engineering and Inspection	**$103,700**
Total Capital Costs (Excludes Leased T1 Lines)	**$488,000**
Communications Media	
1 T1 leased line for 15 years, between Hub and Central @ $107,900 (present worth)	$107,900
Total Project Costs, Including Leased T1 Lines (present value)	**$595,900**

Exhibit 7-17
Comparison of CCTV Scenario Costs

Scenario	Description	Capital Costs	Project Costs(1)
1	Local Central with Leased T1 Lines	$101,100	$316,900
2	Downtown Central with Leased T1 Lines	$115,300	$439,000
3	Local Central with User-owned Fiber Optic Cable	$473,900	$473,900
4	Downtown Central with User-owned Fiber Optic Cable	$765,300	$765,300
5	Downtown Central with combination of Leased T1 Lines and User-owned Fiber Optic Cable	$488,000	$595,900

(1) Includes present value of leasing T1 communication lines for 15 years.

CCTV System Expansion - The CCTV system may be easily expanded as funds become available. Additional CCTV cameras may be purchased, installed and integrated into the system for approximately $25,000 per site.

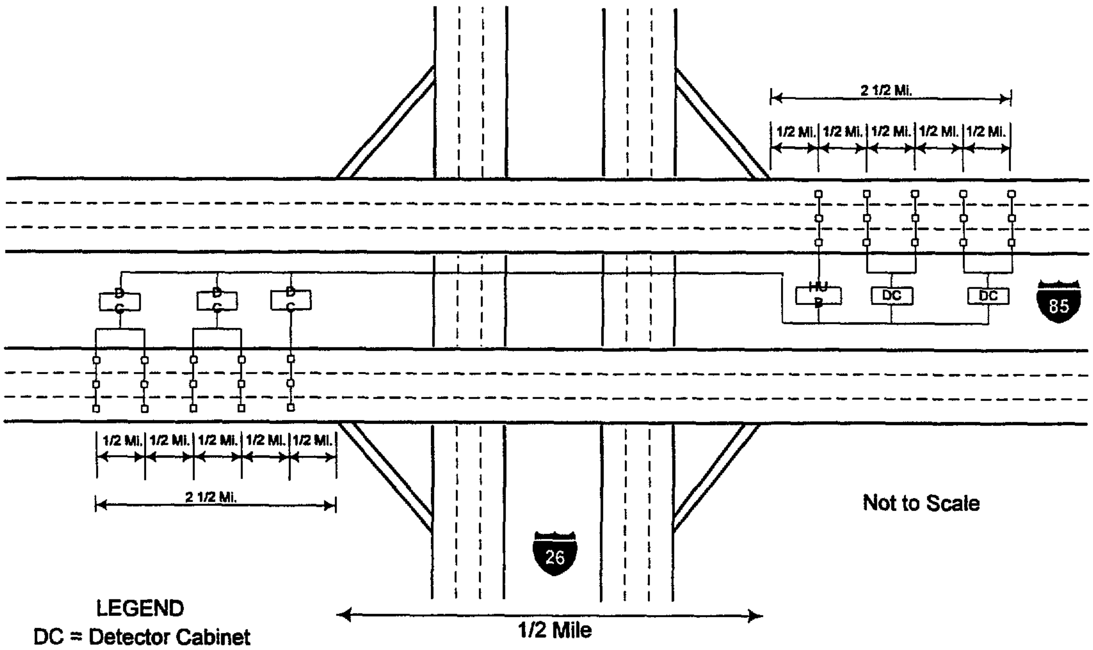
INCIDENT DETECTION SYSTEM COST ESTIMATES

It is assumed that budget constraints will limit initial implementation of an incident detection system to a short stretch of interstate. For cost estimate purposes, it is assumed I-85 Bypass traffic is monitored as it approaches the I-28 interchange. Lane changes on the approaches to this major interchange may result in a higher than average rate of incidents.

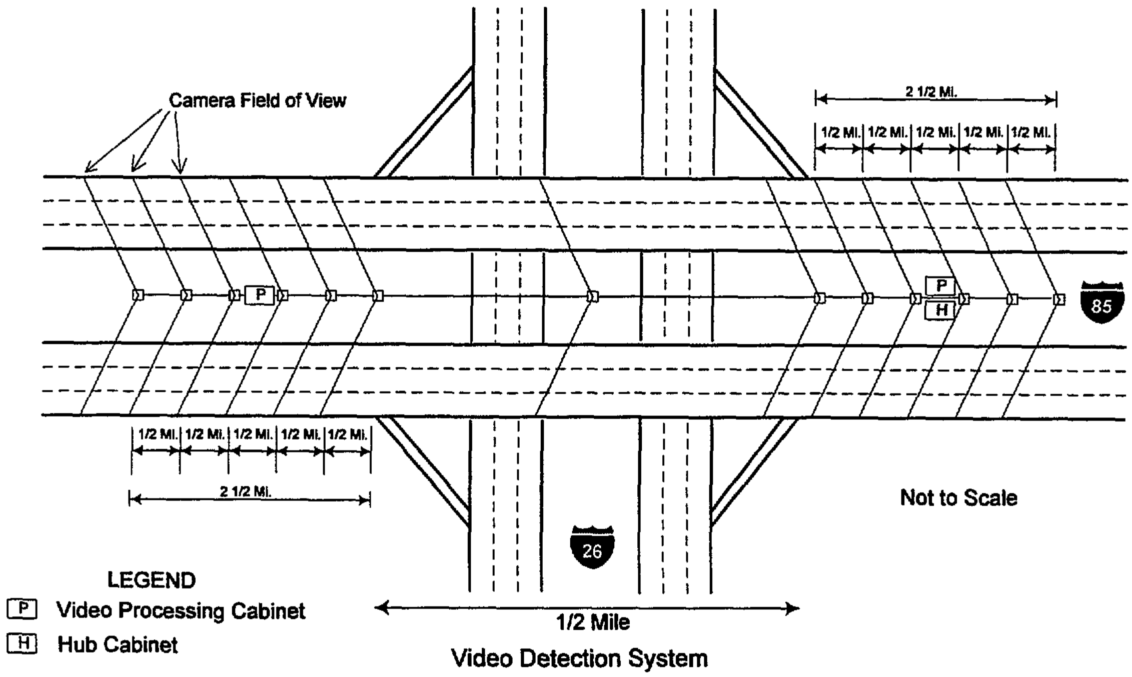
A wide variety of vehicle detectors are available or under development for use in traffic management systems. The detection technology to be used should be determined at the system design stage, based on cost, performance and reliability characteristics. For purposes of this conceptual design report, cost estimates are presented for two technologies:

- Scenario 1 - loop detectors; and
- Scenario 2 - video detection.

The area of coverage of this initial system, which may be viewed as a pilot incident management program, is illustrated in Exhibit 7-18.



Loop Detection System



Video Detection System

Exhibit 7-18
POTENTIAL INCIDENT DETECTION SITE

Loop Detectors

In this scenario conventional, 6 ft by 6 ft, induction loops are installed in each lane of I-85, at ten detector stations (five northbound, five southbound). The detection stations are spaced half-a-mile apart and monitor traffic approaching the I-26 interchange. Traffic moving away from the interchange is not monitored.

Field Equipment The detector electronics are installed in a small detector cabinet. One cabinet can serve two detector stations. The third cabinet (in the northbound direction) includes the electronics for one detector station. The third cabinet (in the southbound direction) includes the electronics for one detector station and the electronics required to transfer the data back to a central computer site (field hut).

The following field equipment is needed:

- Six detector cabinets one of which doubles as the "hub."
- 5 1/2 miles of trench for 3 conduits required to carry power, data and the detector signals to their appropriate locations. All three conduits will share the same trench.
- 5 miles of power cable to the detector cabinets (this length estimate assumes that the distance across I-26 is 1/2 mile).
- 5 miles of twisted pair (or fiber) cable to transfer data from five of the detector cabinets to the hub cabinet.
- 6 miles of lead-in to carry the detector signal from the detector cabinet to each loop.

Hub to Central The central site will be equipped with a PC type of computer in which the incident detection algorithm(s) are included and from which the results of the analysis are made available to the system operator.

Data flow is only in one direction; the data from the detectors is sent to the computer. No response is required at the hub, except to confirm that handshaking between the hub and the central has been established.

The bandwidth required is quite small. The data sent to the central from each detector is vehicle presence. The presence must mirror the length of time the vehicle is in the field of influence of the detector. It is not necessary to monitor the length of time for each vehicle; i.e., an average over 30 seconds is usually considered adequate. Also, generally speaking, the occupancy (with a precision of 1%) is considered more than adequate. Considering all of these factors, 16 bits per detector every 30 seconds is required. In this example, we have 30 detectors x 16 bits per detector divided by 30 seconds = 16 bits/second. This is a very low data rate, of course. Even assuming an overhead of lOO%, the data rate is insignificant. The number of detectors which can be handled over one voice grade line (assuming 4800 bits/second capability) could be 150 times larger than used in this analysis.

The data can be transmitted from the hub to the central either by leased telephone line (voice grade) or by a spread spectrum radio technique. It is most likely that the most cost-effective method for transferring the data to central is via the leased line method.

Central Site Requirements The incident detection algorithms can be easily handled by a moderate speed PC. Should the number of detectors be limited to the number suggested herein, the computations can be done in the same computer as the sign control software. However, because of the low cost of the typical PC, the software cost of combining the two functions in one computer would be more than the extra hardware. Exhibit 7-19 illustrates the central site configuration.

The outputs from the incident detection algorithm are:

- Between which two detector stations the incident has occurred
- An estimate of which lane the incident has occurred
- An estimate of the severity of the incident.

These will normally be displayed on the computer's monitor. Should the central site be unmanned, the resulting data can be easily transmitted to a police agency via a leased telephone line.

An optical read/write device is provided for the purpose of archiving of incident data. This archival function (and data retrieval software to make the archived data easy to retrieve) will prove to be invaluable in accident investigation and in the litigation process.

Incident Detection Scenario 1 Cost Estimates A cost estimate for Scenario 1, based on the concepts and assumptions described above, is shown in Exhibit 7-20.

The cost estimate does not include costs for office space and staff for the central equipment, as it is assumed central facilities will be shared with other systems (VMS, CCTV) or agencies. Costs also do not include leased line costs for the single telephone line between hub and central. For estimation purposes it is assumed that local agencies already have adequate test and maintenance equipment to operate and maintain the detection system.

Cost for Expansion of the Loop Detection System Based upon the estimates provided, the cost of expanding the incident detection system is approximately $27,000 per detector station (or per half-mile of interstate monitored). Note that approximately 66 percent of this cost is for the installation of conduits in a trench. If conduits are already in place, or their costs are covered by other ATMS components, such as CCTV communications, the costs associated with a loop based incident detection system are considerably reduced.

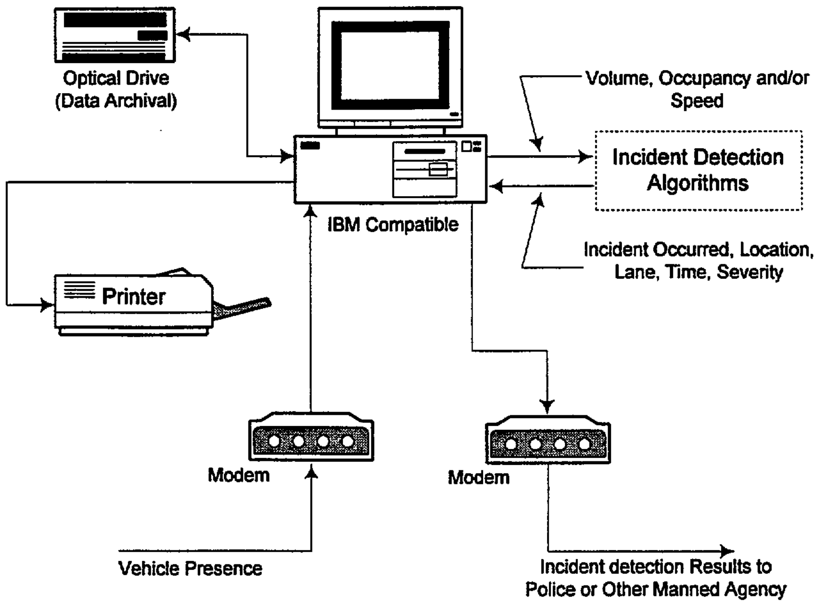


Exhibit 7-19
INCIDENT DETECTION
CENTRAL SITE CONFIGURATION

Exhibit 7-20
Cost Estimate for Incident Detection Scenario 1
Loop Detectors

ITEM	COST
Construction (Furnish and Install)	
Central	
Computer and peripherals, 1 @ $5,000	$5,000
Remote Sites	
Loop installation; 30 @ $500	$15,000
Loop electronics, incl. cabinets; 6 @ $2,000	12,000
Hub electronics; 1 @ $500	500
Trench with 3 conduits; 29,040 ft @ $5.00	145,200
Power circuits; 26,400 ft @ $0.50	13,200
Detector lead in circuits; 31,680 ft @ $0.50	15,900
Detector data from cabinet to hub; 26,400 ft @ $0.50	13,200
	$214,940
Total Construction Costs	**$219,900**
Engineering & Inspection Costs	
PS&E costs (at 12% of the construction costs)	$26,400
CEI **costs (at** 15% of the construction costs)	32.900
Total Engineering & Inspection Costs	**$59,300**
Total Project Costs	**$279,200**

Video Detection

Video Detection is a sophisticated method for determining traffic characteristics via video/digital techniques. The image from a camera mounted so that it can see one or more lanes of traffic, is fed to a data processor. The data processor separates out moving vehicles from all of the background video information and from that, provides a variety of traffic parameters.

For purposes of incident detection, the data of interest are speed, volume and occupancy. These data are then fed to another “incident detection” computer which operates identically to an incident detection computer working with loop detectors or radar detectors.

The advantage of the video image detection device is that the data it produces is somewhat more accurate than from loops or radars. The disadvantage is higher cost.

A typical installation of a single camera consists of a camera mounted on a 40 ft pole.’ When the two freeway directions are reasonably close together (as in the vast majority of cases), the pole can be mounted between the two directional roadways. With this configuration, the camera can “see” and the system can “analyze” traffic in both directions. The data is analyzed on a “per lane” basis in both directions.

Note that cameras used in vehicle detection systems are normally fixed in position. This allows the system to “learn” about background information and distinguish between stationary vehicles and fixed objects, such as buildings, structures or trees etc. This contrasts with cameras used in video surveillance systems discussed previously, which are usually mounted to allow pan, tilt and zoom capabilities, controlled by the system operator.

Field Equiument If 13 cameras are used as illustrated in Exhibit 7-18, 5.5 miles of I-85 may be monitored in both directions. This compares with 2 miles in each direction with the 10 loop detector stations. The reason for the greater coverage with video detection is that a single camera can generally view all lanes in both directions of travel simultaneously.

The cameras are installed at the top of a 40’ pole. The camera electronics required to transmit the video to the processor cabinet (P) are installed in a small cabinet. One cabinet serves each camera. One processor cabinet is required for each group of 6 or 7 cameras. The computer in this processor cabinet analyzes the video from each camera and produces the required volume, occupancy and speed; one data set for each camera. All of the data from this processor cabinet (and its companion on the other side of I-26) is sent to the “hub” cabinet. The hub cabinet collects all of the data and sends it back to the central site.

The following field equipment is needed:

- Thirteen cameras and camera electronics;
- Two processor cabinets;
- One hub cabinet;

- 5 ½ miles of trench for 3 conduits required to carry power, video and the detector data to their appropriate locations. <u>All cable conduits will share the same trench.</u>
- 5 ½ miles of power cable to the cabinets.
- 8 ½ miles of twisted pair (or fiber) line to transfer data from the cameras to the processor cabinets and from the processor cabinets to the hub.

<u>Hub to Central</u> - The central site will be equipped with a PC type of computer in which the incident detection algorithm(s) are included and from which the results of the analysis are made available to the system operator.

Data flow is only in one direction; the data from the detectors is sent to the computer. No response is required at the hub (except to confirm that handshaking between the hub and the central has been established).

The bandwidth required is quite small. Essentially, it would be the same as required for the loop detector case. However, because the data are more accurate and the processor in the processor cabinet does analysis on site that is more extensive than required by the loop processor case, we can assume that the amount of data sent is 3 times that of the loop detector case. Considering all of these factors, 48 bits per camera every 30 seconds is required. In this example, we have 13 cameras x 48 bits per camera every 30 seconds = 21 bits/second. Even assuming an overhead of 100%, the data rate is insignificant. The number of cameras which can be handled over one voice grade line (assuming 4800 bits/second capability) could be 100 times larger than used in this analysis.

The data can be transmitted from the hub to the central either by leased telephone line (voice grade) or by a spread spectrum radio technique. It is most likely that the most cost-effective method for transferring the data to central is via the leased line method.

<u>Central Site Requirements</u> - The central site requirements are identical to that of the loop detector case, as shown in Exhibit 7-19.

<u>Incident Detection Scenario 2 Cost Estimates</u> - A cost estimate for Scenario 2, based on the video detection concepts described above, is shown in Exhibit 7-21.

As before these costs do not include costs for office space and staff, the leased line costs between the hub and central, nor test and maintenance equipment costs.

<u>Cost for Expansion of the Video Detection System</u> - Based upon the estimates provided, the cost of expanding the incident detection system is approximately $35,500 per camera (or per half-mile of interstate monitored - both directions). Once again a large part of the cost is for the installation of conduits in a trench. If conduits are already in place, or their costs are covered by other ATMS components, such as CCTV communications, the costs associated with a video based incident detection system are considerably reduced.

Exhibit 7-21
Cost Estimate for Incident Detection Scenario 2
Video Detectors

ITEM	COST
Construction (Furnish and Install)	
Central	
Computer and peripherals, 1 @ $5,000	$5,000
Remote Sites	
Monochrome cameras; 13 @ $500	$6,500
Pole installation and camera mounting; 13 @ $5,000	65,000
Camera communication electronics and cabinet; 13 @ $5,000	65,000
Processor electronics and cabinets; 2 @ $25,000	50,000
Hub electronics; 1 @ $500	500
Trench with 3 conduits; 29,040 ft @ $5.00	145,200
Power circuits; 26,040 ft @ $0.50	14,500
Video and data circuits; 44,880 ft @ $0.50	22.400
	$369,100
Total Construction Costs	**$374,100**
Engineering & Inspection Costs	
PS&E costs (at 12% of the construction costs)	$44,900
CEI costs (at 15% of the construction costs)	56.100
Total Engineering & Inspection Costs	**$101,000**
Total Project Costs	**$6,475,100**

Viewing the Video Image With the video detection system as described above, traffic data is returned to the central office for use in incident detection algorithms. Selected video images may also be transmitted to the central office for use by the operator, to assist in incident verification. Still pictures may be transmitted over the leased voice-grade telephone line, assumed above, with the addition of appropriate electronics at the processor and hub cabinets. Full real-time video images may be received by use of a leased T1 line between the hub and central office or by the implementation of the proposed fiber optic backbone communications network.

GREENVILLE DOWNTOWN ATIS/ATMS COST ESTIMATES

The cost estimate presented in this section covers components of a traveller information system for the downtown area of Greenville. The initial focus of the system will be to assist visitors to the planned Greenville Sports Arena. However, the system will be able to provide information on traffic conditions and parking availability in the Greenville area 24-hours a day, 7-days a week.

Assumations The conceptual design of the system has been described in Section 5 of this Report. Information is provided to arena patrons via Highway Advisory Radio (HAR) and Variable Message Signs (VMS). For purposes of developing cost estimates the following quantities were assumed:

- 3 - VMS, fixed;
- 2 - VMS, portable;
- 3 - HAR transmitters; and
- 5 - HAR signs.

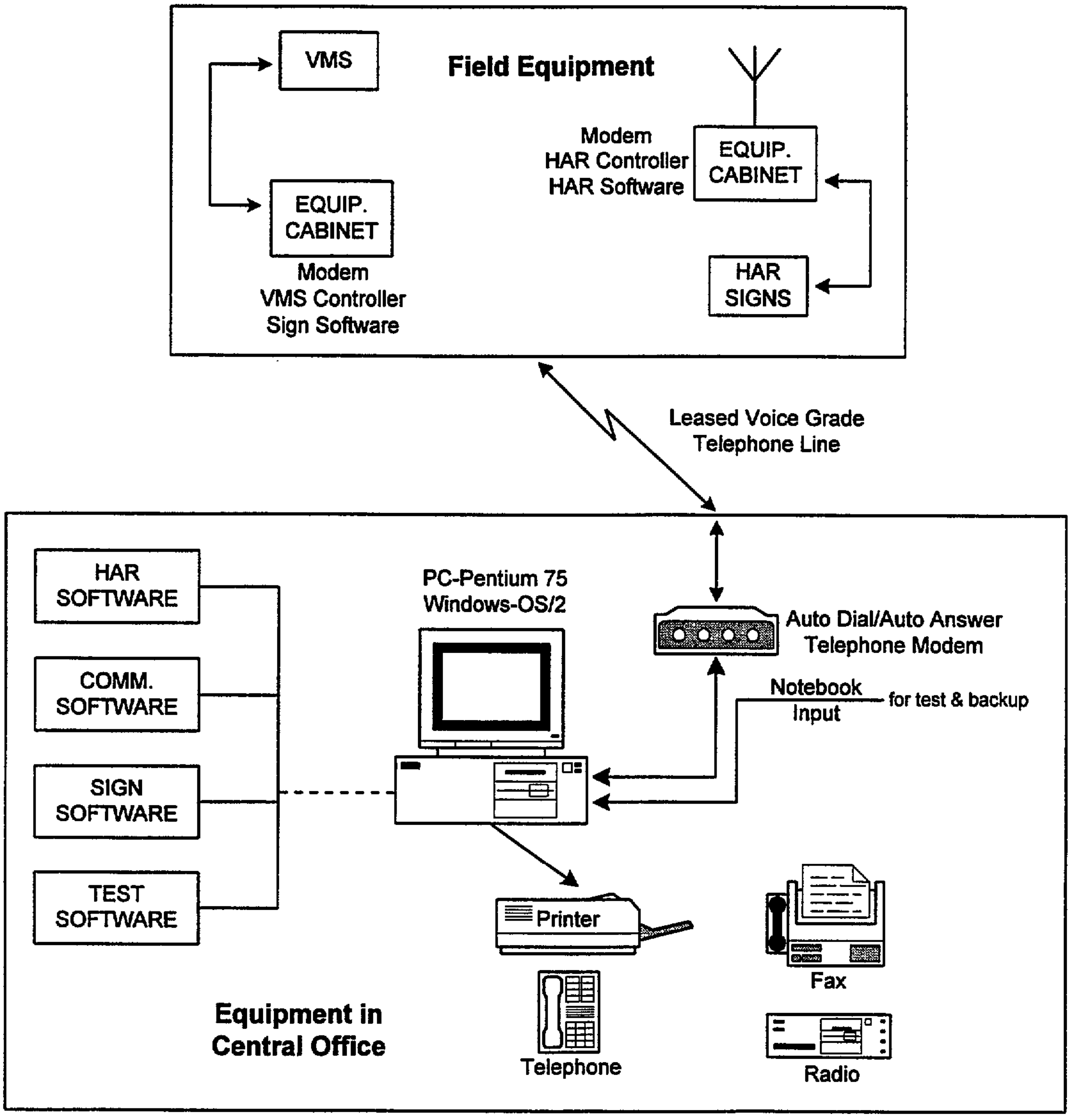
A schematic diagram of the conceptual design is shown in Exhibit 7-22.

It is assumed that the fixed VMS are located in the downtown area to provide specific parking guidance to arena patrons. Potential locations include:

- northbound on Church Street (south of East North St.);
- southbound on Church Street (north of Academy St.); and
- exit from I-385 to downtown area.

The two portable VMS may be used to provide more general guidance and directions to parking facilities. Potential locations include major arterials from the north of the downtown area, such as Poinsett Highway and Wade Hampton Boulevard.

Three HAR transmitter sites are assumed. The first would be located in the vicinity of I-85 and the I-185 spur for patrons approaching Greenville on I-85 from the south. The second would be near the junction of I-85 and I-385 for traffic on I-85 from the north and on I-385 from the south. The third may be located closer to the arena to provide information to patrons approaching on non-interstate routes such as Poinsett Highway, Academy Street, Laurens Road and North Church Street//Wade Hampton Boulevard. This third site could also provide guidance after arena events to traffic leaving the downtown area.



Schematic Diagram of Greenville Downtown ATIS

Exhibit 7-22

A total of five signs are assumed in connection with these HAR transmitter sites. These signs, equipped with remotely controlled flashing beacons, will advise motorists to tune to a particular radio frequency when information is being transmitted.

Central System For cost estimate purposes the central system is assumed to include computers and communications equipment to control and monitor the VMS and **HAR** systems. No CCTV and signal system interface components are assumed in the initial implementation of the system due to anticipated budget limitations. However, these capabilities could be added at a later date.

A small room or office type facility in the downtown area would therefore serve as an adequate control center. No costs have been included related to the provision of central office space or staffing.

Communications It is assumed that communications between the control center and field equipment be accomplished through the use of leased voice grade telephone lines.

Downtown ATIS Cost Estimate A cost estimate for the Downtown ATIS, based on the concepts and assumptions described above, is shown in Exhibit 7-23.

In reviewing these estimates it is important to recognize that operational costs (other than leased phone lines) are not included in the estimates. These costs include:

- central office costs;
- costs of maintenance after acceptance;
- costs of staffing after acceptance;
- costs of telephone and radios for maintaining contact with police and other agency personnel; and
- costs of electrical power.

Existing HAR Systems As noted in Section 5, two HAR stations are currently in operation in the Greenville vicinity. One is located at SC 153 for northbound traffic and the other is located at US 276 (Laurens Road) for southbound traffic. These stations are being used to advise motorists of ongoing I-85 construction work. It is understood that when this work is complete these stations will be handed over to the Department.

These stations are conveniently located for use within a Greenville ATMS system. If these existing stations can be used for this purpose, cost savings of approximately $70,000 may be realized.

FUNDING

The implementation of recommendations resulting from this study will require funding. This is true whether the recommendations are "system" related, such as components of an ATMS/ATIS for the I-85 couplet north of Spartanburg or unrelated to physical infrastructure, such as a Motorist Assistance Patrol program.

Exhibit 7-23
Cost Estimate for Greenville Downtown ATIS/ATMS

ITEM	COST
Construction (Furnish and Install)	
Central	
- Computer and communications equipment; 1 @ $12,000	$12,000
■ Software/System Integration; 1 @ $15,000	15,000
■ Training and documentation; 1 LS @ 64,000	4,000
	$31,000
Remote Sites	
■ Variable Message Signs - fixed; 3 @ $100,000	$300,000
■ Variable Message Signs - portable; 2 @ 640,000	80,000
- Highway Advisory Radio Transmitter; 3 @ $35,000	105,000
■ Highway Advisory Radio Signs; 5 @ $15,000	75,000
- Directional Signing (Stalic) to Arena; lump sum of $7,500	7,500
- Direction Signing (Stalic) from Arena; lump sum of $7,500	7,500
	$575,000
Communications	
2-way communications to/from car parks; lump sum of $5,000	$5,000
Total Construction Costs	**$611,000**
Engineering and Inspection Costs	
PS&E Costs (at 12% of the construction costs)	$73,300
CEI Costs (at 15% of the construction costs)	91,700
Total Engineering and Inspection Costs	**$165,000**
Total Capital Costs (Excludes Phone Lines)	**$776,000**
Communications Media	
Phone lines for 15 years, 10 @ $5,100 (present value)	$51,000
Total Project Costs, Including Phone Lines (present value)	**$828,200**

This study was funded by FHWA's "IVHS Early Deployment" program which was created by the Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991. This same ISTEA legislation provides the principal rules and regulations governing the funding of federal surface transportation related projects in the USA.

A general discussion of funding categories defined by ISTEA is given below. This is followed by a summary of air quality and related topics to provide the necessary background to funding issues. The funding of congestion management related projects in the Greenville/Spartanburg area is then addressed. The discussion of funding is broken down into the following topics:

- Funding and ISTEA Legislation
- 1990 Clean Air Act Amendments
- Effect on Planning of ISTEA and CAAA
- ISTEA Management Systems
- CAA Attainment Status in South Carolina
- Funding of Study Recommendations

Funding and ISTEA Legislation

The purpose of ISTEA was to develop a National Intermodal Transportation System that is economically efficient, environmentally sound, provides the foundation for the Nation to compete in the global economy, and moves people and goods in an energy efficient manner.

One of the major changes of the Act was the redirection of the Federal-Aid Highway Program, which for the past 20 years had been directed primarily toward the construction and improvement of four Federal aid systems. Now, instead of these four Federal-aid systems - Interstate, Primary, Secondary and Urban -there are two systems, the National Highway system (NHS), and the Interstate System, which is a component of the NHS. The focus of federal attention and resources under this legislation is the 155,000 mile nationwide NHS. The NHS is the core highway system and consists of roads and highways important to interstate travel, national defense and connectivity to other modes of transportation that are essential for national economic development. An additional program, the Surface Transportation Program, will also be available for all roads not functionally classified as local or rural minor collector.

A key feature of the ISTEA is it's flexibility. States and local governments are given more flexibility in determining transportation options and solutions by having the ability to "flex" dollars between categories and modes. In addition to this, more activities are eligible for funding, and some funds can even be used for either highway or transit projects, depending upon state and local priorities.

ISTEA defined a number of funding programs, including:

- Surface Transportation Program (STP);
- Congestion Mitigation and Air Quality Improvement Program (CMAQ);

- Interstate Construction;
- Interstate Maintenance;
- National Highway System;
- Bridge Replacement and Rehabilitation Program; and
- Equity Adjustment Categories.

Each of the programs is summarized below.

Surface Transportation Program The most flexible program in the ISTEA is the Surface Transportation Program (STP). Funds can be used for transportation improvements on any public highway (except those classified as local or rural minor collectors) as well as transit projects. The program includes 10% set asides for safety improvements and for transportation enhancements as well as a 50% set aside based on population (urbanized areas over 200,000 and the remaining areas of the state). Construction, reconstruction, resurfacing, restoration, rehabilitation, capital costs for transit projects, highway and transit safety improvements, capital and operation costs for traffic management and control, parking facilities, carpool and vanpool projects, transportation enhancements, bicycle facilities, and pedestrian walkways are examples of eligible activities.

Congestion Mitigation and Air Quality Improvement Program ISTEA recognizes the need to address critical congestion needs and air quality problems. This funding category has been established for congestion management initiatives which will facilitate the attainment of air quality standards under the more stringent requirements of the 1990 federal Clean Air Act Amendments. Funds in this category are directed to projects which will contribute to attainment of the National ambient air quality standards. Projects must be located in ozone or carbon monoxide non-attainment areas.

Interstate Construction Interstate funds were established to complete remaining sections of the Interstate system. These funds will be the final authorizations for this work. Projects must be in an Interstate Cost Estimate approved by the US Congress to qualify for this funding. There are no new Interstate Construction funds available.

Interstate Maintenance Interstate Maintenance funds are apportioned on the basis of Interstate system lane miles and Interstate system vehicular miles of travel. Rehabilitation, restoration, resurfacing, and reconstruction (if no additional capacity added) are eligible activities. Preventative maintenance may also be an eligible activity under this program, provided a state can demonstrate through its pavement management program that such activities are a cost efficient way of extending Interstate pavement life.

National Highway System The focus of these funds is the core highway system. Construction, reconstruction, resurfacing, restoration, rehabilitation, safety improvements, carpool and vanpool projects, and fringe and corridor parking facilities are examples of eligible projects.

Bridge Replacement and Rehabilitation Program This category essentially funds bridge replacement and bridge rehabilitation projects. However, bridge painting, seismic retrofitting, and calcium magnesium acetate applications are also eligible. Projects may be located on any public road.

Equitv Adiustment Categories Several categories of funds were legislated to achieve equity in funding levels among the States. Funds in these categories are treated like Surface Transportation Program funds.

1990 Clean Air Act Amendments (CAAA)

As indicated above one of the ISTEA programs specifically addressed the link between highway congestion and air quality. The 1970 CAA amendments began to shape the clean air/transportation relationship by requiring each state to develop a State Implementation Plan (SIP). The SIP is to provide for the attainment of clean air standards in an expeditious way and contain a program for enforcing emissions limits. A SIP is developed for each air quality control region in a state and must include the adoption of certain Transportation Control Measures (TCMs) listed in section 108(f) of the CAA that will allow the area to reach attainment. The most significant change in the 1990 CAAA is the inclusion of new control measures, applicable to nonattainment areas for ozone and CO, which are to be placed in the SIPS, with the severity of mandatory controls hinging on the degree of noncompliance. The USEPA has the authority to approve or disapprove the SIP; it can also call for revisions to the Plan.

Nonattainment Areas The CAA contains national ambient air quality standards (NAAQS) for six pollutants, three of which (ozone, CO and particulates) are regulated for mobile sources. Nearly 100 areas in the United States exceed the ozone standard, 38 exceed the CO standard, and 83 exceed the particulate standard. These areas are considered in *nonattainment* with the NAAQS and the 1990 CAAA required the states to submit SIPS based upon the type and degree of air pollution that will allow the area to reach attainment. Each area must have an approved SIP that demonstrates attainment of the NAAQS by dates specified in the CAAA.

Effect on Planning of ISTEA and CAAA

The ISTEA set forth new requirements on the submittal and preparation of statewide/MPO transportation plans and Transportation Improvement Programs (TIPs). The plan is a long-range document describing policies, strategies and facilities to accommodate current and future travel demands while making efficient use of the existing transportation system.

The TIP is a specific program of projects consistent with the transportation plan that includes a list of projects to be carried out in the five-year period following adoption. The MPO develops the TIP and updates it annually. The plan must be approved by the MPO, while the TIP must be approved by the MPO and governor.

The FHWA and FTA review the TIP to determine if the planning process was carried out in accord with Title 23 and, in nonattainment areas, if the TIP conforms with the SIP. Section 176 of the CAA also requires transportation planning to conform to the requirements of the CAA. The most obvious overlap between air pollution and transportation planning is the TCMs in the SIP and TIP aimed at reducing transportation-related pollution. The use of TCMs to reduce pollution is controversial, as such measures may not provide much air quality benefit. Although available data fails to demonstrate that TCMs will contribute significantly to air quality improvement, they must still be part of transportation planning and TIPS because the plans must conform to SIP emissions budgets.

ISTEA strengthened the metropolitan planning process and emphasized measures to reduce congestion. For nonattainment areas (ozone or CO) federal funds may not be used for any project that will result in a significant increase in capacity for single-occupant vehicles (SOVs) unless the project is part of an approved congestion management system.

The 1990 CAAA linked transportation funding to the adoption of regional transportation plans that conform to specific targets in the SIP. Both planning and implementation failures allow sanctions to be imposed on transportation programs. However, sanctions cannot be imposed to block projects that benefit air quality. Thus, the 1990 CAAA increase the responsibility of the MPOs and strengthen the linkage between transportation planning and air quality planning.

ISTEA Management Systems

The ISTEA legislation of 1991 required states to develop a Traffic Congestion Management System (CMS). This subject is raised primarily to distinguish this CMS from the congestion management systems referred to in this and early reports written during this study. A secondary reason is that the ISTEA management systems were intended to form an integral part of the planning and project selection process for transportation improvements in the future.

However, as a result of The National Highway System Designation Act of 1995, States may choose not to implement in whole or in part any of the management systems required in ISTEA. The Secretary of Transportation may not impose the 10% penalty on funds if a State elects this option. However, this provision does not affect the requirement of 23 U.S.C. 134 that the planning process in all Transportation Management Areas (TMAs) shall include a Congestion Management System that provides for effective management of new and existing transportation facilities eligible for federal-aid funding through the use of travel demand reduction and operational management strategies. This system should include the need to relieve congestion and prevent congestion from occurring where it does not yet occur. TMAs are defined as urban areas with, population of more than 200,000, such as Greenville.

Management Systems The ISTEA required states to develop six management systems and one monitoring system, as follows:

- Pavement Management System (PMS);

- Bridge Management System (BMS);
- Highway Safety Management System (SMS);
- Traffic Congestion Management System (CMS);
- Public Transportation Facilities and Equipment Management System (PTMS);
- Intermodal Facilities and Systems Management System (IMS); and
- Traffic Monitoring System for Highways (TMS/H).

The management systems are related in that they all are to provide outputs (strategies, actions, projects, etc.) that optimize current and future transportation system performance. The interrelationship between the CMS, PTMS and IMS is particularly evident in metropolitan areas.

The ISTEA recognized this interrelationship by requiring these three systems, to the extent appropriate, to be part of the metropolitan planning process (Metropolitan Planning Rule, 23 CFR 450.320(a)). Furthermore, the ISTEA required coordination of the development, establishment, and implementation of the CMS, PTMS, and IMS, as stated in the Interim Final Rule (23 CFR 500.505(g), 500.605(d), and 500.705(e)).

The TMS/H is a systematic process for collecting, analyzing, summarizing and retaining highway-related person and vehicular traffic data (including public transportation on public highways and streets). The TMS/H was required to support the management systems, as stated in Section **500.805(a)(2)** of the Interim Final Rule. The TMS/H covers all public roads except those functionally classified as local or rural minor collector, or those that are federally owned (23 CFR 500.805(c)).

Traffic Congestion Management Svstem (CMS) The joint FHWA/FTA Interim Final Rule on Management and Monitoring Systems (23 CFR 500) provided direction on the development of management and monitoring systems mandated by ISTEA. Specifically, Section 500, Subpart E, addressed the development of the CMS.

Revised directives from FHWA relaxed the required coverage of a state CMS. FHWA required development of a CMS in Transportation Management Areas (TMAs) only; outside TMAs, the extent of the CMS would be as deemed appropriate by the state and local officials and can be satisfied by addressing congestion in the existing statewide and metropolitan planning processes.

Section 500.503 of the Interim Final Rule offered the following definition:

> "Congestion management system (CMS) means a systematic process that provides information on transportation system performance and alternative strategies to alleviate congestion and enhance the mobility of persons and goods. A CMS includes methods to monitor and evaluate performance, identify alternative actions, assess and implement cost-effective actions, and evaluate the effectiveness of implemented actions."

The CMS and the Planning Process - There has been concern that the CMS will replace the existing 3-C (continuous, cooperative and comprehensive) planning process. This is not the intent of the ISTEA. The CMS should be designed to supplement, and **even enhance,** the existing planning process and should be reflected in the development of metropolitan and statewide transportation plans.

However, there is one clause in the Metropolitan Planning Rule (23 CFR 450) that could possibly impact the traditional 3-C process. Section 450.320(b) says that in TMAs designated as nonattainment for ozone or carbon monoxide, Federal funds may not be programmed for any project that adds general purpose lanes unless the project results from a CMS. Prior to the ISTEA, projects that added general purpose lanes based on existing or projected capacity deficiencies may nor may not have gone through a process in which all other reasonable alternative strategies may have been addressed first.

Distinguishing this Study from ISTEA's CMS As indicated above the Traffic Congestion Management System (CMS) required by ISTEA is a cyclical, management process. In contrast this study is a one-time effort, funded by the IVHS Early Deployment Program and designed to develop recommendations on a range of subjects related to congestion management in the Greenville/Spartanburg area.

CAA Attainment Status in South Carolina

Of the three pollutants regulated by the Clean Air Act for mobile sources Ozone presents the most concern for South Carolina. At the present time, no areas of the state are defined as "nonattainment areas." However, Cherokee County, immediately to the east of the Greenville/Spartanburg study area, is classified as a "maintenance area" for ozone. The entire I-85 corridor may also be considered to be at risk for ozone nonattainment due to the high rate of growth in industrial development and traffic along the corridor.

DHEC Summary of Ozone Issues South Carolina Department of Health and Environmental Control (DHEC) have prepared a summary of issues related to the status of attainment for ozone. This summary is provided below.

Ozone is a gas formed when other pollutants combine in the atmosphere. The primary components needed for ozone are nitrogen oxides, produced by combustion in motor vehicles, furnaces or boilers, and hydrocarbons from automotive exhaust and industrial solvents. At ground level, high ozone concentrations can cause health and environmental problems. Formation of ozone is usually greatest during the summer when sunlight is stronger and temperatures are high. In South Carolina, levels are highest between April and October. The U.S. Environmental Protection Agency (EPA) has set a National Ambient Air quality standard at 0.12 parts per million (ppm). Compliance is determined by comparing the highest daily one-hour average at each of the 21 monitoring stations in the state with the national standard. More than three exceedances at a single station within a three-year period results in that area being designated by the EPA as a "nonattainment area."

- *Currently, South Carolina meets the federal ozone standard.*

- *in 1988, Cherokee County exceeded the standard four times. Because there were no exceedances for the next three years, Cherokee County was reclassified as a "maintenance area for ozone.*

- *Other areas in the state are at risk of becoming ozone "nonattainment areas." Monitorreadings in York County and Columbia exceeded the standard twice in 7993. A monitor in the Greenville area exceeded the standard once in 1993. No exceedences were recorded in 7994. If the York or Columbia monitors exceed the standard mom than once during 7995, or if the Greenville monitor has more than two exceedences, these areas would become "nonattainment areas.*

- *Where nonattainment occurs, the Clean Air Act requires additional controls to return to compliance with the standard. Stringency of controls vanes with the amount by which the standard was exceeded. Many industrial facilities are already subject to controls on hydrocarbon emissions. Additional controls may affect industrial growth and could include:*

  - *more stringent permitting requirements for new or expanded industrial facilities;*
  - *possible retrofitting of existing sources to provide additional emissions controls;*
  - *reducing existing emissions to offset emissions from any new sources.*

  Once nonattainment occurs, control measures put in place must continue regardless of whether or not the standard is subsequently met.

- *Exceedence of the federal standard could also tngger requirements to control vehicle emissions, possibly through an Inspection and Maintenance program. Automotive emissions remain a major contributor to ozone precursor levels in the state.*

- *Some sources of ozone precursors cannot be readily controlled. Interregional transport from areas to the north and west and emissions from biogenic sources also contribute to the problem.*

- *Attainment status may also be affected by changes in ambient air quality standards. The Clean Air Act requires the EPA to review standards every five years. The ozone standard is currently under review, and a standard in the range of .07 to 0.9 ppm averaged over eight hours has been discussed, Many counties, if not the entire State, would not be in attainment with this lower level.*

Consequences of Non-attainment in South Carolina The section on congestion management funding has included considerable discussion of air quality issues even though all parts of the state are currently in attainment. The reasons for this include:

- future attainment status cannot be taken for granted (Columbia, the I-85 Corridor and York County may be considered to be at risk);

- a non-attainment status in any part of the state would trigger a variety of transportation planning and funding restrictions not currently applicable; and

- a non-attainment status would reduce the level of flexibility among ISTEA funding programs presently available to SCDOT and the MPOs.

Every effort should therefore be made to ensure continuation of an attainment status in all parts of the state.

Ironically, if the I-85 Corridor became a non-attainment area it is likely that more funds would have to be directed towards congestion management projects of the type recommended by this study. However, it is far better to choose to fund congestion management projects and other activities beneficial to air quality now and so avoid reaching a non-attainment status, with its resulting restrictions and loss of flexibility in the funding of transportation projects.

Funding of Study Recommendations

Although FHWA funded this and over 70 similar studies across the country through a specially funded program (ITS Early Deployment Program), FHWA have not set aside special funds for ITS implementation. If recommendations from this study are to be implemented most of the funding will have to be provided by existing funding programs, such as Guideshare. Consequently traffic management and other ITS projects will have to compete for funds with other roadway projects.

Guideshare Guideshare is the term for the funds whose expenditure is determined by each of the ten MPOs in the state. Guideshare funds come from STP, CMAQ and NHS funding programs. SCDOT planning division have developed formulae in conjunction with FHWA to determine the share of each of these programs to be allocated to each MPO. For the five-year period covering FY 95-99, the GPATS and SPATS estimated Guideshares amount to $47.4 million and $24.6 million respectively.

Projects Exempt from Guideshare Some projects within the jurisdiction of an MPO may be funded outside of Guideshare. These may range from large interstate reconstruction projects to interchange beautification projects. A listing of GRATS projects exempt from Guideshare is shown in Exhibit 7- 24.

Exhibit 7-24
GRATS Projects Exempt from Guideshare
(FY 95-99)

PROJECT	AMOUNT ($000s)	FUNDING
I-85 Pelham Road to GRATS Boundary	40,500	Interstate NHS
I-85 Saluda River to Reedy River	—	Interstate
White Horse Road Appalachian Dev.	15,950	Appalachian
I-385	68,310	Interstate NHS
Southern Connector	4,300	Demonstration
Safety Projects	3,090	STP - Safety
Resurfacing Projects	3,900	STP and NHS
Bridge Replacement	735	Bridge Replacement
Interchange Beautification	890	STP Enhancement
GRATS Enhancement Projects	2,155	STP Enhancement
Greenville Transit Authority	7,083	FTA Section 9
Greenville Transit Authority	1,040	FTA Section 18
TOTAL	**147,953**	

Existing Projects - In view of the limited funds available for congestion management related projects, it will be important to take full advantage of existing planned projects to implement components of the proposed regional ATMS for the Greenville/Spartanburg area. For example, where widening of I-85 is planned the installation of conduit (and possibly cable) should be incorporated in the plans for the ATMS communications network. Advantages would include:

- lower cost of installing conduit within a large construction project compared to a standalone project;
- avoids a second disruption to traffic during conduit installation; and
- may be eligible to use funding sources such as interstate maintenance.

It may be possible to implement recommendations or proposed system components in part through existing projects. Examples include:

- installation of communications network during interstate widening;
- installation of a VMS or CCTV camera during interchange improvements; and
- installation of closely spaced location markers during interstate maintenance, rehabilitation or reconstruction projects.

Additional Funding Sources It was stated earlier that FHWA does not have a special funding program for implementing recommendations resulting from IVHS Early Deployment Studies. The only IVHS projects which receive special funds are those classified as "Operational Tests." These projects are designed to evaluate unique technologies and institutional/financial arrangements in a real world transportation related application. An integral part of these projects is an evaluation process performed by a party independent of the team implementing and operating the technology components.

Federal funding restrictions may severely limit the number of new additional operational tests each year. Interest in participating in these tests is solicited through Federal Register notice. Specific technical areas are identified as priority areas for funding support and interested parties are invited to prepare and submit proposals. These proposals are evaluated using the published National Selection Criteria.

Non-Traditional Funding Sources A regional ATMS of the scope proposed provides the potential for public/private partnerships which may be used to help finance implementation and/or operational costs. As discussed in Section 2, Overview of Regional Congestion Management System, it is anticipated that functions associated with the collection, processing and dissemination of traveller information will have an increasing role over time.

Reliable, up-to-date information on travel conditions presented in a convenient, efficient manner is a valuable commodity which companies and individuals may be willing to pay for. A comprehensive ATIS is likely to emerge only in the third phase (long term) of system implementation. However, the possibilities of cost sharing between system provider and system user should not be overlooked, even in earlier phases when partial or local system components are implemented.

Examples of public/private partnerships may include:

- trucking companies and local businesses with significant freight movements - on-line connections to the ATMS system to receive current traffic information;

- major generators of traffic (shopping malls, offices, factories) - on-line information kiosks or displays to receive traffic information (to provide competitive edge or as a service to their patrons/employees);

- special event traffic generators (sports arenas etc.) - video displays, VMS, HAR addressed specifically to the travel needs of their patrons;

- local businesses, commuters - automatic generation of traffic reports sent by fax, E-mail etc., tailored to their specific needs (e.g., congestion near their work/home location); and,
- cable television company - reserves a channel for local/regional travel information, covering all modes (highway, rail, air, transit).

Other sources of non-traditional funding which may be considered include adding an amount to ticket prices or parking fees associated with new traffic generators, such as the planned Sports Arena in downtown Greenville.

Conclusions on Funding Recommendations resulting from this Congestion Management Study will be competing with other transportation projects for funding. There is no single source of funding with adequate resources to ensure implementation within a reasonable time frame. It is likely that a variety of funding sources will need to be utilized including Guideshare, interstate funds (for existing projects) and public/private partnerships.

Obtaining funding for system implementation and operations presents a major challenge. It is vital that those concerned with congestion management in the region recognize this and adopt an aggressive, flexible and innovative approach to this issue.

Section 8
OTHER CONGESTION MANAGEMENT RECOMMENDATIONS

INTRODUCTION

This section provides a summary of recommendations developed during the course of the Greenville/Spartanburg Area Congestion Management Study and Design project. The focus of this section is on recommendations and issues not directly involving the design or construction of physical infrastructure or systems.

Many of the recommendations contained in this section have been discussed in greater detail in earlier study reports's [2,3,4]. The reader is referred to these earlier reports where a full discussion of recommendations and their background are provided.

Recommendations are described in this Section under the following headings:

- Traffic Management Team;
- Motorist Assistance Patrol Programs;
- Incident Management Recommendations;
- Legislation and Regulations; and
- Public Education Programs.

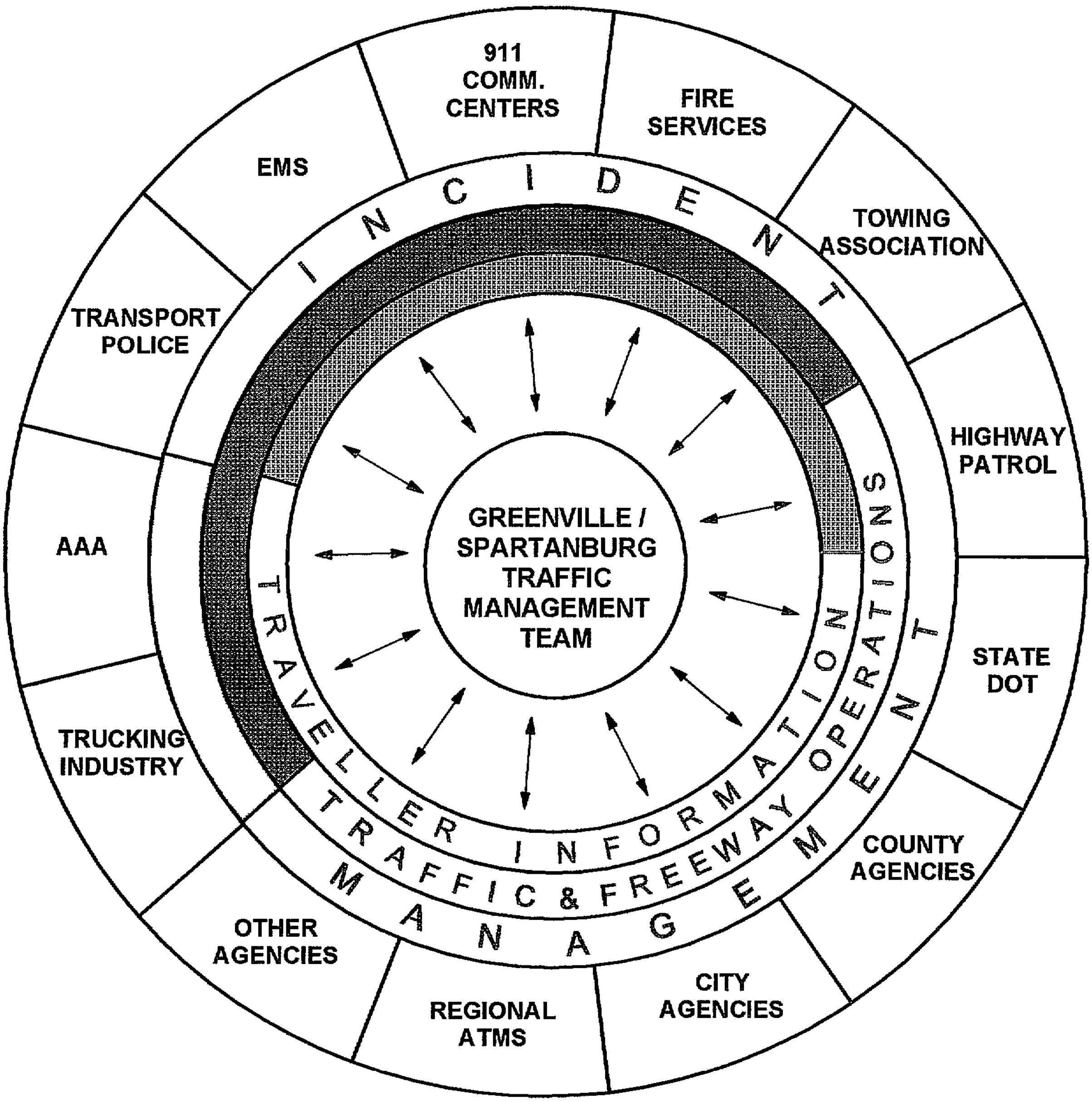
The section ends with a brief summary of the study's conclusions.

TRAFFIC MANAGEMENT TEAM

It is recommended that a Greenville/Spartanburg Traffic Management Team be established. The formation of such a team is regarded as an essential first step to enhancing existing incident management planning activities. The Team should include representatives from all agencies involved in incident management, and from major highway user groups such as AAA, the trucking industry and towing associations.

The Team would be responsible for initiating and overseeing other incident management recommendations, as discussed later in this section. Meetings of the team would provide a forum to discuss programs aimed at improving response time, identify the need to initiate and improve incident management systems and review progress through post incident debriefings.

The Traffic Management Team would oversee all incident management planning activities and provide valuable input to the regional ATMS on needs for incident management support functions and for congestion management functions, related to daily transportation problems in the area. As such, the Traffic Management Team will have a key role in driving the scope and rate of expansion of the regional ATMS. The broad perspective and coordinating role of the proposed Greenville/Spartanburg Traffic Management Team is illustrated in Exhibit 8-l.



COORDINATING ROLE OF
GREENVILLE/SPARTANBURG TRAFFIC MANAGEMENT TEAM

Exhibit 8-1

Initially, as local rather than regional projects are conceived and implemented, it may be appropriate for Greenville and Spartanburg to form their own Traffic Management Teams. As local projects expand and interact, the organization of these teams should evolve as necessary to address regional issues and concerns.

MOTORIST ASSISTANCE PATROL PROGRAMS

As stated in Section 2 of this Report, it is recommended that Motorist Assistance Patrols (MAP) be one of the four initial functions of a regional ATMS. Indeed, MAP programs may be established in advance of other components, as they do not rely on extensive communications infrastructure and do not require significant time to design and implement.

In parallel with Phase 2 of this study, SCDOT has initiated detailed planning efforts which will lead to the introduction of the state's first MAP program in the Columbia area in early 1996. This program will be known as the State Highway Emergency Patrol (SHEP). The abbreviations MAP and SHEP may be used interchangeably. MAP is used in the remainder of this Section to provide consistency with earlier study reports.

The Role of MAP Programs

MAP programs typically provide specially equipped vehicles to regularly patrol the interstate **highway, to:**

- detect incidents or other potential hazards (stranded motorists, debris, etc.);
- assist with traffic control during incident management and clearance activities;
- assist disabled motorists to prevent secondary incidents; and
- assist the Highway Patrol in the surveillance and detection of abandoned vehicles.

The MAP program is considered an important component in the proposed ATMS concept for the region. It will assist in efforts to mitigate congestion and enhance safety. Its importance is underlined by the fact that 75-80 percent of urban freeway incidents are minor.[5] Such incidents include:

- "Silent Incidents"
  - noticeable but not blocking road
  - stopped, disabled vehicle or debris on shoulder

- Minor Incidents
  - pushable/towable/moveable
  - fender-bender accidents
  - debris in roadway

Any silent or minor incident provides a distraction and/or increased hazard to the driver and so contains the potential for causing a much more serious incident, with associated congestion, injuries or loss of life.

The creation of a MAP program is an important step towards a more proactive approach to traffic management. It also provides a visible indication of a willingness and desire to improve traffic conditions and safety for the benefit of the travelling public.

MAP Program Locations

In the long term, a MAP program for the I-85 corridor should ideally be administered from the proposed regional ATMS Traffic Operations Center (TOC). Until the TOC is established smaller, but highly effective, programs may be implemented for critical segments of the corridor. Until full coverage of the corridor can be achieved, it may be appropriate to operate MAP programs centered around the urban areas of Greenville and Spartanburg.

Greenville MAP Program An initial MAP program in Greenville should focus on the stretch of I-85 between I-165 and I-365 which is nine miles in length. It could also cover I-185 (2 miles) and I-385 between Simpsonville and the downtown area (13 miles). This area would cover approximately 25 miles of interstate highways in total. The program could operate from an existing DOT or other agency facility with appropriate office and parking space.

Spartanburg MAP Program The most critical roadway in need of MAP services in the Spartanburg area is probably I-65 Business (the original stretch of I-85 north of the City center). The opening of I-85 Bypass should reduce volumes on I-65 Business but the proposed improvements to I-85 Business will result in difficult driving conditions for a number of years to come. A MAP program can be highly effective in such circumstances. The initial MAP service should also cover I-85 Bypass and portions of I-26.

During the period before implementation of the proposed I-85 Couplet ATMS/ATIS described in Section 4, portable VMS should be available to MAP to advise drivers to divert to I-85 Bypass (or I-65 Business) in the event of a major incident on I-85 Business (or I-85 Bypass). During this period MAP operations would also greatly facilitate incident detection and verification functions, before automated systems are in place.

Responding to a request from SPATS, the SCDOT has recently (September 1995) prepared a proposal for the development of a MAP program for the Spartanburg area. The proposal calls for the procurement of three specially equipped vehicles. Two units will patrol I-85 (from US 221 to SC 14) I-85 Business and (possibly) portions of I-26 during peak travel periods from Monday through Friday. The third vehicle will be used in a backup capacity. Daily operations of the program would be under the direction of SCDOT and would be located in an SCDOT facility in Spartanburg. The patrol vehicles would be operated by three full-time employees and one part-time employee of the SCDOT.

Scope of MAP Operations

Initially, programs may be initiated with as few as two or three vehicles. Assuming approximately 25 miles of highway are covered by two vehicles, a stranded motorist should be seen by a MAP driver travelling in the same direction within 30 minutes. A motorist should be seen by a MAP driver on either side of the median within 15 minutes. Times may exceed these values when a MAP driver is already assisting a motorist for an extended period.

Depending upon staffing and budget constraints, it may be necessary to limit hours of MAP operations to periods of peak traffic activity. Where limited, but regular, hours of operation are anticipated, it is recommended that permanent roadside signs be installed to advise motorists of the times when MAP vehicles will be on patrol.

INCIDENT MANAGEMENT RECOMMENDATIONS

A large number of options are available for improving the response to incidents which occur on the highway system. These options, which were described in some detail in earlier reports[2,4] are listed in Exhibit 8-2.

The list of options include two which have already been discussed in this section, namely

- Administrative Traffic Management Teams; and
  Dedicated Freeway/Service Patrols (MAP or SHEP programs).

It is recommended that these options receive the highest priority of those options classified as relating to incident management planning. These options are viewed as the foundation upon which other incident management measures may be implemented.

In particular the Greenville/Spartanburg Traffic Management Team should evaluate the need for each of the options listed in light of existing and projected requirements in the Greenville/Spartanburg corridor. Ten planning related options are recommended for early consideration by the Traffic Management Team. The recommended options are highlighted in Exhibit 8-2 and are summarized in Exhibit 8-3.

Most of the options recommended for early consideration by the Traffic Management Team require only minor to moderate costs." Many of the options represent attempts to improve existing procedures (e.g., Improved Media Ties) or to more clearly define roles and actions during incidents (e.g., Alternative Route Planning or Hazardous Materials Manual).

It is recognized that incident response occurs every day in the I-85 corridor and that improvements are being made constantly (e.g., utilization of the new 600 MH, communications system). Nevertheless it is likely that significant further improvements can be made through implementation of these incident management options, under the guidance and direction of the proposed regional Greenville/Spartanburg Traffic Management Team.

Exhibit 8-2
Incident Management Options

Options[1]		Area of Impact of Incident Management Options				
Descriptions	**P/S**	**Reduce Detection Time**	**Reduce Response Time**	**Improve Site Management**	**Reduce Clearance Time**	**Improve Motorist Information**
Accident Investigation Sites	P				✔	
Administrative Traffic Management Team	P		✔	✔	✔	
Aircraft Patrol	P	✔				
Alternative Route Planning	P		✔	✔	✔	
Cellular Telephone	P	✔				
Central Information Processing & Control Site	S	✔	✔	✔		✔
Citizens Band (CB) Radio Monitoring	P	✔				
Closely Spaced Location Markers	P		✔			
Command Post	P			✔		
Dedicated Freeway/Service Patrols (MAP/SHEP)	P	✔	✔		✔	
Electronic Loop Detection	S	✔				
Emergency Vehicle Access	P		✔		✔	
Equipment and Materials Resource List	P		✔			
Equipment Storage Sites	P		✔			
Externally Linked Route Guidance (ELRG) Systems	S					✔
Flashing Lights Policy	P			✔		
Hazardous Materials Manual	P				✔	
Highway Advisory Radio	S					✔
Identification Arm Bands	P			✔		

Exhibit 8-2
Incident Management Options

Options[1]		Area of Impact of Incident Management Options				
Descriptions	**P/S**	**Reduce Detection Time**	**Reduce Response Time**	**Improve Site Management**	**Reduce Clearance Time**	**Improve Motorist Information**
Identification of Fire Hydrant Locations	P				✔	
Improved Interagency Radio Communication	P		✔	✔		
Improved Media Ties	P					✔
Incident Phone Lines	P	✔				
Incident Response Manual	P			✔	✔	
Incident Response Teams	P			✔	✔	
Inflatable Air Bag Systems	P				✔	
Motorist Aid Call Boxes/Telephones	S	✔				
Ordinances Governing Travel on Shoulder	P		✔		✔	
Peak Period Motorcycle Patrols	P	✔	✔	✔		
Personnel Resource List	P		✔			
Personnel Training Programs	P		✔	✔	✔	
Policy Requiring Fast Vehicle Removal	P				✔	
Properly Defined Parking for Response Vehicles	P			✔		
Properly Defined Traffic Control Techniques	P			✔		
Public Education Programs	P		✔		✔	
Push Bumpers	P				✔	
Radio Data Systems (RDS)	S					✔

Exhibit 8-2
Incident Management Options

Options[1]		Area of Impact of Incident Management Options				
Descriptions	**P/S**	**Reduce Detection Time**	**Reduce Response Time**	**Improve Site Management**	**Reduce Clearance Time**	**Improve Motorist Information**
Responsive Traffic Control Systems	S				✔	
Ties with Transit/Taxi Companies	P	✔				
Ties with Trucking Companies	P	✔				
Total Station Surveying Equipment	P				✔	
Tow Truck/Removal Crane Contracts	P		✔			
Variable Lane Closure	P				✔	
Variable Message Signs	S					✔
Closed Circuit TV	S	✔				
Volunteer Watch	P	✔				

(1) P - Incident Management Planning (non systems) related options.
S - System related options.

■ High Priority Planning Related Options.
▒ Ten Planning related options recommended for early consideration by the Traffic Management Team.

Exhibit 8.3

PLANNING RELATED OPTIONS RECOMMENDED FOR EARLY CONSIDERATION BY THE TRAFFIC MANAGEMENT TEAM

TYPE OF PROGRAM	POTENTIAL BENEFITS	POTENTIAL COSTS	COMMENTS
Alternative Route Planning	💡💡	💰	Can reduce congestion and allow quicker access to incident site by response vehicles.
Cellular Telephones	💡💡💡💡	💰	Information should be distributed to cellular phone users describing proper incident reporting techniques.
Closely Spaced Location Markers	💡💡	💰	Allows fast, accurate location of incidents, to improve speed with which response actions can be brought to bear.
Hazardous Materials Manual	💡💡💡	💰	Once developed, should be included in regular training procedures to further benefit clearance efforts.
Improved Interagency Radio Communication	💡💡💡	💰 ⇨ 💰💰	Direct communication between responding agencies can improve incident response and interagency relationships.
Improved Media Ties	💡💡	💰	Information disseminated by the media must be effective and accurate and therefore come from a single dissemination point.
Incident Response Manual	💡💡💡	💰	Once developed, should be included in regular training procedures to further clearance efforts.
Incident Response Teams	💡💡 ⇨ 💡💡💡💡	💰 ⇨ 💰💰💰	Highly trained, coordinated response teams can greatly reduce site management delays and interagency conflicts.
Personnel Training Programs	💡💡💡	💰💰	Highly trained personnel can speed the management process as well as reduce interagency conflicts.
Ties with Trucking Companies	💡💡💡	💰	Emphasis on local and regional companies making regular use of the freeway corridor.

💡 .... Minor benefits

💡💡 .... Moderate benefits

💡💡💡 .... Substantial benefits

💡💡💡💡 .... Very substantial benefits

⇨ .... Indicates a range of benefit/cost levels

💰 .... Minor costs

💰💰 .... Moderate costs

💰💰💰 .... Substantial costs

💰💰💰💰 .... Very substantial costs

LEGISLATION AND REGULATIONS

The actions of those involved in or responding to incidents on the highways of South Carolina are dictated, in part, by various laws and regulations. Such legislation has been reviewed in earlier reports as was similar legislation in North Carolina and Florida[3,4]. Recommendations are made on potential amendments to legislation and regulations to improve the efficiency of incident management on the state's highways.

Relevant Documents

South Carolina Legislation - Legislation relating to incidents on the highway system is contained within "Laws Relating to the Department of Highways and Public Transportation," 1990 and subsequent supplements.

South Carolina Regulations - Code § 56-5-6180, Promulgation of rules and regulations, authorizes the Department to issue rules and regulations which have the full force and effect of law. One such regulation which is of particular relevance to congestion management is R 63-600, Regulation of Wrecker Services. This regulation dictates the procedures followed by the Highway Patrol in requesting wrecker services at the scene of an incident on the Interstate.

Issues Relating to SC Legislation and Regulations

Some Legislation/Regulations have a direct impact on current incident management procedures and practices within the State, including:

- Spilled loads (§ 56-5-4100);
- Removal of unattended vehicles (§ 56-5-2520);
- Property damage only accidents (§ 56-5-1220); and
- Regulation of wrecker services (R 63-600).

Each of these issues is discussed below.

Spilled Loads - When a load spills on the roadway, current law requires that the vehicle operator *"shall immediately cause the public highway to be cleared of all glass or objects and shall pay any costs for the cleaning."* In practice, of course, the spilled load is often not cleaned away "immediately." It takes time for the vehicle operator to organize the necessary equipment and crews. They may have to travel some distance to reach the incident scene. The operator may also be more concerned about salvaging some of the spilled load, than cleaning the roadway "immediately."

Legislation §57-7-220, Removal of obstructions in highways, states *"Any time during the year when any public highway shall be obstructed, any overseer of the district in which it may be shall forthwith cause such obstruction to be removed."*

It is recommended that legislation relating to spilled loads be clarified to permit the Department to remove spilled loads as expeditiously as possible and to recover costs from the vehicle operator.

Removal of Unattended Vehicles - Legislation/Regulations reviewed do not identify the duration for which an unattended vehicle may be left standing on the shoulder of an interstate highway. It is understood that it is the practice of the Highway Patrol to tag abandoned vehicles, giving the owner 48 hours to remove the vehicle before the Highway Patrol will request removal by a wrecker service. In Maryland and Virginia any vehicle on the shoulder is defined as a hazard and may be towed immediately. In North Carolina abandoned vehicles may currently be towed after 48 hours, if not regarded as a hazard. Consideration is being given to permit towing after two hours for vehicles abandoned in designated areas.

Consideration should be given to clarifying legislation, regulations, and/or policies regarding removal of unattended vehicles, including issues such as: should an unattended vehicle on a shoulder be considered an obstruction or safety hazard, or should the current 48-hour period be reduced in urban areas, along major corridors or on all interstates?

Property Damage Only Accidents - Legislation Code § 56-6-1220 requires the driver of a vehicle involved in an accident resulting only in damage to a vehicle to stop and remain at the scene of the accident until he has provided information required by Code § 56-5-1230, Duty to give information and render aid. Code § 56-5-1220 requires that *"every such stop shall be made without obstructing traffic more than is necessary."*

Vehicles involved in an accident, even when on the shoulder, are a hazard. The vehicles and their occupants are exposed to the risk of being involved in secondary accidents while they exchange information.

Some states now require drivers involved in property damage only accidents in metropolitan areas to drive off the interstate before exchanging information. In Texas, the relevant law is Section 39, Article IV of the Texas Motor Vehicle Laws Uniform Act, 1981-82. The wording of the first part of Section 39 is very similar to SC Code § 56-5-1220. The Texas law then continues:

> *"However, when an accident occurs on a main lane, ramp, shoulder, median or adjacent area of a freeway in a metropolitan area and each vehicle involved can be normally and safely driven, each driver shall move his vehicle as soon as possible off the freeway main lanes, ramp, shoulders, medians and adjacent areas to a designated accident investigation site, if available, a location on the frontage road, the nearest suitable cross street or other suitable location to complete the requirements of Section 40 (Duty to give information and render aid), so as to minimize interference with the freeway traffic."*

In the early 1990s a survey showed that 71 percent of Texas drivers were unaware of this law. Many drivers refused to move their vehicles until a police officer investigated the collision. In recent years Texas DOT have undertaken an extensive public education program known as

"Move It" to inform drivers of the law and their duties when involved in minor property damage only accidents.

Consideration should be given to amending SC Code § 56-5-1220 along the lines adopted in Texas and to initiating a public education program to inform drivers of their duties and responsibilities when involved in property damage only accidents.

Regulation of Wrecker Services Regulations for the use of wrecker services by the Highway Patrol to remove vehicles from the interstate roadway are contained in R 63-600, Regulation of Wrecker Services. These regulations have been incorporated into the SC Highway Patrol Manual. Paragraph A. (2) of this regulation states:

> *"Unless the owner or driver of a vehicle is incapacitated or unavailable, the owner or driver of a wrecked or disabled vehicle shall have the right to the wrecker service of his choice. Before calling any wrecker service to tow a wrecked or disabled vehicle, the investigating officer on the scene shall, if practical, determine the owner's or driver's preference of wrecker services and the wrecker service designated by the owner or driver shall be called."*

The process of determining whether the owner or driver has preference of wrecker service takes time. It frequently requires contact with the vehicle operator's home office, who may or may not be able to give a response immediately. If the owner does have a preference, his preferred wrecker service may be further away from, and take longer to get to, the accident site than a wrecker service from the Highway Patrol's rotation list. The Highway Patrol officer at the scene uses his judgement to determine what is a reasonable amount of time to allow the owner to get his preferred wrecker service to the accident scene. Paragraph A. (8) of this regulation states:

> *"Each Highway Patrol District shall establish zones for towing and a wrecker rotation list shall be prepared for each zone. No wrecker service may have its name placed on the rotation list for a zone unless the wrecker service is physical/y located within the zone. Provided, however, that if a wrecker service has a separate business and a separate storage lot in more than one zone it may place its name on the rotation list in any zone where such separate business and storage lot are located."*

This paragraph establishes a rotation list to ensure work is spread evenly over all approved wrecker services on the list. At times this results in a wrecker service being used which is a considerable distance further from the incident scene than other services on the list. This is most likely to happen when the rotation list zone is large.

It is strongly recommended that consideration should be given to reviewing wrecker service regulations with a view to minimizing situations in which site management activities and the clearance of incidents are delayed by waiting for the arrival of wrecker service equipment and vehicles.

Recent Legislative Developments

A bill is currently being considered by the South Carolina House and Senate which would give EMS attendants who arrive at an emergency scene authority to direct traffic until police or firefighters arrive. It would also require motorists to use caution and drive at a reasonable speed when passing through the area or face a fine of $200 and/or up to 30 days in jail.

At present (prior to this bill becoming law) motorists in South Carolina are only required to yield right-of-way to ambulances in motion. Paramedics attending to patients have no more right to be in the roadway at an accident than any other pedestrian.

This legislation is an excellent example of the way incident management and traffic management operations may be improved through simple, low cost measures. It exemplifies two key characteristics of the congestion management recommendations resulting from this study:

- a team approach - if EMS arrive first, they need the authority to direct traffic to create a safe environment in which to provide emergency medical services, as required; and
- public involvement - all road users need to be aware of their responsibilities when involved in or passing by an incident.

The subject of public involvement in congestion management issues and public education is discussed further in the next section of this chapter.

The types of issues this legislation seeks at address are precisely those issues which are likely to surface with the formation of the proposed Traffic Management Teams. By bringing together all parties involved in incident and traffic management, inconsistencies and inefficiencies in existing legislation, regulations and procedures can be identified. The Traffic Management Teams should then take the lead in addressing and rectifying deficiencies, as necessary.

PUBLIC EDUCATION PROGRAMS

The development and implementation of the Greenville-Spartanburg ATMS will provide a range of improvements to the community. The improvements are expected to include:

- improved network capacity;
- increased safety;
- reduced delays;
- faster response to incidents;
- assistance to stranded motorists;
- improved traveller information and guidance; and
- improved (more rapid) reporting of incident occurrence.

The full potential of these improvements will not be realized without the involvement and cooperation of the highway users.

Objectives of Public Education

To achieve an acceptable level of involvement and cooperation from the community will require education. The general public cannot be expected to respond to elements of the ATMS unless they possess sufficient knowledge of the system. They must understand the generalized purpose and goals of the ATMS. Technical details of how the system works is of little importance to the vast majority. However, they need to know, in general terms, what the system provides, how to interface with the system, how they can assist the system and how the system can help them meet their travel needs, safely and efficiently.

To accomplish this will require a range of public education programs oriented to components and services of ATMS which are comparatively new to drivers in South Carolina, such as:

- MAP - Motorist Assistance Patrol program;
- VMS - Variable Message Signs;
- HAR - Highway Advisory Radio; and
- *HP - For Cellular Telephone users.

In addition to educating the public about new developments it is also important to refresh their memories on traditional topics related to freeway travel and safety. Such topics could include:

- what to do if involved in a highway accident; and
- When can a vehicle, involved in an accident, be moved from the roadway?

As stated above in the discussion on legislation and regulations, these issues are not clearly understood by many drivers.

Specific Examples of Education Programs

Examples of potential education programs are summarized below.

Motorist Assistance Patrol Programs Motorists need to know the operational hours of the motorist assistance patrol and where they operate. They also need to know how to identify a MAP vehicle and their personnel for security purposes. Static signs, appropriately placed, can keep the public informed of operating hours and routes. They could possibly even identify MAP vehicles and personnel. However, other educational approaches or methods also need to be utilized to ensure the driving public fully understands the types of assistance which can and cannot be provided by MAP personnel.

Education programs can be costly. It's therefore recommended that maximum use be made of events which news media will naturally cover. The initiation or expansion of a MAP program will attract medial attention and indeed such attention should be encouraged. Information provided to the media about such events should include key educational and safety messages.

Cellular Phone 911 and *HP Services - With the ever increasing number of mobile telephones, the use of "911" and "*HP" should be extensively promoted. Motorists should be asked to report an incident along with the mile post location of the incident to the 911 Center or to the Highway Patrol. When in doubt as to who to call, the motorist should dial 911. If only the Highway Patrol is needed to respond, the call can be easily forwarded to them. Spartanburg Communications Center has published a leaflet explaining the use of 911 from a cellular phone. Cellular phone companies provide a copy of this information to all new cellular phone users in Spartanburg County.

Variable Message Signs - Motorists need to be appraised of the importance of reading and responding to variable message signs (VMS) whether displayed by a permanent or portable VMS installation. They need to realize that the messages are "not commercials" but intended to improve the safety and capacity of the transportation network.

Highway Advisory Radio - The purpose and importance of flashing signs requesting motorists to tune to a frequency for highway advisory radio (HAR) needs to be emphasized. Motorists could be encouraged to preset their radios to the two frequencies used for HAR (530 KHz and 1610 Khz on the AM band) to reduce the hassle of re-tuning the radio while driving.

Potential Means of Public Education

A significant portion of the benefits of incident management (a component of ATMS) is safety oriented. This should be stressed in the public education programs. Regional and state agencies with responsibilities for public safety should be encouraged to coordinate with the Department and to provide assistance in educating the public.

Agencies and offices which could assist in public education include:

- Department of Public Safety;
- SCDOT Public Affairs Office; and
- Governor's committee on safety.

Drivers Manual - The SC Driver's Manual should be revised and updated to give motorist information regarding new traffic control methods (HAR, VMS) and services (MAP). This could provide new drivers, either beginners or immigrants, from other states or countries, with a basic knowledge of the purpose and operation of key elements of ATMS.

Public Service Announcements - Public service announcements or messages should be utilized to the extent possible in all media forms including bill boards.

Internet's World Wide Web - SCDOT could disseminate educational information via the Internet, through establishing a "home page" on the World Wide Net. While this would not reach a high percentage of the general public, it would be accessed by a growing number of youngsters and adults - an important segment of the population to reach for travel and safety related messages. Costs for incorporating education messages in an SCDOT web-site are minimal.

Brochures - A brief, informative brochure or pamphlet should be prepared by SCDOT. Versions could potentially be prepared in different levels of detail. Information packets could be available at SCDOT, South Carolina Department of Public Safety, SCDOT Public Affairs Office and other state agencies.

Newspaper Supplements - Supplements to the newspapers, especially the Sunday edition, should also be considered. SCDOT could develop and print the supplement and have it included with the newspaper delivery.

SUMMARY OF STUDY CONCLUSIONS

The Greenville/Spartanburg corridor in upstate South Carolina is a rapidly developing region. I-85, which links the urban areas of Greenville and Spartanburg, is a major interstate facility which serves local, regional and national transportation needs.

Long-term Perspective

Recommendations by the study team were based on a long-term view of corridor transportation needs and likely developments in traffic management technologies and operations. Based on this perspective it is recommended that a regional Advanced Traffic Management System (ATMS) be developed and implemented in the Greenville/Spartanburg region. System functions have been considered in four major categories:

- Incident Management;
- Motorist Assistance Patrols;
- Freeway Operations (ATIS and Incident Management Support); and
- Signal Systems.

Incident Management

Incidents are a major cause of congestion on the nation's highways. This is particularly true on I-85, where heavy volumes and a high percentage of trucks frequently results in severe delays whenever incidents occur.

A range of incident management options are suggested. The principal recommendation is that a Greenville/Spartanburg Traffic Management Team be established. Meetings of the team would provide a forum to discuss programs aimed at improving response time, identify the need to initiate and improve incident management systems and review progress through post incident debriefings. The Traffic Management Team would oversee all incident management planning activities and have a key role in driving the scope and rate of expansion of the regional ATMS.

Motorist Assistance Patrols (MAP)

MAP programs provide specially equipped vehicles to regularly patrol the interstate highway to assist disabled motorists. MAP drivers can also assist the Highway Patrol in the surveillance of abandoned vehicles, detection of incidents and potential hazards (debris on the road) and with traffic control during incident management.

Implementation of MAP programs in the most congested portions of the I-85 corridor are strongly recommended. Such programs are an important step towards a more proactive approach to traffic management. They also provide a visible indication of a willingness and desire to improve traffic conditions and safety for the benefit of the travelling public.

SCDOT is planning to implement the state's first MAP program in the Columbia area early in 1996. This program will be known as the State Highway Emergency Patrol (SHEP). Responding to a request from SPATS, the DOT have also prepared a proposal for implementation of a similar program for the Spartanburg area.

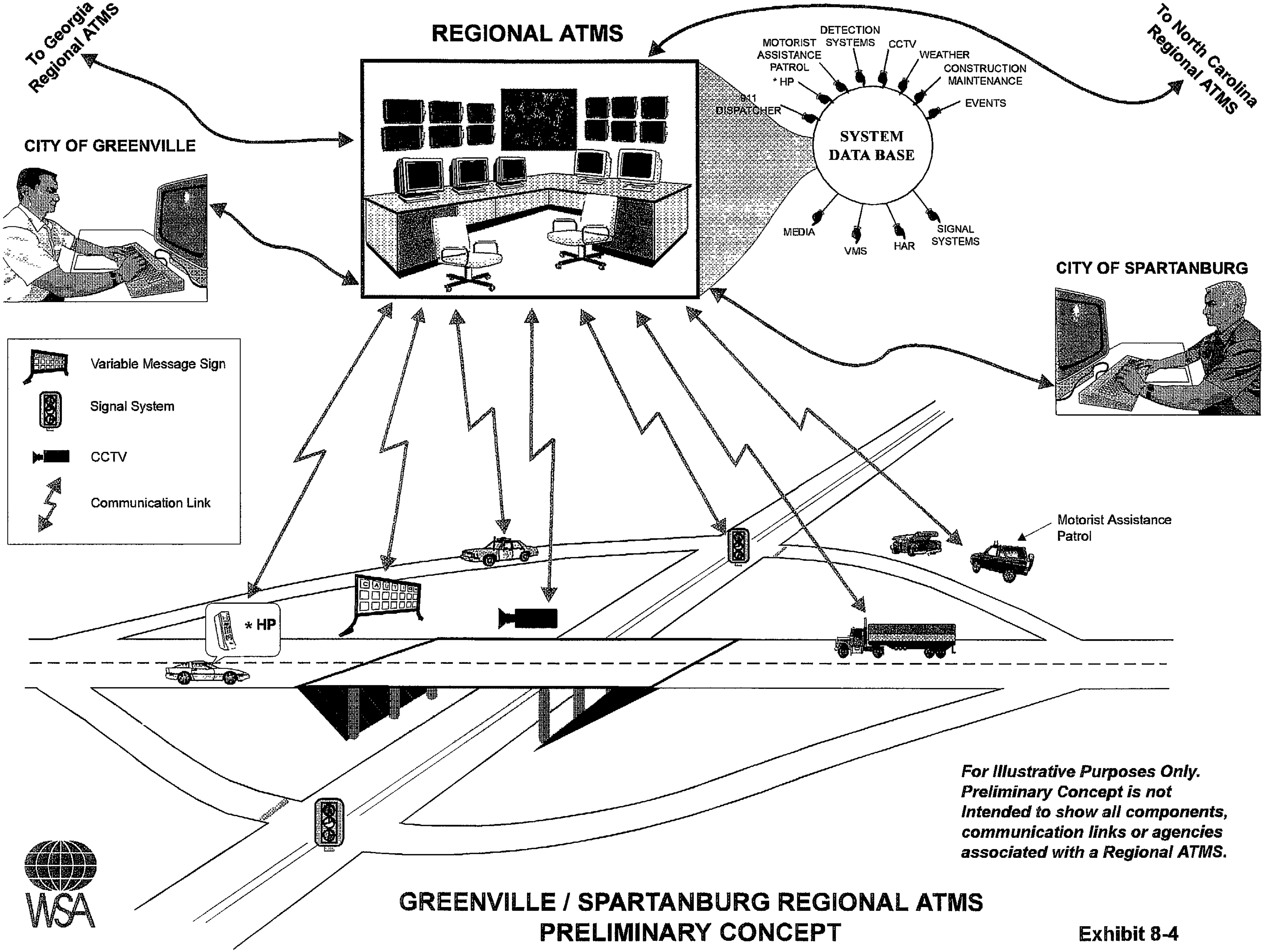
ATMS System

The term "ATMS System" is used to represent not a single, fixed entity, but a collection of integrated, networked systems and components. Such a system will provide a range of functions, including incident management support, freeway operations, traveller information and signal systems. Some of the principal concepts proposed for the Greenville/Spartanburg ATMS are shown in Exhibit 8-4.

The proposed ATMS should be regarded as dynamic in nature; constantly growing to meet changing needs. As an example of the changes anticipated, functions associated with the processing and dissemination of traveller information are likely to evolve and assume increasing importance over time. Initially, functions in this area will focus on informing motorists of incidents, through conventional radio and TV media, variable message signs and highway advisory radio. Then, provision of detailed traveller information will be provided by these means on a routine basis, plus additional channels such as cable television, monitors in major traffic generators (employment centers, shopping malls, airport), computer dial-up facilities etc. Finally, freeway operation functions will encompass support of ATIS systems using in-vehicle route guidance displays and equipment.

In the future, freeway operations facilities should support Commercial Vehicle Operations (CVO) and should be linked to similar regional ATMS systems in neighboring states and in other parts of South Carolina, such as potential centers in Atlanta, Charlotte and Columbia.

In addition to supporting a wide range of functional requirements the system should also be designed to provide both centralized and distributed control functions. This reflects the systems role in serving local as well as regional and national transportation needs. Distributed control capabilities would support multi-jurisdictional access and control capabilities from multiple centers,



For Illustrative Purposes Only. Preliminary Concept is not Intended to show all components, communication links or agencies associated with a Regional ATMS.

GREENVILLE / SPARTANBURG REGIONAL ATMS PRELIMINARY CONCEPT

Exhibit 8-4

so that the Cities of Greenville and Spartanburg can retain responsibility for the operation of signals under their jurisdiction, while being integrated into a region-wide system.

Phased Implementation

It is recommended that the regional ATMS be implemented in stages. The pace of developments will be determined by a variety of factors, including budgetary constraints, local priorities and the increase in traffic congestion on the region's highways. Implementation will also be influenced by the rate at which Intelligent Transportation System (ITS) concepts and technologies are proven and gain wide acceptance, among both transportation professionals and the travelling public.

To provide a guide to long-term implementation a three-phase approach is recommended:

- Short Term
  - Focus: Traffic Management Team
    Motorist Assistance Patrols
    Local Control Centers
  - Projects: Spartanburg I-85 Couplet ATIS
    Greenville Downtown ATIS/ATMS
    ATIS for I-85 Widening Projects
- Medium Term
  - Focus: Integration of local projects into regional system
    Expansion of MAP and other ATIS services
  - Projects: Regional ATMS in permanent TOC
    Additional ATIS Projects
    Adaptive Traffic Signal Control
    Region-wide Communications Network
- Long Term
  - Focus: Full range of ATMS, ATIS, ARTS and CVO services
    Links to other regional ATMS Systems
  - Projects: Provision of ATIS data to major traffic generators (offices, factories, malls etc).
    Support of In-vehicle ATIS displays and systems

- Spilled loads (§ 56-5-4100);
- Removal of unattended vehicles (§ 56-5-2520);
- Property damage only accidents (§ 56-5-1220); and
- Regulation of wrecker services (R 63-600).

Amendment of Legislation, Regulations and Policies should be accompanied by appropriate Public Education programs so that laws and responsibilities are fully understood and supported by those who use South Carolina roadways.

Public Education Programs

Public education initiatives are needed to ensure the travelling public understands and respects developments in traffic operations aimed at congestion management and safety. Such developments include new services such as Motorist Assistance Patrols and expanding services such as Variable Message Signs, Highway Advisory Radio and Cellular Phones (*HP).

Public education initiatives are also recommended to clarify the duties and responsibilities of drivers involved in property damage only accidents.

As the proposed regional ATMS for the Greenville/Spartanburg area develops it will become the central focus for the collection, processing and dissemination of a wide range of travel related information. The potential benefits to the community will only be fully realized if the travelling public properly understands how such systems can assist them and how they (the drivers) can assist themselves and other road users by being aware of and complying with traffic controls, traffic advisory messages and highway related regulations.

Compatibility with ITS Developments

In March 1995, FHWA issued a paper on “Core ITS Infrastructure Elements for Metropolitan Area ATMS/ATIS "Deployment.” This paper presented definitions for “core infrastructure” elements for deploying ITS traffic management and traveler information services in a metropolitan area.

The paper stated that “In the near term, implementation of the ATMS/ATIS core infrastructure elements is expected to be lead by the public sector, and development of these capabilities is expected to occur in an evolutionary manner.” It also notes that “Metropolitan areas should be working toward development of these capabilities, with a special emphasis of laying the foundation for future ITS advancements through selection of open-architecture systems and region-wide institutional cooperation.”

The recommendations of this study are fully consistent with FHWA’s guidance as provided in the referenced paper:

Other Congestion Management Recommendations

- The recommendations are based on a long-term perspective and emphasize a phased implementation process - recognizing the impact of both budgetary constraints and the evolutionary nature of ITS technologies.

- Conceptual designs developed during the study focus on small-scale local projects, which can be expanded as necessary, and on development of a high capacity backbone communications network - a key component for open-architecture systems of regional/national scope.

- The formation of a Traffic Management Team(s) in the Greenville/Spartanburg region is considered a high priority action. The Team would oversee incident management planning activities, play a key role in driving the scope and rate of expansion of ATMS/ATIS and other ITS projects and provide the catalyst for region-wide institutional cooperation.

END NOTES

1. Technical Memorandum on Incident Management Strategies, prepared by WSA, January 4, 1994.

2. Technical Memorandum on Conceptual ATMS System Functions, prepared by WSA, May 17, 1994.

3. Technical Memorandum on ATMS Organization and Legislation Issues, prepared by WSA, August 31,1994.

4. Greenville/Spartanburg Area Congestion Management Study and Design, Preliminary Study Report, prepared by WSA, November II, 1994.

5. Incident Management Workshop, FHWA Demonstration Project Number 86.

6. Framework for Developing Incident Management Systems, prepared by Washington State Transportation Center for Washington State Transportation Commission and U.S. Department of Transportation, August 1991.

7. Core ITS Infrastructure Elements for Metropolitan Area ATMS/ATIS Deployment. FHWA/HTV-10; Version 1, March 9,1995.

Appendix A

INCIDENT DETECTION ALGORITHMS

Appendix A
INCIDENT DETECTION ALGORITHMS

The subject of automated incident detection is discussed in Section 4 of this Report, in connection with the conceptual design of an ATIS for the I-85 couplet north of the City of Spartanburg. To provide some background for that discussion this Appendix contains a brief review of the development of incident detection algorithms.

"CALIFORNIA" ALGORITHMS

The most frequently used algorithm for determining incidents has been the "California Algorithm". This algorithm, of which there are ten different versions, is based on measures of occupancy. It is intuitively obvious that the occupancy measured in a lane of traffic is going to be higher upstream of an incident than it is downstream of an incident. Thus, the algorithm and its various versions compares occupancy at each detector station against the occupancy at the next downstream detector station. The various versions of the algorithm includes sophisticated techniques for improving detection sensitivity, while decreasing the false alarm rate by comparing occupancies not only on a spatial basis but also in time.

When the occupancy is averaged across multiple lanes, the comparison of the upstream occupancy against the downstream occupancy also provides a measure of the severity of the accident. For example, if an incident is restricted to a stalled car in one of the lanes, the upstream occupancy and downstream occupancy will be somewhat different, but since motorists are very adept at "squeezing around" such incidents, the difference in occupancies is usually quite small. However, when an incident occurs in which vehicles are left straddling two lanes or when the incident has sufficient graphic impact to cause much motorist distraction, the upstream and downstream occupancies will be significantly higher. Thus it is possible to estimate the severity, and thus provide a measure of emergency service priority, by this technique. Finally, it is also an elementary exercise to determine which lane or lanes an incident is in, by comparing on a lane by lane basis, the upstream and downstream occupancies. This can be a significant factor when dispatching emergency vehicles.

Calibration Requirements

The California Algorithm is based on comparing occupancy values in terms of threshold levels. These threshold levels apply to each pair of detector stations. In general, each threshold level for the algorithm must be calibrated for each detector station. Additionally, the calibration tends to change as a function of the time of day and weather conditions so that for optimum performance, a massive amount of calibration is required. The calibrated thresholds are also subject to diurnal variations, seasonal variations and long term (growth) variations. This situation is not unlike the development of timing plans for a traffic control system. As with timing plans, the threshold values constantly require re-calibration.

Mis-identification of Incidents

Conditions often occur on a freeway which might appear to be an incident to an algorithm but which is not really an incident. These can be from two sources:

- Traffic conditions which "look* like an incident but which are not one: This is the most difficult to eliminate source of "false alarms". This most often happens when traffic volumes are near the saturation point. Traffic flow is sufficiently uneven that upstream occupancies might be quite high and downstream occupancies can be lower because of the effect of the "compression" wave occurring under such circumstances. The algorithm signals an alarm because the algorithm is not sufficiently sensitive or is improperly calibrated for the performance of its function. The many variations of the basic California algorithm are all designed to address this problem.

- Traffic conditions which are effectively an incident but which require no emergency or remedial action: Typical of this type of incident is when the queue at an off ramp backs onto the freeway. This typically happens in the urban areas in the morning and in the suburban areas in the evening. About the only way of eliminating this "false alarm" is to ignore the alarm at those ramps and at those times of day when it most often occurs. Ignoring it can, of course, also be the cause of ignoring **a** real incident at the same location.

Use of Parameters Other Than Occupancy

The California "occupancy only" algorithm is perhaps marred by failing to use volume in its calculations. High occupancy values can be a result of either:

- High volumes moving at high speeds

- Low volumes moving at low speeds.

Thus, the California Algorithms, in effect, do not have the ability to discriminate between traffic flowing at a high speed from that moving at a low speed. However, it isn't clear whether this (theoretical) weakness contributes to the algorithm's problems.

Since speed can be determined from volume and occupancy by the simple equation

$$\text{Speed} = \frac{\text{Volume} * K}{\text{Occupancy}}$$[1]

---

1 The value of K is a function of the combination of car length and loop length. When the unit of volume is vehicles/hour, the unit of occupancy and the unit of speed is miles/hour and for a car length of 16 feet and a loop length of 6 feet, the value of K is 0.416.

it is quite possible that incident detection algorithms based on "speed" can utilize data from loop detectors as well as from radar detectors[2].

However, since speed can be measured directly by radar type devices, the use of radar technique clearly eliminates the problem caused by non-use of volume information in the California Algorithms.

ALGORITHMS BASED ON SPEED

How is speed used in incident detection algorithms?

- "Mean Speed" Algorithm: Monitor the average speed at each detector station. When the average speed falls below a threshold value, it can be assumed that this signals that an incident has occurred. The threshold value would most likely have to be calibrated and made a function of the time of day/day of week to distinguish between normal saturated traffic conditions (at peak hours) and abnormal traffic conditions due to an incident.

- "Difference in Speed" Algorithm: The difference in speed, as measured at two adjacent detection stations, is comparable to the California algorithm technique except that it uses speed. Intuitively, it is obvious that the average speed upstream of an incident will be lower than the average speed downstream of an incident. As "difference in speed algorithms become better defined, they will probably tend to exhibit the same logic as in the California algorithms; i.e., consider both the spatial domain and the time domain. The latter will be required to separate the effect of the "compression" wave which results during normal heavy traffic conditions.

- The same algorithm as directly above with the addition of time limits over which the thresholds are applicable. This is comparable to a time of day algorithm.

- "Standard Deviation" algorithm: this algorithm has been programmed into the system described in Connecticut's experience[3] It is not clear at this point what merit this algorithm might have.

It is also probable that "thresholds" will have to be calibrated and made time dependent so

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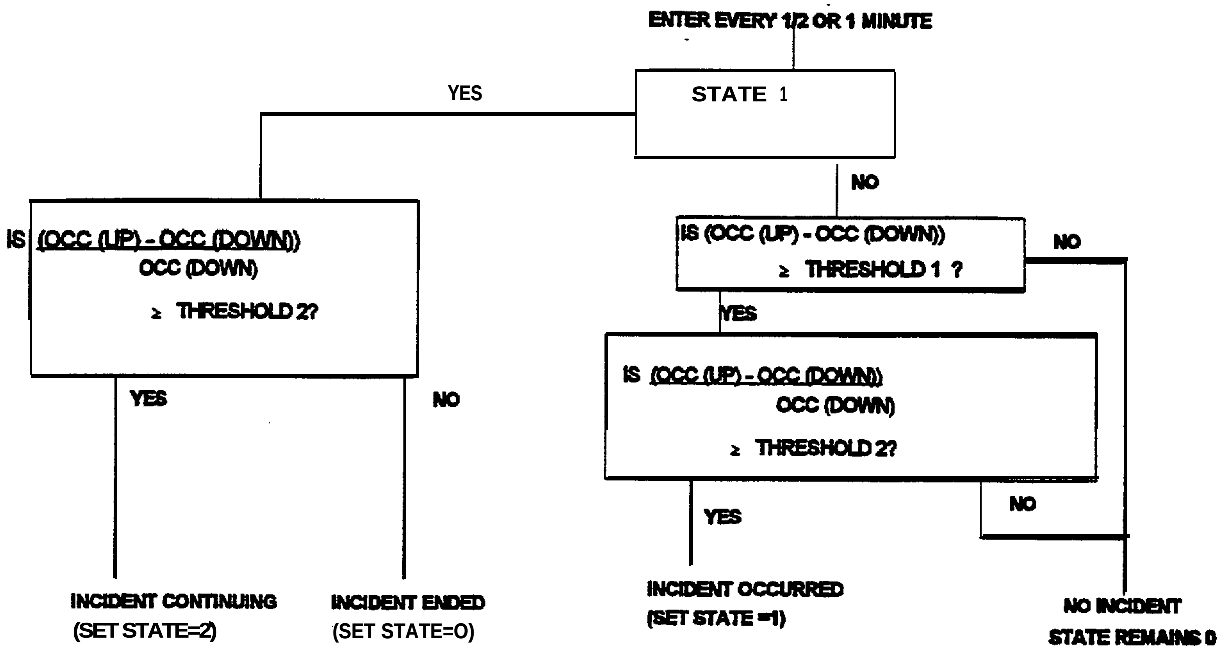
2 Most incident detection systems "sample" the data every 30 seconds or one minute. It may be that these short term measures of volume would vary widely (in even normal traffic conditions) that the resulting speed would also be too random to be of use in this process. "Smoothing," of course, reduces this randomness but also tends to obscure the information being sought. Additionally, smoothing slows down the "time to detect."

3 Mauretz, M. R. and Stoeckert, W. W., "Speed Based Traffic Monitoring: Connecticut's Experience with Radar Detectors," pp *447-453, Proceedings of the IVHS American 1994 Annual Meeting,* April 1994.

as to reduce the false alarm rate. Finally, there isn't any obvious means that the speed algorithms can be made to differentiate between a true incident and a condition such as **a** ramp backing up onto the mainline. Exhibit A-l illustrates the logic of one of the simpler California Algorithms; the analogous "speed" algorithm is shown in Exhibit A-2.

It is anticipated that as incident detection algorithms are improved, the basic improvement will be through the inclusion of a "learning" process where the thresholds will be self-calibrating and where repetitious conditions will be recognized as an annoyance but not as an incident. These types of algorithms will be analogous to the "traffic adaptive" signal timing algorithms (such as SCOOT or RT-TRACS).

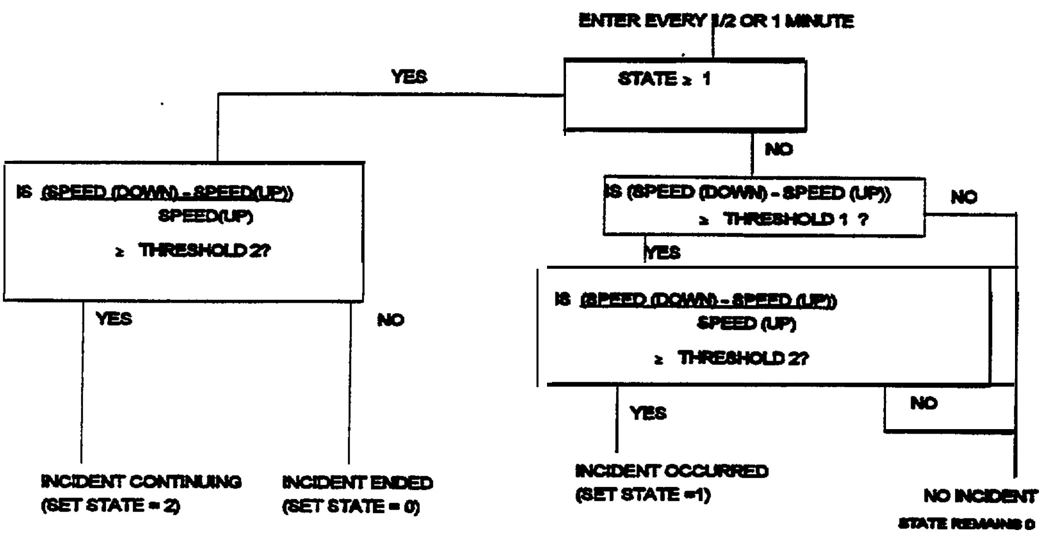
In either of these examples, the algorithm is entered at the end of each sampling period for each pair of adjacent detector stations. The value of “state” when the algorithm is entered controls the decision path.



“STATE” is the detected incident status upon entry to the algorithm.
0 means there is currently no detected incident.
1 means an incident was detected at tine last entry.
2. means that there was an ongoing incident during the last entry and it is continuing.

Exhibit A-l : Typical California Algorithm

In either of these examples, the algorithm is entered at the end of each sampling period for each pair of adjacent detector stations. The value of "state" when the algorithm is entered controls the decision path.



"STATE" is the detected incident status upon entry to the algorithm.

0 means there is currently no detected incident.

1 means an incident was detected at the last entry.

2. means that there was an ongoing incident during the last entry and it is continuing.

Exhibit A-2: Speed-Based Analog of Exhibit A-l

Appendix B

RADAR DETECTION DEVICES

Appendix B
RADAR DETECTION DEVICES

Radar detection devices are mentioned in Section 4 of this Report as a potential component of an incident detection subsystem. This Appendix expands upon the theory of operation of such devices and discusses characteristics relevant to design and implementation activities.

THEORY OF OPERATION

Radar detectors measure speed directly. They operate on the Doppler shift principal; i.e., a radar beam with a given frequency is "bounced" off a moving vehicle; if the vehicle is moving toward the detector, the frequency of the "bounced" signal returning to the radar detector has increased. The amount the frequency has increased is a function of the speed of the vehicle and the viewing angle of the radar. Referring to Exhibit B-1 the frequency shift of the radar will be given as follows:

$$\begin{aligned} \Delta f &= f_t \frac{c+v}{c-v} - f_t \times \cos\Theta \\ &= \frac{2v}{c-v} \times f_t \times \cos\Theta \\ &\approx \frac{2v}{c} \times f_t \times \cos\Theta \end{aligned} \qquad (1)$$

rearranging,

$$v \approx \frac{c \times \Delta f}{2 \times f_t \times \cos\Theta} \qquad (2)$$

where Δf = is the difference between the transmitted frequency and the received frequency (Hz)
f_t = the transmitted frequency (Hz)
c = the speed of light (same units as v)
v = the speed of the vehicle (same units as c)
Θ = the angle at which the radar beam vector is removed from the velocity vector of the vehicle.

In this equation, note that the constant (2) is necessary to account for the Doppler shift of the radar beam as it strikes the vehicle and the shift as the reflected beam is returned to the radar site. Also note that if the vehicle is standing still ($v = 0$) there is no Doppler shift. Further note that if the radar beam and the velocity vector of the vehicle are congruent, the angle Θ is zero and the cosine of the angle is 1. Note also that if the velocity vector of the vehicle and the radar beam differ by 90°, the cosine of the angle is 0, so there is no Doppler shift. Finally, note that the approximation above arises and is acceptable because the speed of the vehicle (v) is orders of magnitude lower than the speed of light (c).

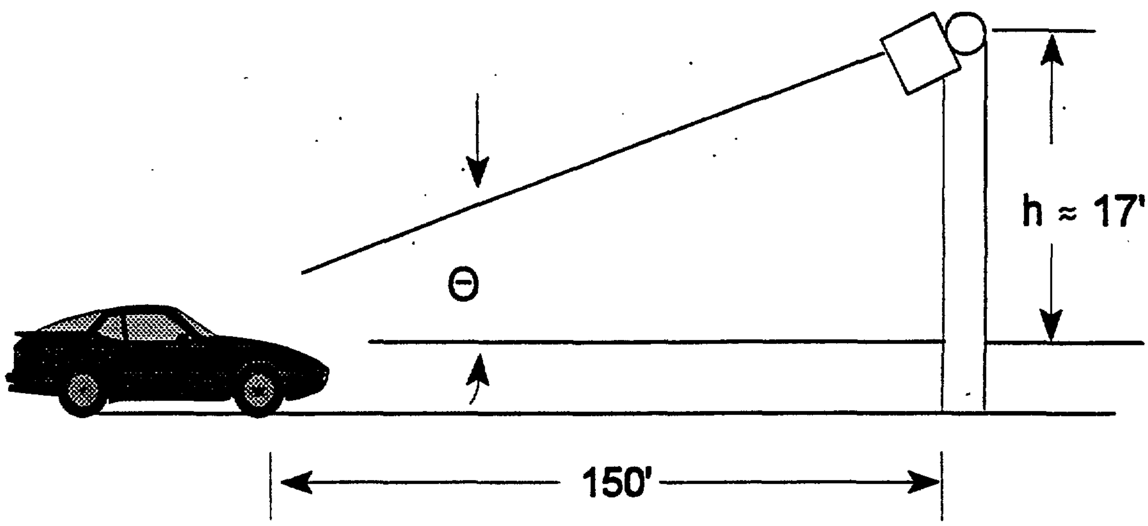


Exhibit B -1 Radar Geometry

Location of Radar Detectors

It is preferable to mount detectors over the road. However, considerable success has been achieved by using radar detectors mounted along side the road. These detectors look down the road; similar to the way a police radar is employed. When there is more than one lane of traffic, it is difficult to discriminate between one lane and the other. However, depending on the quality of the algorithm and the amount of effort made to calibrate the algorithm, using the "average" lane speed may be acceptable.

Thus, the following attributes for the location of radar detectors may be defined:

Preferred Implementation:

- Detectors should, ideally, be able to measure the speed on each lane independently of the other lanes.
- Detectors must be mounted over the road, one for each lane of the road.
- Detectors can measure the speed for vehicles going away from it or approaching it (v is a vector, not a scalar, and has a sign (+ or -) depending on the direction of motion.).

Secondary Implementation:

- Detectors could be installed on the side of the road and look downstream (or upstream) the traffic flow.
- This approach would not be able to measure the speed of individual lanes of traffic and would, therefore, provide data with less accuracy than the "above the road" method.

Spacing of Detectors Along the Route

The considerable amount of research done on the California algorithm suggested that one mile spacing between detector stations was adequate for incident detection purposes. However, in the case of I-85, since there are ingress and egress points approximately every mile, it seems apparent that traffic flow deviations due to access and egress might materially increase the false alarm rate. It is suggested that the detectors on I-85 be spaced at one half mile intervals. Because of the effect of calibration, there is no need for "exactness" in the separation of the detector stations. Any distance from 0.5 mile up to 1 mile should be satisfactory. The calibration of the algorithm for each set of detector stations will compensate for differences between adjacent stations.

Radar detectors can be and preferably are mounted over the roadway. A typical mounting location would be on an overpass which crosses the mainline. Perhaps from the point of view of consistency, it might be advantageous to have all of the detectors measure either the approaching traffic or the receding traffic. However, it makes no difference to the algorithm (as long as its database "knows" which direction of flow is being measured.. Therefore, it is suggested that the exact locations be made on the basis of getting good "clean" data rather than the direction of flow. For instance, it is best to avoid weaving sections and merging areas where the speeds measured do not reflect the mainline free flow speed.

Height of Radar Detectors

When mounted over a roadway on a sign bridge or overpass bridge, heights from 17 feet to 20 feet can be readily accommodated. This being the case, mounting and pointing parameters may be identified as follows:

- Mounting height above roadbed = 18 feet
- Average vehicle height above roadway = **3** feet
- Maximum range of radar beam = 150 feet

Thus, the angle of the radar beam off of that of the vehicle's velocity vector is about 5.7" and the speed measured by the radar will be Cos 5.7" = 0.995 of the actual speed.

Note that the correction factor is very small. Therefore, mounting the detector either lower or higher than suggested here will not alter the subsystem significantly.

Radar Detector Electrical Characteristics

Radar detectors are available in several microwave and infrared frequency bands. The level of accuracy required in this application is not the same as required in an enforcement application. The data from these detectors will not be used in a court of law to prove anything. Therefore, accuracy is not the most important attribute of this type of detector.

Beamwidth - Beamwidth is the effective detection width of the device and is given in degrees. All radar type devices have a beam that has the appearance illustrated in Exhibit B-2. The dashed line indicates the level of energy that reaches the receiver from a fixed energy source at any angle from the center line of the beam. The beam width is usually stated as being the angle in which the energy level is at least 1/2 of the energy level received at the peak point. Since the "gain" of an antenna is expressed in terms of decibels (db), the beam width is sometimes expressed as the 3 db beamwidth.

Converting this to values that are expressible in terms of Exhibit B-l, it can be said that:

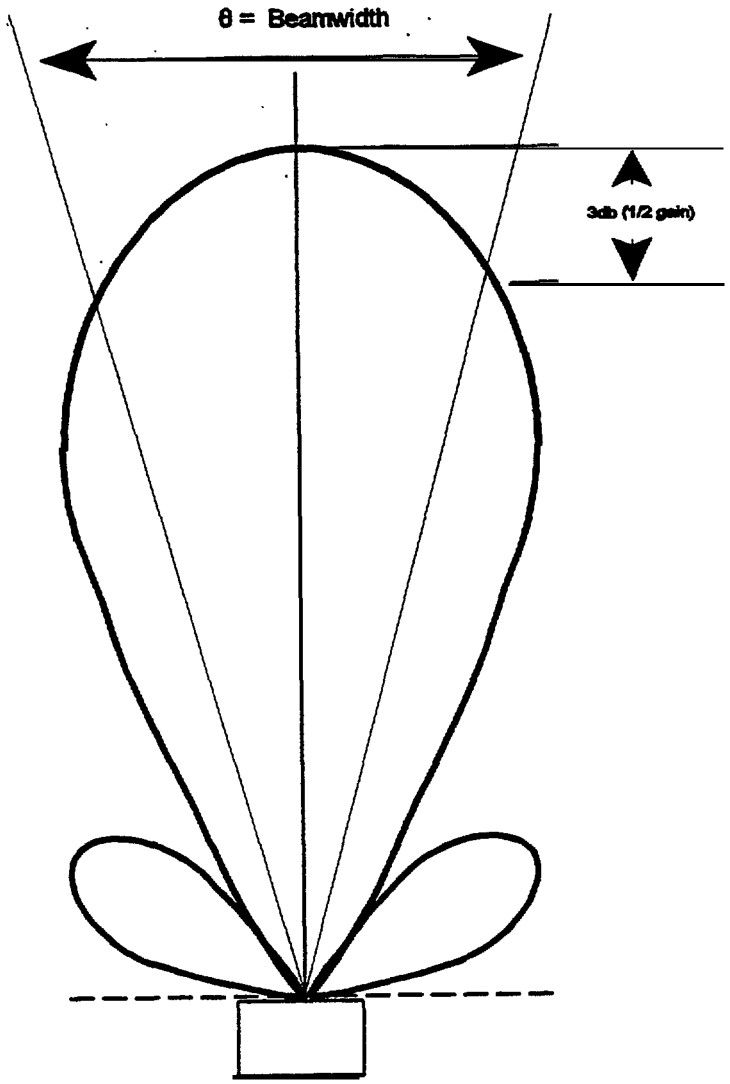


Exhibit B - 2

Antenna Beamwidth Considerations

- Assuming that a vehicle is recognized 150' upstream of the antenna and assuming the antenna height is 15' above the vehicle, the recognition distance is 150.7'.
- Assuming a vehicle width of 6', then the beam width should not exceed 2 x arctan 3/1 50.7 = 2.28 degrees.

The beamwidth of an antenna is an inverse function of the frequency of the device and the radius of the antenna. Thus, for a given frequency, the beamwidth decreases as the frequency increases. Comparably, for a given antenna radius, as the frequency increases, the beamwidth decreases.

It is for this reason that police radars continue to increase in their usage frequency. The higher the frequency, the smaller, thus less noticeable, is the radar device itself. Since stealth is not necessarily a requirement of the detector subsystem, the size of the device is not of total importance. However, of course, cost and mounting difficulties increase as the amount of material in it increases.

Interference Rejection - When radar type detectors are mounted overhead and side by side, separated say by the lane width; i.e., 12 feet, there will be reflections of energy off of a vehicle in one lane which will be received by the radar in the adjacent lane (or lanes). Since this interference will cause measurement errors, it is necessary to separate the frequencies sufficiently so that bandpass filters included in the radar device can reject the unwanted energy. Similarly, a radar site at one location which looks directly upstream at a radar detector station looking upstream on the opposing roadway can also cause interference in the same manner. Thus, the design must include sufficient radar frequencies and care in selecting which radar has which frequency so that this problem is eliminated.

Energy and Sensitivity - The effective "range" of a radar device is defined by the following equation:

$$\mathbf{R(miles)} = (P_t * G_t * G_r * S_r * R * K)^{1/4}$$

where P_t = the transmitted power output

G_t = the gain of the transmitting antenna

G_r = the gain of the receiving antenna. (In most radar systems, the receiving antenna and the transmitting antenna are the same device, therefore, the factor $G_t * G_r$ can ordinarily be replaced by G^2.)

S_r = the sensitivity of the receiver

R = the reflectivity of the vehicle

K = a constant depending on several other minor factors.

It is, therefore, the radar system vendor's function to design a system which has adequate power out and adequate receiver sensitivity, along with adequate antenna gain to detect vehicles at a reasonable range. The ability to detect motorcycles, with a much smaller reflectivity than a car or truck, may be a concern in systems where detection of every vehicle is important. In the case of incident detection, the inability to "see" a small vehicle or a motorcycle would not be important unless an attempt is made to include vehicle classification along with its other functions.

Detector Mounting Characteristics - Radar detectors of the type needed for this system will ordinarily weigh approximately ten pounds, and measure about five inches in diameter and about one foot in length. The housing will be iron, steel or aluminum except for the front end. The front will be covered with a plastic material which is transparent to radar frequencies. Power required for the device will probably be 110 VAC at perhaps 10 watts (0.1 amps).

Other than the electrical service leads, another wire or wires will be required for the data being returned by the device. Finally, it is possible, that there may be a wire required for a signal to turn off the device.

The unit must be adjustable along all axes so that it can be pointed up or down the roadway at the correct angle and direction. The mounting device must be of the type which is easy to adjust but when "tightened down", will not move because of wind or vibration.

Mounting on Existing or New Sign Bridges - Mounting of this type of detector on an existing fixed sign bridge or a new variable message sign bridge should be relatively simple. Aspects to consider when designing the mounting are:

- Access to the device for electrical power and the signal wires
- Enough freedom of movement so that it can be "pointed" and, if necessary, be turned around to face the opposite direction
- Access for maintenance purposes. The most likely maintenance access will be a bucket truck. However, in the case of units attached to a VMS bridge, access via the same method that the sign is maintained may be possible.
- Invisibility/aesthetics. The device can not be mounted in a place which obstructs a sign or which obstructs lighting of a sign. In addition, care must be taken to ensure that the aesthetics of the device does not detract from the existing structure nor should it call attention to itself. There is a high likelihood that motorists will at first assume that the device is a radar for enforcement purposes. Although that result may be noble, it also may cause some motorists to lose concentration on what they are doing; that is, driving safely.

Mounting on Existing Overpass Bridges - Wherever possible, it would be desirable to mount the detectors on existing overpasses. It would seem likely that this would provide the most transparent location; that getting power to and from the station and to the detectors would be easy, and construction costs would be minimized. As stated earlier, not maintaining a "fixed" distance between the stations should not constitute a problem if the algorithm is properly designed and calibrated.

Detector Subsystem Operational Characteristics

As stated above, the purpose of the detector data is to provide speed information to an algorithm which, in turn, determines if an incident exists, its location, if possible its severity, and, when possible, the lane or lanes affected by the incident. Although not specifically designed for the purpose, there seems to be no reason why a radar detector can not supply "presence" information as well. The presence information can be readily converted to volumes (vehicles per hour). And, with these two pieces of data, it would take little additional computation to compute occupancy (or density).

Data Precision - A radar detector might convert the frequency deviation data directly to speed (see Equation 2) for transmission to a hub or concentrator.

All the values in equation 2 are constant for any given installation except for Δf which is the parameter measured by the radar detector. Therefore, in order for the radar detector to send back the measured speed to the control site, it would need to include a small computer which could store all of the constants as one parameter, K, where:

$$K = \frac{C}{2 f_t \cos \theta}$$

The speed would then be computed using the formula:

$$V = K \times \Delta f$$

It might, instead, simply transmit back to the hub or concentrator the value of Δf (in terms of a numerical unit) or $\Delta f / f_t$, in terms of percent. The value Δf is the easiest value to send to a computing point as it is the "raw" data from a radar detector. It is doubtful, from the incident detection algorithm point of view, if the precision of the measurement and its transmission to a hub or to central needs to be better than 2%. (1 mile per hour at 50 miles per hour is 2%.) It is doubtful that the precision of the radar detector will be any better than this value. Therefore, using one byte of data, which provides a precision of 1 out of 255, would be more than adequate for the purpose.

Where Should Computations Be Done?

This is a difficult question which can only be answered in conjunction with the design of the rest of the I-85 diversion system. The principal deciding factor for where to do the computing is the communications costs:

Detection Subsystem Only - If the detection subsystem were the only user of communications in the subsystem, the analysis would include such factors as:

- The data rate from each detector which will depend on the type of algorithm. When the algorithm of choice requires somewhat high data rates (as in the case of the “standard deviation” speed algorithm, it is quite likely that it would less expensive to do the computations locally than to send them to a central site. The trade off considerations would be the cost of the telephone (or user owned) lines to get the data to central vs the cost of the local computing equipment capable of doing the calculations. A possible configuration might include several subsidiary computing points which process the data and determine the results and then send those results to the central site for dispatcher action.
- When the algorithm of choice has low data rates **(say,** one which uses the average speed over multiple lanes as measured by a radar); all of these data could be multiplexed on to one phone line. The cost of the multiplexing equipment would be nominal in comparison with the distributed processing required by the concept described above.

Another factor which must be considered in this analysis is the need for downloading data. When distributed processing is done, and the algorithm requires many constants which vary as a function of the time of day, day of week, consideration must be given to the data requirements for downloading all of these constants to the various distributed processors. Perhaps when, and if, algorithms are found which are self calibrating, this will not be a consideration. However, at this point in time, it would appear that it is a factor which must be considered.

Incident Detection Combined with Other Freeway Operations - The addition of CCTV and other freeway operational functions completely changes the decision process. CCTV requires very large data rates (say 1000 times larger than the incident detection process, alone). Thus, the use of one or more TI channels (with a data rate of 384 kbs per channel) leased from the telephone company or using user-owned fiber optic communications will most likely make the use of central processing more attractive. The very low data rate Incident Detection data can be multiplexed on to the same T1 or fiber lines as the video image. The extra cost of carrying the raw incident detection data to a central site would be negligible.

However, we can address the specific requirements of the detection subsystem before going on to the rest of the system.

Communication Considerations - Assuming that the speed incident detection algorithm can use averaged and/or smoothed data, then some assumptions about the data rate can be made.

With one exception, incident detection algorithms use speed average data over either a half or one minute period. These data are accumulated at a local hub and are transmitted back to the central site. The incident detection computations are done at the central site. In the California algorithm, it has been found that when 1/2 minute averages of data are used, it is then necessary to smooth the 1/2 minute data to further reduce its randomness.

It is possible, of course, to do more of the computations locally (and transmit only the results to central). For example, a fairly unsophisticated computer in the local hub cabinet could process the data from two or three (or more) detector sites and then only send the results back to the central site.

Although this concept utilizes the current enthusiasm for distributed computing systems, it may cause more problems than sending the data back to the central site. For example, suppose that one hub processes data from 4 adjacent detector stations, numbered 1, 2, 3 and 4. Suppose hub number 2 processes data from the next 4 adjacent detector stations, numbered 5,6,7 and 8. Because detector stations number 4 and 5 constitute a detector station pair, as needed for the second, third and fourth speed algorithms discussed above, the data from detector station 4 would have to be sent to hub number 2 so that the data could be processed with the data from detector station 5. This opens the need for a data transmission path which is not required should the centralized concept be used instead.

The algorithm which is the exception, noted above, uses the speed of individual vehicles and determines the standard deviation of this data. If the individual speeds are transmitted to central, considerable wider bandwidth would be needed to send this data to central. A local processor could be utilized to do this processing and only the results could be sent back to central. Once again, however, this technique requires some level of capability in the local processor (although the computing power required is insignificant when compared with current computers).

Example 1: Lowest Data Rate Scenario

First, assume that the data rates and operation on both the Business and the Bypass I-85 roadways have the same Incident Detection Requirements. Further, assume that there is a detector in each station every 1/2 mile and assume each station monitors (thus averages) two lanes simultaneously.

Also, assume that the length of the dual roadways is, for each, 9 miles. Therefore, there would be 18 detector stations per roadway in each direction; or a total of 72 detector stations.

- Assuming 1/2 minute averaging and assuming that the data from each detector station would consist of one byte per detector station (adequate for speeds from 0 to 255 mph). The accuracy of the raw data would not justify sending the data with a precision of 0.1 mph.

  Thus, the total data rate would be 72 samples x 1 byte/sample x 10 bits/byte x 1/30 sample/second; a data rate of 24 bits/second. Even assuming 200% overhead, the data rate would be negligible.

Example 2: Highest Data Rate Scenario

In this scenario, it is assumed that the algorithm to be used is the "standard deviation" speed equation described earlier. In this case, the speed of each vehicle is used in the computations, Assuming we have 1,000 vehicles/hour in each of 8 lanes, the data rate required will be:

> 1,000 veh/hour/lane x 18 detectors x 1 byte/vehicle x 10 bits/byte x 113,600 hours/second = 50 bits/second/lane. Since there are 8 lanes, the total data rate is 400 bits/second.

Again, assuming 200% communication overhead, the data rate is still quite low.