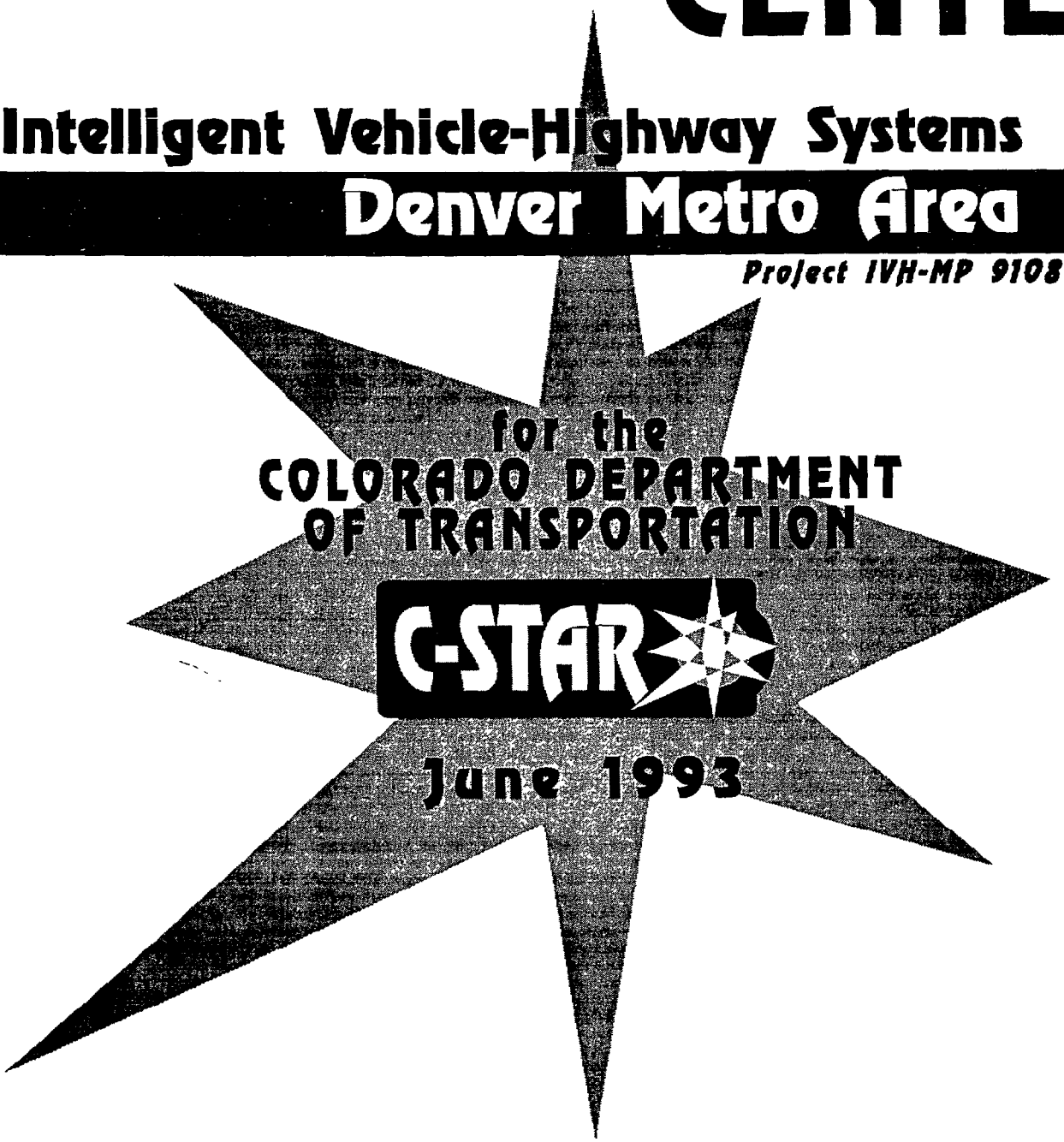
TRAFFIC OPERATIONS CENTER

Intelligent Vehicle-Highway Systems

Denver Metro Area

Project IVH-MP 9108(1)



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LIST OF ACRONYMS / ABBREVIATIONS

APTS	Advanced Public Transportation Systems
ATIS	Advanced Traveler Information Systems
ATMS	Advanced Traffic Management Systems
AVCS	Advanced Vehicle Control Systems
AVI	Automatic Vehicle Identification
AVL	Automatic Vehicle Location
CAD	Computer Aided Dispatch
CCTV	Closed Circuit Television
CDOT	Colorado Department of Transportation
CIMC	Colorado Incident Management Coalition
CSP	Colorado State Patrol
CTI	Colorado Transportation Institute
cvo	Commercial Vehicle Operations
DAB	Digital Audio Broadcasting
DPS	Department of Public Safety
DRCOG	Denver Regional Council of Governments
EIS	Emergency Information System
EON	Enhanced Other Networks
FHWA	Federal Highway Administration
FMCS	Fleet Management and Control Systems
FTE	Full Time Employee
FTA	Federal Transit Administration
GPS	Global Positioning System
HAR	Highway Advisory Radio
HOV	High Occupancy Vehicle
ISTEA	Intermodal Surface Transportation Efficiency Act of 1991
IVHS	Intelligent Vehicle Highway Systems
MAC	Metro Area Connection (Light Rail)
MIS	Management Information System
OS1	Open Systems Interconnection
POSIX	Portable Operating Systems Interface
PRV	Platte River Valley
RDS	Radio Data System
RTD	Regional Transportation District
SONET	Synchronous Optical Network
TCSP	Traffic Control Support Project
TIC	Traffic Information Center
TMC	Traffic Message Channel
TOC	Traffic Operations Center
TP/TA	Traffic Program/Traffic Announcement
TSM	Transportation Systems Management
VMS	Variable Message Signs
VMT	Vehicle Miles Traveled

1.0 OVERVIEW

1.1 Introduction

Establishing a TOC is central to several elements of the Denver Area IVHS program. Its importance will continue beyond the short-term phase and well into the future when the TOC expands its role in supporting and managing available and emerging IVHS technologies over these time periods. This report describes the conceptual design, construction, and implementation of a Traffic Operations Center (TOC) for the Denver Metropolitan Area. It has been prepared as a part of Task 8 of the Denver Area Intelligent Vehicle-Highway Systems (IVHS) study and builds upon the goals of the IVHS Strategic Plan and Early Action Plan.

The TOC will be a multi-jurisdictional, multi-agency facility. Space will be provided for Colorado Department of Transportation (CDOT) and Colorado State Patrol **(CSP)** personnel, as well as for Public/private sector staff including traffic engineers from cities and counties in the Denver Area, the media, traffic information services, enforcement and fire agencies and emergency medical response organizations. CDOT and CSP will integrate staff positions for dispatch and call-taking functions, to take advantage of the cost efficiencies inherent in a pooled, multifunctional employee base. The TOC will be an important platform from which to improve dialogue and cooperation between Denver Area jurisdictions. It will also provide opportunities to establish educational and research programs as well as partnerships with the private sector. The broad multi-jurisdictional base of the Denver area TOC, along with the range of functions provided, will combine to form an operations center unmatched in North America.

Earlier in 1992, the Federal Highway Administration (FHWA) announced it was embarking on a program to establish TOCs in the largest 75 urban areas in the United States. Discussions between CDOT and FHWA revealed that funding is available now for the design of such a facility in 1992-93. Consequently, CDOT has secured this funding and implementation of a Denver Area TOC could occur by late 1994.

Between now and late 1994, CDOT will implement an interim TOC to begin organizing the existing field systems, such as ramp metering, ice detection, telephone hotlines, and Highway Advisory Radio (HAR), into a group of systems operated from a single location. Users of the interim TOC will also begin to evaluate and organize methods to process this information. Implementation of activities subsidiary to the TOC, such as construction and enhancement of the communications system, could begin almost immediately.

1.2 TOC Purposes

The TOC will Serve multiple purposes. These include the following:

. The TOC will be a focal point for multi-agency and public/private sector traffic managementefforts. Operators will be able to monitor and manage traffic flows on area freeways and ultimately influence traffic flows on the arterial street network.

- The TOC will serve as a foundation for short, medium and long term IVHS activities in the Denver Area. These include Advanced Traveler Information Systems (ATIS), Advanced Public Transportation Systems (APTS), Fleet Management Control Systems

(FMCS), Advanced Vehicle Control Systems (AVCS), Advanced Traffic Management Systems (ATMS), demand management systems and the data collection and information dissemination functions associated with these systems.

- The TOC will be a regional incident detection and response center. Coordination of local incident management initiatives will take place under one roof. TOC capabilities will include automated and manual detection of incidents, initiation of response plans including transmission of advisory messages to the appropriate agencies, and the provision of "war room" capabilities for major emergencies which impact traffic and require coordination between multiple agencies, as well as accurate, timely press information. The TOC will also be the coordination center for a cellular call-in system to report accidents and other road problems, and the Denver Area courtesy patrol program.

- The TOC will be a dispatch center for CSP enforcement personnel and CDOT Region 1 and 6 maintenance forces. Communication links to other public safety agencies and jurisdictions will enhance the regional aspect of the TOC and improve incident response capabilities. Construction permitting and traffic control planning activities for construction will also be housed within the TOC.

- The TOC will communicate with travelers at home, in-vehicle, and from remote locations such as office building lobbies or shopping centers. Information to be available will include current conditions, weather updates, advance notice of congested areas or construction zones, potential routing options and transit schedules and status. The TOC will generate traffic messages for telephone hotlines, HAR, variable message signs (VMS), and other communications media as well as maintain the appropriate data bases for traveler enquiry services.

- The TOC will provide a location for high technology research in cooperation with local colleges and universities, the Colorado Transportation Institute (CTI), FHWA or other agencies interested in transportation research.

- The TOC will function as the source for a public awareness and education program to inform travelers about the purposes, benefits and activities of the TOC and IVHS in general.

Conceptual planning for the TOC will include these factors as they relate to the Denver Area's IVHS-related data collection and information dissemination efforts. One important TOC function will be to unite existing Denver Area traffic management technologies and demand management efforts under one roof, into a single integrated traffic management system, while remaining flexible enough to incorporate future expansions and enhancements in IVHS.

The implementation of a TOC is crucial to many of the Denver Area's proposed IVHS and incident management initiatives. The TOC will provide a focal point for these activities in traffic and incident management, thereby supporting the operation of an integrated transportation information system. The amount of data base integration and sheer volume of incoming data will require a state-of-the-art computer system for system facilitation and management.

1.3 TOC "Vision"

Initial and long term success of the TOC depends upon a multitude of broad conditions and specific design issues. Broad ideas to be considered during the design process should include the following:

- The TOC building should be attractive. Since the TOC will be a point source from which to build public support for the regional IVHS program, the building should function as a showcase for the CDOT media and public relations efforts, creating a positive first impression for visiting officials.

- There should be a commitment to operate and staff the TOC on a continuous basis as major incidents and weather-related situations do not regularly occur during peak hours or on weekdays. The TOC must disseminate accurate and timely information to have a continuing positive impact on trip making patterns. It is crucial that the TOC provides highly credible information to the traveling public.

- Goals and standards should be set for reaction and response to freeway incidents. For example, the recent design of a TOC in San Antonio includes the capacity to handle one incident per freeway mile per hour, provides for incident detection in two minutes or less, with a response in less than a minute following the detection period (Reference 1). Similar capacity and reaction levels may be appropriate for the Denver area.

- Both the building itself and computer systems should be flexible and expandable. Unforeseen developments in MIS technologies and CDOT/CSP personnel levels make the flexibility to enlarge the building a must. Initially, the building itself should be as large as possible, incorporating a vision for the next 20 or so years, so that TOC users have sufficient space to grow and expand. The building will likely form a relatively inexpensive component of the overall system. New technologies which could become a part of me TOC are already emerging. For example, microwave, infrared, and video detectors promising expanded data collection capabilities and lower maintenance are emerging to compete with inductive traffic loops as a method of data collecting. The TOC should accommodate new systems such as these.

- The TOC needs to be designed using an open systems architecture and off-the-shelf equipment, wherever possible. For example, POSIX provides a platform between the computer operating system and the application software so the central computer can be replaced without spending $3 - $5 million for new software. SONET standards dictate hardware interchangeability, maintenance, formats, and multiplexing techniques in fiber optic networks.

- CDOT should consider a "fault tolerant" computer system. Two computers are provided in this configuration. One is the main and one is the alternate, but both process the same data so if the main crashes, the alternate picks up where the other left off.

- The TOC should be designed to be implemented in phases as funding becomes available over the next several years. The initial phase would include construction of the building and sufficient TOC and field equipment to allow a "running start."

- Extensive consideration should be given to the initial programs to be managed by the TOC in its early years. CDOT is currently developing a program for an interim TOC where many of the problems and coordination issues can begin to be resolved. It is very important that the initial programs and information dissemination from the TOC be perceived by the media and the driving and taxpaying public as a benefit. Future expansions and projects which await funding must be explained so they recognize the full potential of the facility.

- Staffing requirements, responsibilities, and interactions must be resolved during the design process. It has been suggested that there be full integration of the work efforts of CSP dispatching, CDOT maintenance dispatching and new IVHS related operations and activities. This is definitely a worthwhile goal, but it will require extensive coordination and communication to fully realize.

"Vision" for the Denver area TOC also includes the incorporation of regional IVHS efforts extending into the long term. The multi-jurisdictional aspect of the TOC will allow for multiple use of traffic information, communications, dispatching facilities, traffic control, monitoring, and will also allow for coordinated incident management,

The Denver Area IVHS Strategic Plan identified those IVHS activities most appropriate for implementation in the Denver area. A summary of those activities and their relationship to the TOC are depicted in Figures 1.1 and 1.2. Figure 1.1 shows activities and elements acting as inputs to the TOC. Conversely, Figure 1.2 shows activities and elements as potential outputs from the TOC. While it is unlikely that the full scope of these activities could be provided due to funding and logistical constraints, it is the range of the potential projects which demonstrates the "Vision" for the Denver area TOC.

1.4 TOC Services and Opportunities

IVHS technologies have been identified internationally as having significant potential to move vehicles and people safely and efficiently in the face of social, environmental, economic, and geographic restrictions- A key goal of the Denver Metro Area IVHS study is to integrate the region's existing transportation systems with the most promising and effective IVHS technologies into an overall program. The design and implementation of a TOC will provide the cornerstone for this initiative.

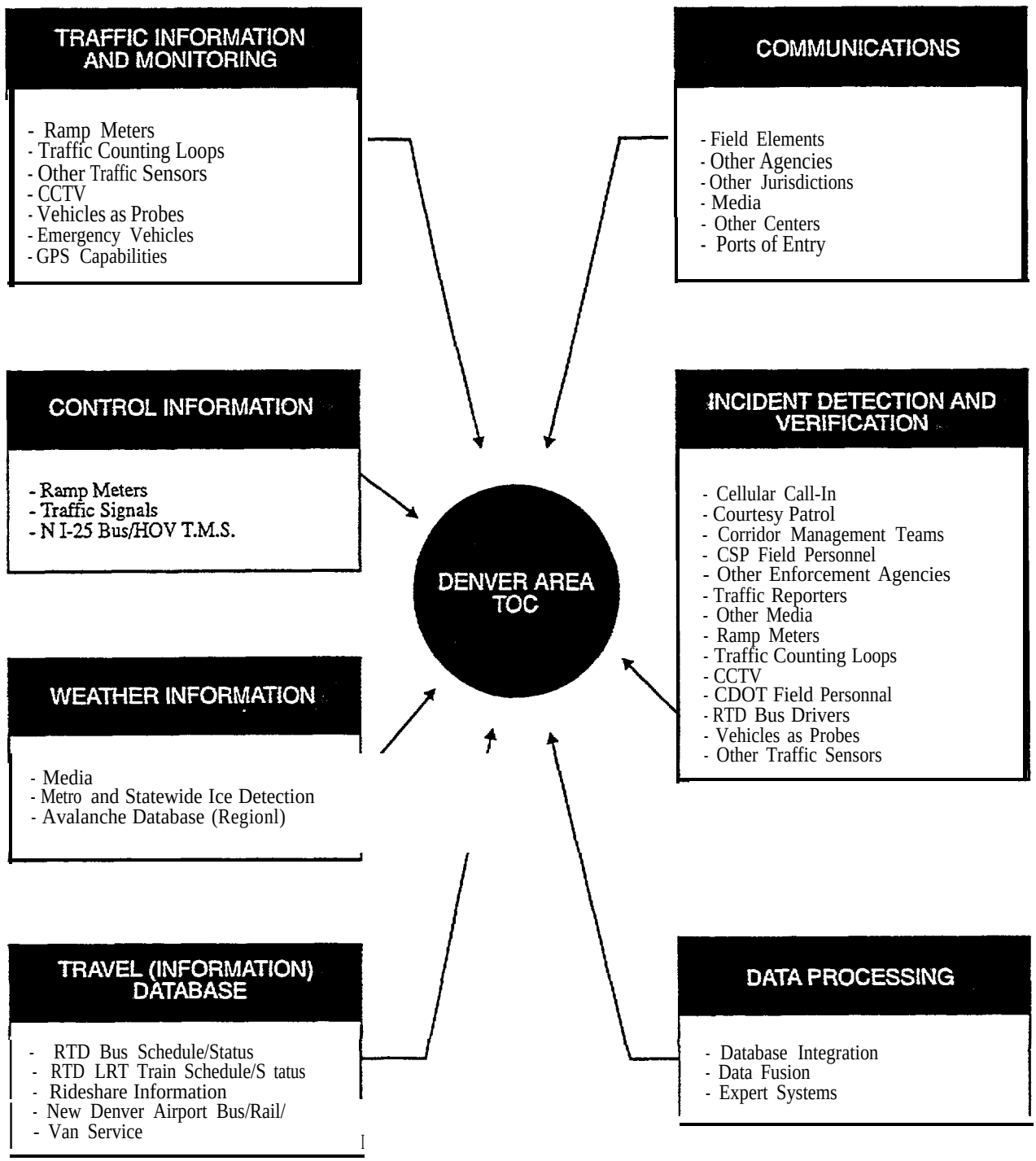

Figure 1.1 - Denver Area TOC Inputs

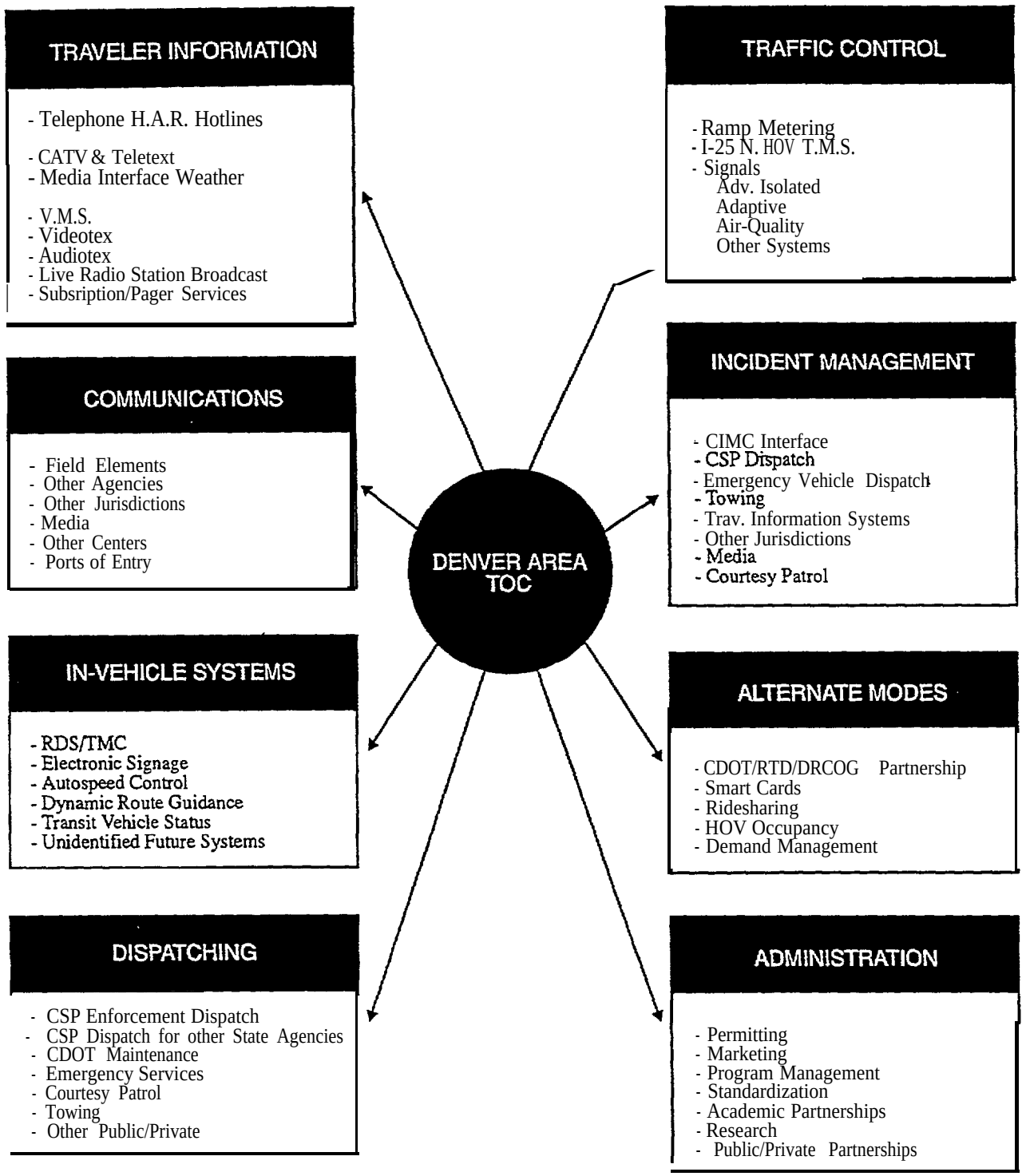

Figure 1.2 - Denver Area TOC Inputs

The TOC will serve as an invaluable tool in the monitoring and management of freeway and arterial traffic operations, with control of arterial traffic conducted through the appropriate jurisdiction. It will support the operation of an integrated transportation information system, including data and information sharing capabilities with other jurisdictions' Traffic Information Centers (TICs), existing control centers such as the I-70 Eisenhower Tunnel, and any future satellite TOCs. The facility will also be a transportation information clearinghouse - the center for the dissemination of regional travel information to the public. Successful integration of these areas will enable the TOC to support a safe and efficient highway environment in the Metro Area.

Within the TOC, there are a number of opportunities for private sector participation, particularly where these will support commercial ATIS efforts. Potential arrangements with private sector companies concerning in-kind contributions to the TOC's various activities should be considered. These could include unpaid software or equipment deployment by firms wishing to test new systems in a real-world environment, showcase their products, or provide a basis for follow-up ATIS ventures. Private firms may be particularly willing to provide data analysis or fusion software packages that assemble TOC-collected data in a format suitable for commercial ATIS ventures. The possibility of a privately-run broadcast service franchise out of the TOC provides an excellent opportunity for public/private partnerships. In addition, the potential exists to involve private sector firms in many staffing areas. These firms could be awarded contracts to operate the TOC's control center, provide IVHS-related equipment maintenance or provide media liaison support for ATIS dissemination efforts.

The TOC's intent to combine traffic operations with communications/dispatching support is unique. Integrated communications/dispatch functions, led by CSP, provide an excellent opportunity for increased cooperation between all state public safety agencies as well as consolidated manpower requirements. There are tremendous cost advantages for the TOC if a single pool of dispatchers can be utilized for all of the dispatching efforts. In addition, integrated staffing arrangements within the TOC's traffic operations will improve teamwork, coordination efforts and efficiency between all participating agencies and jurisdictions. The facility's integrated staffing arrangements and consolidated dispatching functions may ultimately serve as a model for other TOCs in North America.

1.5 TOC Design Process

The Denver Metro Area TOC has the potential to become the first facility in North America to integrate traffic operations with a region-wide communications/dispatch center. Primarily, these traffic functions will relate to all aspects of the ATMS and incident management programs, along with their associated ATIS efforts. The communications/dispatch functions intend to provide interjurisdictional, multi-agency information sharing as well as full communications support for CSP, CDOT Regions 1 and 6, Courtesy Service Patrols, corridor management teams, and other state public safety agencies. It is this type of "Vision" which gives the Denver Metro Area facility the potential to represent a significant step forward in TOCs.

The design, construction and implementation of the TOC will best be realized by a logical, incremental program approach. The different aspects of the TOC should be

divided into phases where activities and services can be incorporated over time as funding becomes available. Critical issues affecting the conceptual and preliminary design process of the TOC include the following:

- Functions, responsibilities and service provisions of the TOC.
- Staffing requirements.
- Integrated systems architecture.
- Facility layout.
- Facility location.

Each of these areas is addressed as a separate chapter within this document. Review of these analyses will then support informed decision-making concerning the Denver Metro Area TOC. In addition, it is important that the initial and planned programs selected for implementation within the TOC be perceived by the media and the public as providing a benefit to society.

The next sections provide introductory descriptions which outline the activities and functional outlook of the TOC by phase. These snapshots depict what the Denver TOC is expected to accomplish within each phase and the corresponding benefits realized by the Denver region.

1.5.1 Interim TOC

CDOT will implement an interim TOC facility in early 1993. The interim facility will likely be in a rented space and centrally located in the Denver area. The purposes of such a facility would be largely the same as for the permanent TOC with four added advantages:

- CDOT will have a testing ground in which to learn the best methods and techniques in running a TOC prior to the opening of the permanent facility.
- The CIMC has completed its first year of work and made recommendations. Implementation of an interim. TOC will give CDOT a running start at establishing incident management teams, priorities and strategies prior to opening the permanent TOC. Related activities such as the establishment of the cellular call-in and 800 MHz communications systems, establishment of corridor management teams, and enhanced coordination of the courtesy patrol program, could be implemented almost immediately.
- CDOT could immediately begin investigating ways to upgrade the HAR and hotline systems to provide near real-time information.
- CDOT would have a platform from which to initiate and build inter-jurisdictional relationships which would carry into the future.

The interim TOC will probably include the following systems as a minimum:

- Ramp metering.
- Ice detection
- H.A.R
- Telephone hotlines (573-ROAD, 639-1111, and 639-1234).
- Courtesy Patrol Coordination.
- 800 MHz interjurisdictional communiations.
- Incident management intiatives as may be recommended by the CIMC.

Implementation of an interim TOC has the advantage of allowing CDOT an initial look at TOC operations and to identify functional relationships which work best. This working experience will allow CDOT to identify design parameters which should or should not be incorporated into the design of the permanent facility.

1.5.2 TOC Start-up Phase

The start-up phase will focus primarily on the design and construction of the TOC itself. In addition, this period will include the design process required for the procedures and equipment necessary for initial TOC operations. To maximize the initial effectiveness of the TOC, the majority of the activities that will be coordinated from the facility will include systems already operating in the Metro Area and their potential upgrade, enhancement and integration with other NHS-related services. Many of these activities are referenced in the Strategic Plan and Early Action Plan documents for IVHS implementation in the Denver Region.

It is envisioned that the following activities will establish the foundation for the TOC's start-up operations:

- TOC Facility Design
  - Building architectural and civil/site design and construction.
  - Integrated computer systems architecture design and procurement.
  - Operations consoles and interior design and implementation.

- ATMS Functions
  - Expanded ramp metering system.
  - Ice detection monitoring systems.
  - North I-25 Bus/HOV traffic management system (in particular, the control functions, CCTV cameras, and inductive loops).
  - Additional in-pavement inductive loop detectors.

- Incident Management
  - Initiatives recommended by the CIMC.
  - Organized cellular phone call-in system.
  - Metro Area Courtesy Service Patrols and Corridor Management Teams.
  - Incident/emergency response plans.
  - Preplanned incident diversion routes.

. ATIS Functions.
- Enhanced HAR system.
- North I-25 Bus/HOV VMS system.
- Expanded telephone hotline program.
- Liaison/communication with the media and private sector traffic information services.

. Communications/Dispatch
- Consolidate CSP, CDOT and other public safety agencies' dispatching and communications.
- Identify key communications locations (e.g., data collection stations, traveler dissemination nodes, participating agencies' databases, etc.).
- Select communications media (e.g., fiber optic, telephone lines, coaxial cable, microwave, etc.).
- Establish links with Eisenhower Tunnel and Glenwood Canyon control centers.

1.5.3 TOC Short-term Operational Phase

The short-term operational phase will build upon the foundation established within the start-up phase. This time period will see a continuation of these activities as well as a phased implementation of the TOC's newly-selected systems and technologies.

Within the short-term, it is anticipated that the TOC will possess the following features:

- ATMS Functions. A reliable, extensive and comprehensive information collection system. will be established to provide the foundation for the TOC's traffic management strategies, incident management efforts and ATIS activities. This areawide surveillance, detection and management system will incorporate the following activities:
  - Expanded CCTV coverage.
  - Expanded traffic data collection system.
  - Additional environmental sensors (fog, rain, air pollution).
  - Reversible lane strategies.
  - Graphical and textual presentation of field data (link travel times, speed/volume/ occupancy/congestion map displays).

. Incident Management. The Denver TOC will continue its coordinated incident management approach. Enhancements in the short-term are expected to include:
- Advanced incident detection algorithms.
- Expanded incident detection/verification sources.
- Direct communications links with participating agencies (city and county police and fire departments, emergency medical services).
- Videotaping of CCTV images, documenting incident details and tracking equipment and procedures to develop improved incident response plans for future application.

- ATIS Functions. The Denver TOC will provide in-vehicle information on congestion, traffic, weather and highway conditions. ATIS will also provide pretrip information, allowing travelers to plan their journey before leaving the home or workplace. This

area provides numerous opportunities for the formation of public-private partnerships as well as the establishment of valuable ties with the participating media agencies. These strategies include:

- Expanded HAR and VMS systems.
- Cooperative exchange systems with local television and radio traffic information services.
- Teletext and cable television information systems.
- Audiotex information systems.
- Continual public and commercial radio traffic reports.
- Digital Traffic Message Channel services.

- Communications/Dispatch. Further efforts to consolidate the TOC's integrated dispatching functions will continue. These efforts and additional communications ties with the Metro Area's participating agencies will establish a high level of information sharing and cooperation. This is expected to improve the efficiency, consistency and timeliness of incident response plans as well as day-to-day traffic management.

1.5.4 TOC Medium-term Operational Phase

As the TOC extends its operations to the medium-term, it will receive significant information from vehicles (potentially including using RTD buses and/or government vehicles as probes), roadway sensors, traffic control systems, and other TOCs. Building on the multiple database integration foundation established within the short-term, the next step will combine the data from these multiple sources to fonn a single, reliable database for TOC operations. Data fusion will improve the precision and reliability of the reported information to enable real-time assessment of traffic conditions that require controller intervention.

In the medium-term, new technologies and systems should assist the TOC's traffic management and traveler dissemination strategies. Adaptive traffic control strategies like SCOOT and air-quality responsive traffic control will improve signalized intersection management techniques on a real-time basis. Newly incorporated route guidance and videotex information systems will expand the information dissemination process. Route guidance (in-vehicle) and videotex (home/office terminals) systems offer the Denver resident route planning facilities based on real-time information collected at the TOC.

As more sophisticated sensing and communications equipment becomes available, interpretation of the incoming data and dissemination of the processed information will focus the TOC's medium-term efforts on enhancing its computer operations. Much of the advancements within the TOC are expected to follow the improved ability of computers to collect, interpret, and respond to highway information. As computers assume this load, the TOC will be able to handle more data, provide more information to vehicles, and improve response time for emergency situations.

New forms of artificial intelligence techniques, data fusion principles, expert systems and ATIS activities will be central to the TOC's new activities within this time period. Fully-automated responses to repetitive tasks, real-time data analyses presented in an easily interpreted form, and operator decision aids for maintenance scheduling and dispatching

will be implemented. Efforts along these lines will not only support region-wide operations, but will provide a platform to support a statewide, seamless IVHS network.

1.5.5 TOC Long-term Operational Phase

IVHS technologies have advanced beyond recognition from their predecessors over the past few years. With IVHS now a major focus of national and international attention, even greater changes can be expected in the years ahead. This leads to uncertainties in predicting the precise systems and functions of future TOC facilities. To address this issue, many researchers have utilized the option of narrative sections, outlining the types of approaches which are considered likely to be developed and applied.

In describing the TOC's long-term operational phase, therefore, a previously published narrative section has been used as base material (Reference 2). This has been modified to better match conditions in the Denver Metro Area. The intent is to provide a vision of the TOC's characteristics and capabilities reflecting projected technological advances. While this does not necessarily define specific TOC functions and components, it gives a flavor of what is believed to be achievable over this time period.

It's 4:30 p.m. in the middle of the Denver area afternoon rush hour. The TOC's rain sensors are ***detecting 0.2 inches per minute along I-25 near Colorado Boulevard. Visibility detection sensors are reporting readings of less than 50 feet in the same area. The TOC also knows*** that ***scheduled road construction in the area has narrowed the median lanes in both directions. Ramp metering patterns have already been adjusted for rush hour and in-vehicle electronic signage images indicate a speed advisory of 40 mph in the immediate area.***

Suddenly, five vehicles in the northbound lanes report "IMPENDING COLLISION" and subsequently cannot be contacted. Emergency services are immediately notified, with the suggestion for response vehicles to take University Boulevard (vehicles on Colorado Boulevard, an alternate route, are reporting congestion). Traffic signal controllers are notified that an emergency vehicle will be coming so they can begin to cycle to "fast-flash green" along the emergency vehicles' route (a new signal convention established to indicate emergency vehicles are coming) and "fast-flash red" in the directions crossing the emergency vehicles' path. Vehicles on I-25 northbound, south of the accident, are given the "Possible Hazard Ahead" warning and the geographic coordinates of the accident. Vehicles will inform the driver with urgency dependant on distance from the hazard.

Within one second of the accident, a TOC operator is advised of the situation and informed that the rerouting process is beginning. To determine how much freeway capacity has been lost, the TOC compares logs of traffic one mile south of the accident (collected from video image processors) with current traffic flow. After analyzing the rate of increased congestion, it is ***determined that two lanes are blocked and emergency crews may slow traffic more. Therefore, the decision to route traffic to alternate routes (SH 88 and I-225) is recommended. The operator confirms this option and the TOC broadcasts this information to vehicle navigation systems, VMS units, signal controllers (to enable handling of the extra capacity), and to the local media traffic information services,***

2.0 TOC FUNCTIONAL DESCRIPTION

2.1 Introduction

This chapter describes the TOC's functions and responsibilities as they apply to the short-, medium-, and long-term timeframes of the Denver area IVHS implementation program. The functions and responsibilities identified for the TOC fall within five broad categories. They are as follows:

- Colorado State Patrol (CSP) functions.
- ATMS.
- Multi-jurisdictional and multi-agency information sharing.
- ATIS.
- Incident management.

Functional requirements for the TOC are based upon the successful management of these operations over all time periods. During the TOC design process, CDOT and CSP should work with other Denver area agencies to define future functional requirements in more detail.

2.2 Colorado State Patrol (CSP) Functions

2.2.1 Introduction

The decision that CDOT and CSP should consider jointly operating the Denver area TOC came about as a result of two separate actions. In 1991, the Long Appropriations Bill passed by the Colorado State Legislature required CSP and the Division of Telecommunications to develop a statewide communications plan to replace, update and modernize the current statewide radio/microwave system. The plan recommended the phased implementation of a digital trunked radio system between the years 1992 and 2000 This technology will allow levels of functionality, flexibility and capacity which are superior to the existing radio system.

The participation of both agencies in the CIMC also was a critical factor in the decision to implement a joint TOC. CDOT identified the need for a TOC from an IVHS/incident management point of view, and the CIMC from an incident management/communications point of view. Discussions between CDOT and CSP representatives within the CIMC forum disclosed a willingness to investigate the benefits of operating a shared facility.

Several specific CSP functions will be brought to the TOC along with the physical relocation of the dispatch unit from the current location at 700 Kipling Street. These include:

- Provision of professional radio communications services for all Department of Public Safety (DPS) personnel, CSP and CDOT vehicles, and other State, Federal and local agencies.

- Provision of first point of contact for citizen call-ins. This includes 911 cellular emergency calls outside of the City and County of Denver, *DUI (x384) cellular calls for reporting suspected drivers under the influence of alcohol or drugs, and

the *77 cellular calls for reporting accidents and road conditions currently being investigated by the CIMC.

- Gathering and dissemination of statewide road and weather travel information. Two telephone hotlines are currently maintained - one for road and weather conditions within two hours of Denver and a second for road conditions statewide.

- Monitoring hazardous material carriers and provision of communications support for hazardous material response including sharing of Emergency Information System (EIS) and Geographic Information System (GIS) information.

- Support the CDOT/CSP 800 MHz radio system for mutual aid communications with other public agencies and contact with the media during incident management. Two channels are currently being implemented by the CIMC.

- Data entry for information associated with enforcement, incident management, CSP resource (trooper, dispatcher and support staff! management, and DPS Management Information System (MIS).

- Provision of paging services for DPS, CDOT and other State, Federal and local agencies.

- Dispatching for CSP enforcement vehicles in CSP Districts 1, 3 and 6.

- Dispatching of maintenance vehicles for CDOT Regions 1,4, and 6, as well as a portion of Region 3.

- Dispatching of the CSP communications van to allow temporary communications centers to be established "on location."

CDOT and CSP have proposed integrating various staff positions so that CSP functions can be carried out by the same staff responsible for IVHS functions. More information on potential integration of staff is included in Chapter 4.

2.2.2 CSP Consolidation

CSP currently operates seventeen around-the clock dispatch centers in Colorado. Implementation of the digital trunked radio system along with new Computer Aided Dispatch (CAD) systems will allow CSP to consolidate to five centers in Denver, Pueblo, Montrose, Glenwood Springs and Alamosa. Existing CSP centers in Greeley, Sterling, Limon and Hot Sulfur Springs will be merged with the Denver unit, creating the new unit to be housed in the TOC. The new service area of the Denver CSP unit will include all of the following counties:

- Adams.
- Arapahoe.
- Boulder.
- Cheyenne.

- Clear Creek.
- Denver.
- Douglas.
- Elbert.
- Gilpin.
- Grand.
- Jackson.
- Jefferson.
- Kit Carson.
- Larimer.
- Lincoln.
- Logan.
- Morgan.
- Park.
- Phillips.
- Sedgwick.
- Summit.
- Washington.
- Weld.
- Yuma.

2.2.3 Public Safety Functions

CSP's role as an enforcement agency requires responsiveness in several areas directly related to public safety. These include dispatching of enforcement and highway maintenance vehicles, emergency telephone call taking, tracking hazardous material carriers, responding to hazardous material spills, and response to other emergencies.

2.2.3.1 Dispatching (Enforcement). CSP currently employs dispatchers at seventeen communication centers in the State of Colorado. Depending upon the location of the center involved, existing dispatching may be performed for multiple agencies or for CSP only. Duties of the dispatchers include keeping track of field officers, prioritizing responses, sending troopers to accidents or calls, summoning tow trucks to accident scenes, contacting ambulances when necessary, contacting law enforcement personnel of other agencies or jurisdictions, use of computers to enter weather reports, accident reports, warrants and other enforcement related data into the MIS data base. It is not unusual for individual dispatchers to handle a telephone call and two or three radio calls simultaneously.

CSP will maintain its existing communications services for many agencies in the Denver, Pueblo, Greeley, Sterling and Hot Sulfur Springs areas following consolidation to the Denver center. CSP capabilities to provide these services will be enhanced by the digital trunked radio system as well as implementation of a CAD system with mobile data terminals in the patrol cars. The mobile terminals will streamline existing CSP information flows, allowing field officers direct and much faster access to license, registration and driving records, criminal histories and warrant information, providing benefits toward increased officer safety. Field officers will also have direct access to a hazardous material database to expedite responses to potential hazardous material spills.

The CAD system should improve CSP dispatch operations to the point where some staff resources can be focused in other areas.

Communications services provided for local agencies which will be continued through the consolidated Denver CSP unit include the following.

- Communications Support for:
  Lincoln county.
  Limon Police and Fire Departments and Emergency Medical Services.
  Cheyenne County.
  Town of Hugo.
  Flagler Town Marshall.
  City of Burlington.
  City of Cheyenne Wells.
  Logan County Sheriff and Emergency Medical Services.
  Fleming Police.
  City of Holyoke.
  Phillips County.
  Grand County Sheriff and Emergency Medical Services.
  Kremmling Fire and Police Departments.
  Hot Sulfur Springs Fire and Police Departments.
  East Grand Fire Department.
  Granby Fire Department.
  Grand Lake Fire Department.
  Grand County.

- Back Up communications Center for.
  Adams County - Byers Area.
  Arapahoe County - Bennett Area.

- Pages for the Following: Agencies:
  Colorado State Patrol.
  Colorado Bureau of Investigation
  Colorado Division of Disaster Emergency Services.
  Colorado Attorney General's Office.
  Limon Emergency Medical Services.
  Simla Emergency Medical Services.
  Hugo Emergency Medical Services.
  Flagler Emergency Medical Services.
  Siebert Emergency Medical Services.
  Sterling Area Emergency Medical Services.

- Monitors the Following; Agencies:
  Weld County Communications.
  Larimer County Sheriff.
  City of Estes Park.
  Wyoming Highway Patrol.

Sterling Fire and Police Departments.
City of Wray.
City of Julesburg.
Yuma County Sheriff.
Fleming Bank Alarm.

2.2.3.2 Dispatching Highway Maintenance). CDOT Region 6 (Denver Metro area) maintenance vehicle dispatching is currently done from a console at the CSP facility at 700 Kipling Street. Under normal circumstances, CSP performs the direct dispatching functions for Region 6. During adverse winter weather events, CSP typically becomes overloaded with enforcement responsibilities, so Region 6 sends a CDOT employee to the CSP dispatch center to carry out dispatching for CDOT sand trucks and snowplows.

Region 1 dispatching is much more complex due to the spread of the district from Vail Pass to the Kansas State line and the mixed geography including both mountains and plains. Dispatching is performed through three separate facilities with the assistance of repeaters located at Vail Pass, Lake Hill, Squaw Pass, Mines, Boyero, Bethune and Punkin Center. Normal and storm dispatching in the foothills area west_to the Eisenhower Tunnel is done from Region 1 headquarters in Aurora. Dispatching for the Eastern Plains originates in Aurora but is also secondarily relayed through the CSP facility in Limon. Dispatching in the I-70 vicinity west of the Eisenhower Tunnel to Vail Pass is done from Road Control, located on the west side of the tunnel. Road Control is staffed from November 1 to April 30 each year. The implementation of the digital trunked radio system will allow Region 1 to eliminate the Road Control office. Region 1 maintenance employees also operate the system of existing Variable Message Signs (VMS) along I-70 west of Denver.

An added complexity is that weather conditions can be vastly different in the mountains, in the Denver area, and on the plains. It is not unusual for one of the three areas to be experiencing a major snowstorm while the other two areas are relatively untouched.

CDOT's primary concern in any change of their dispatching functions is that their requirements during storms be met. Regions 1 and 6 have maintained their own capabilities and staffing for winter storm dispatching because police activity during these periods is typically also extremely heavy, and has taken priority over maintenance. Up to three dispatchers could be required if inclement weather is affecting Denver, the plains and the mountains simultaneously.

As part of the staff integration efforts for the TOC, CSP has proposed the creation of dispatching positions which would be specifically dedicated to providing CDOT maintenance dispatching under any circumstances. When no CDOT dispatching is required, these operators would be available to assist with enforcement dispatching or attend to IVHS operations. Once CDOT requires dispatching, these operators would immediately attend to maintenance needs.

2.233 Call Taking. CSP currently receives cellular 911 emergency telephone calls for the Denver region in those areas located outside of the City and County of Denver (the Denver Police Department receives calls within the City limits). Both agencies frequently receive roadway information calls and transfer these to the appropriate agency. The CSP has recently implemented a cellular call-in system, *DUI (*384) to allow motorists to report suspected drivers under the influence of alcohol or drugs. The CIMC has recommended the implementation of a cellular call-in system (*77) to allow the traveling public to report accidents and conditions requiring maintenance (potholes, etc.). CSP feels that their operators would be the most appropriate individuals to receive these calls due to the probable mix of 911, *DUI, and *77 calls on the incorrect line.

One CSP concern is the potential of a publicized cellular call-in system for roadway conditions to overload the call takers as literally hundreds of calls could be sent to report a single incident. CSP, CDOT and the CIMC are currently investigating ways to limit the number of call-ins, as well as investigating manpower requirements which might be created by the implementation of such a system. In any case, CSP will continue to, as a minimum, receive 911 calls at the TOC.

2.23.4 Hazardous Materials and Emergency Information system (EIS). CSP currently tracks the progress of known hazardous material carriers on the Colorado Highway System and will continue to do so. To help protect the public from hazardous material spills and other emergencies, CSP has recently implemented an Emergency Information System (EIS). The EIS will complement operations at the TOC, particularly in terms of emergency incident management.

The EIS is a computer software application which combines digitized color maps of Colorado with emergency resource databases to provide assistance in the comprehensive management of emergency incidents. EIS allows users immediate access to chemical data, personnel, medical facilities, mass care facilities, transportation capabilities including airlift equipment, and many other resources, as well as a hard copy of the chronology of each incident via an event log. The log ensures that emergency reactions to incidents can be properly coordinated in a real-time fashion and documented for future reference. The system's digitized maps enable response teams to know in advance the locations of geographic reference points, equipment, caustic substances, building exits and other facility or natural hazards. A weather interface within the EIS software gives continuous updates of prevailing weather at the site of an emergency incident, to more accurately predict the size, movement and toxicity of hazardous materials released into the atmosphere.

Availability of this technology to CSP, CDOT and other public safety agencies at the TOC gives those agencies access to data in a common format thereby streamlining planning, operational coordination and consequently, the decision making necessary to emergency management.

2.2.4 Communications Functions

In addition to the communications support provided for the local agencies listed above, CSP also provides statewide communications support for the following State and Federal agencies:

- Colorado Department of Transportation.
- Colorado Department of Revenue.
- Division of Lottery.
- Division of Motor Vehicles.
- Division of Liquor Enforcement.
- Division of Ports of Entry.
- Division of Taxation.
- Colorado Department of Wildlife.
- Colorado Division of Disaster Emergency Services.
- Colorado Bureau of Investigation
- Colorado Department of Social Services.
- Colorado Department of Corrections.
- Colorado Division of Telecommunications.
- Colorado and United States Departments of Agriculture.
- Colorado State Parks and Recreation Areas,
- Federal Bureau of Investigation.
- United States Bureau of Land Management.
- United States Forest Service.
- United States Internal Revenue Service.
- United States Department of the Interior.
- United States Marshall.
- United States Department of Energy.
- United States Secret Service.
- United States Drug Enforcement Agency.
- United States Treasury.
- United States Judicial Districts.
- United States Immigration.
- United States Postal Inspector.
- Civil Air Patrol.
- Federal Communications Commission.

2.2.4.1 800 MHz Trunked Radio. CSP is the lead State of Colorado agency in the area of voice communications. CSP provides communications for many State and Federal agencies as indicated above, and will continue to provide this function in the TOC through use of the proposed 800 MHz digital trunked radio system. This system will provide more efficient use of the existing airwaves by State agencies because it uses a central computer to assign locations within a frequency band that a specific radio call will operate, and also makes it much more difficult for unauthorized eavesdroppers to listen in on agency conversations.

This concept has developed, in part, due to overcrowding of existing radio channels, and the inability of enforcement agencies to use the existing radio system during covert

operations. The proposed digital network will integrate all two-way radio systems, data, telephone, and potentially, closed circuit television (CCTV). The biggest advantage of implementing the digital system is the capability for the field officer to have total telecommunications capabilities in the vehicle. Another significant advantage specific to CSP is the ease of programming interjurisdictional communications for operations such as drug interdiction or hazardous material mitigation, which may require a multiple agency response.

The State Division of Telecommunications is currently a participant in an international standards committee investigating compatibility and standardization issues for the implementation of digital, trunked radio. The Division has been working closely with CSP and the CIMC to develop this system and the one described in the following section.

2.2.4.2 800 MHz Incident Channels One offshoot of the digital trunked radio system being investigated by the CIMC is the implementation of two common non-trunked channels to assist in communications between agencies and the public. One channel will be designated as a Motorist Aid Channel, and would provide communications between agencies and the public, especially the media. The second will be designated as a Public Safety Channel and will specifically be used for communications between agencies and jurisdictions, especially as these relate to incident management. Applications for assigned frequencies for the two channels have already been submitted to the local representative of the Federal Communications Commission, and the City and County of Denver has agreed to locate the two required repeaters at their site on Mount Morrison (Reference 5). The use of this frequency will be tied into the TOC and should probably be coordinated through CSP, due to their communication responsibilities in so many areas.

2.3 ATMS Functions

2.3.1 Introduction

The purpose of ATMS is to optimize traffic safety and capacity within existing roadway conditions. In the Denver area, ATMS technologies will aim to achieve this goal by providing traffic operators at the TOC with the tools to monitor and control traffic flow along the region's freeway system, and ultimately to influence traffic use of major arterials.

2.3.2 ATMS Short-Term

Existing Conditions

The initial function of the permanent TOC in this time period will be to incorporate existing traffic monitoring and control capabilities in a single facility, building upon the lessons learned and operational procedures developed during operation of the interim TOC. Existing transportation services in the Denver area which can be considered include:

- The incorporation of the expanded and upgraded ramp metering system, providing real-time traffic data and graphical displays.

- The integration of inductive loops installed by CDOT along the freeways in conjunction with recent resurfacing projects.

- Communications links with the I-70 Eisenhower Tunnel and Glenwood Canyon control centers.

- The incorporation of the North I-25 Bus/HOV Traffic Management System, including its closed circuit TV (CCTV) and variable message sign (VMS) systems (late 1994/ early 1995).

- The incorporation of the Denver Metro Area ice-monitoring network to provide improved maintenance scheduling and dispatching operations.

- The incorporation of, or interface with, other existing CCTV and VMS systems in or near the Denver Metro Area, and to the west along I-70, such as KCNC-TV's camera network of over 20 locations.

The expanded and upgraded ramp metering system is expected to be a major component of the TOC in the short-term. Integration of this system into the TOC should support coordination with the local agencies having jurisdiction over the arterial streets at ramp interchanges. The TOC could ultimately be used to operate ramp metering based on signal progression along the arterial, as well as freeway flow measurements.

Traffic Monitoring

The next step of the ATMS short-term activities will involve expansion and upgrading of existing transportation monitoring operations in the Denver area, complemented by the installation of additional traffic monitoring equipment and data collection systems. This will complete a system of vehicle detectors and related systems along all freeways where traffic monitoring is desired. Technologies for consideration include:

- Additional in-pavement inductive loop detectors.
- Overhead and roadside infrared, microwave, optical or ultrasonic traffic sensors.
- CCTV.
- Environmental sensors (fog, rain, air pollution, etc.).

Included within this effort will be a determination of the best positioning and spacing for the detection equipment, together with an analysis of the appropriate distribution of system intelligence between the TOC and field equipment. Although short-term monitoring will likely depend heavily on loop detectors, other methods such as those listed above, will likely become more viable by the medium term. As detection technologies improve, loop detectors may become obsolete.

Computer Operations

Coordination of the monitoring network and data collection system requires a computer system framework which can integrate and utilize multiple databases. The ATMS computer located at the TOC will serve as the hub for:

- Collection of field information.
- Control of field equipment.
- Analysis of field data.
- Incident management initiatives such as alternate routing.
- Graphical and textual presentation of the data analysis results.
- Storage, retrieval, and access to current and historically developed traffic analysis information
- Calculation of network link travel times.

The computer equipment will operate full-time in the TOC. It should contain a large memory, disk storage for a minimum of one year's traffic data, magnetic tape for backup and archival storage of data, and sufficient communication ports to connect to existing and additional field equipment and the TOC operator's consoles. The computer equipment will consist of either a minicomputer or networked, high-speed, PC-type computers. Suitable hardware will interface the computers to all field equipment via the system's communication links.

Communications Network

An initial fiber optic network will be installed in the North I-25 Corridor to facilitate the Bus/IIOV Traffic Management System. The initial fiber optic system will be expanded in phases as funding allows throughout the Denver area. CDOT has also expressed a desire to install communication links to the Eisenhower and Glenwood Canyon control facilities. The initial network will also include telephone dial-up and leased lines, radio such as the 800 MHz system between jurisdictions being investigated by the CIMC, microwave links to obtain remote CCTV pictures, and so on. The complete communications system is the subject of a separate Task 8 Technical Memorandum and will be discussed in more detail in that document.

2.3.3 ATMS Medium-Term

Continuation of Short-Term Activities

In the medium-term, advancements to the TOC will continue in line with the original schedule developed in the short-ten, while subsequent modifications will be implemented to reflect technology advances. These enhancements will support the introduction of additional sources of data or analysis techniques as further ATMS approaches develop. Also, enhancements concerning further database integration will be considered as they relate to all information collection efforts.

ATMS Medium-Term Activities

Other ATMS items which may be considered for incorporation into the TOC during the medium-term include:

- A traffic operations computer-generated expert system.
- Traffic responsive freeway and arterial corridor coordination.
- Real-time adaptive traffic control.

- Air-quality-responsive traffic control.

- Advanced arterial surveillance, including video image processors, radar monitoring, and vehicle probe-based data collection techniques. RTD buses and government vehicles are among the possibilities for use as vehicular probes.

- A global positioning system (GPS) or similar approach for CDOT Maintenance, Colorado State Patrol, and other appropriate fleets, potentially including integration with RTD's GPS-based system.

ATMS medium-term projects will focus primarily on widespread deployment of preferred approaches. This will follow earlier evaluation of their suitability for use in the Denver Metro Area.

2.3.4 ATMS Long-Term

At this stage of the design process, it is difficult to envision the specific nature of long-term projects in the ATMS area. As technologies advance, new techniques concerning traffic operations and management will be evaluated for inclusion in the TOC, and the most appropriate approaches will be incorporated as they develop. Possible activities include the development of fourth generation signal control, general purpose traffic processors, and various data fusion and weighting techniques.

2.4 Multi-Jurisdictional Information Sharing

2.4.1 Introduction

The TOC provides a unique opportunity for infonation sharing among a multitude of participating organizations and agencies in the Denver area. It has the potential to serve as an information clearinghouse, with data-sharing capabilities for other jurisdictions, as well as king a center for the dissemination of information to the public. An important element in allowing CDOT and other agencies to manage freeway (and ultimately, arterial) traffic and coordinate incident management activities effectively, is the implementation of an interface between the TOC and the other agencies involved in traffic management or provision of emergency services.

2.4.2 Purpose

The purpose of the TOC interface is to share relevant information with all participating agencies in the region. This will allow these agencies to be aware of current operating conditions on the network under surveillance and control. More importantly, this interface will serve to immediately alert and advise the different agencies of incidents or unusual circumstances on the highway system, allowing appropriate multi-agency action to be initiated quickly and efficiently.

This interface is also seen as an initial tool in developing administrative and operational procedures which can be applied during normal traffic operations, as well as during incidents, emergencies, and special events.

Historically, many public agencies operate relatively independently of one another, with some agencies unaware of the others' activities. An interface with the TOC could support

communications and coordination between all participating groups in the Denver Metro Area. An increased appreciation of the roles of the various public service organizations should result from this information sharing and activity coordination. Ultimately, this should lead to improved efficiency through increased utilization of multi-agency resources, removal of the overlap in individual agency response, and automation of communications between and responses of various agencies.

2.4.3 Scope of Participation

The procedures for successful interaction between agencies must be broad enough to cover any set of circumstances and must include all of the participants. However, the information conveyed to each party must be agency-specific in order to achieve effective coordination.

To support this approach, it is necessary to identify the various components of these procedures required for successful operation. These include:

- Identification of all participating agencies.
- Identification of information required by each agency.-
- Identification of required communication equipment.

Successful integration of these components into the TOC procedures will significantly contribute to multi-jurisdictional coordination and cooperation in all areas of traffic and incident management.

Participating Organizations and Agencies

Within the Denver Metro Area, there are a number of agencies and organizations concerned with traffic and incident management. A goal of the TOC development effort is to treat them not as individual agencies, but as members of a team with common objectives. Traditionally, these groups work relatively independently in trying to solve similar problems affecting their particular jurisdictions. With implementation of an interface through the TOC, these agencies should be able to coordinate their individual efforts in a more comprehensive manner beneficial to all involved parties and the highway network as a whole.

A variety of organizations, both public and private, may ultimately be involved in operating, coordinating with or using data collected at the TOC. In the initial stages of operation, potential participants could include:

- CDOT Region Six.
- CDOT Region One.
- CDOT Headquarters.
- Colorado State Patrol (CSP).
- City and County of Denver Traffic Engineering Department.
- Denver area Police Departments.
- Denver area Fire Departments.
- Regional Transportation District (RTD).
- Denver Regional Council of Governments (DRCOG).

- Commercial traffic reporting services.
- Media (radio and cable TV).
- Emergency services such as paramedics, etc.
- Authorized private towing companies.
- Colorado Incident Management Coalition (CIMC).

Some of these groups, such as CDOT and CSP, would maintain a permanent staff presence in the TOC. Others may provide staff on an as-needed basis, or could coordinate or interface with the permanent TOC operations. As the Denver Metro Area TOC system expands, agencies such as the police, fire and traffic engineering departments in additional communities may become involved. Potential areas for consideration include the following cities and counties:

- Arvade
- Aurora
- Broomfield
- Cherry Hills Village
- Commerce City
- Englewood
- Federal Heights
- Golden
- Greenwood Village
- Lakewood
- Littleton
- Northglenn
- Sheridan
- Thornton
- Westminster
- Wheat Ridge
- Adams County
- Arapahoe County
- Douglas County
- Jefferson County

The exact system boundaries for the region controlled or monitored by the TOC are not yet determined. The previous listings are therefore a preliminary illustration of the program's potential extension and impact. As the TOC and its interfaces to other groups become operational, the appropriate participant agencies and organizations will become more evident.

Multi-Jurisdictional Information Sharing

While multi-jurisdictional information sharing will be supported by the involvement of multiple agencies and organizations in the TOC effort, it will also be dependent on the ability of these groups to access data from a variety of systems. A primary goal of the TOC is to provide a focal point for the Denver area's traffic management and control efforts- Initially, the system will concentrate on the freeway network, since this is where the data collection infrastructure is partially in place and undergoing further

implementation and interjurisdictional relationships can be built and strengthened over time before proceeding with efforts on the regional arterial network.

Multi-jurisdictional information sharing should ensure that useful data on freeway conditions are available to all groups interested in this information, rather than being restricted to those agencies directly responsible for the freeways. One of the existing tools to accomplish this type of roadway management is the widespread network of environmental sensors in the Denver Metro Area. These are primarily monitored by CDOT. However, the provision of a direct interface with this system for other agencies could support local winter maintenance operations, traffic management and traveler information advisories.

A longer-term goal of the TOC is the provision of freeway and arterial coordination in corridors where it would be both appropriate and beneficial. At this time, the exact nature of this freeway and arterial coordination has yet to be determined. Close working relationships between CDOT, city and county traffic departments and other agencies are a key requirement for such cooperation, and may be supported through the efforts of groups such as DRCOG. Some issues that need to be considered include:

- Mutual agreement on predefined conditions which necessitate the diversion of freeway traffic to the city or county street system.
- Determination of signal control approaches to accommodate the additional traffic.
- Determination of methods to implement signal timing plans for diverted freeway traffic (e.g., city or county control, traffic-responsive operation, TOC control).
- Determination of criteria to return the signal timing plans back to normal operation.
- Determination of automatic computer implementation (e.g., expert system) versus personnel hands-on implementation with computer-generated advisories.

As noted previously, such freeway and arterial coordination is seen as a longer-term goal rather than an initial feature of the TOC. The issues outlined above may therefore be addressed as the TOC becomes operational. At this stage, it will be possible for the appropriate groups to determine the impact of the TOC's traffic management functions, and to assess the extent to which they can share traffic information and control strategies.

Agency Required Information

The most important aspect of this information-sharing capability is the timely and accurate dissemination of the required information to the proper authority. The detailed TOC design process will assess the data needs of the various participants. Some information will be agency-specific, some multi-agency, and other readily available to all interested parties. To determine actual information requirements in the detailed TOC design, representatives from all participating agencies will be contacted to obtain their desired information needs and minimum requirements. Areas that will need to be considered include:

- Incident information (e.g., time, location, vehicle description, incident type, severity).
- Possible diversion/alternate touting schemes (e.g., route selection, signal timing plans, diversion rationale, diversion duration).
- Existing and predicted link-travel times (e.g., flow rates, ramp metering status, speeds, real-time operations).
- Congestion data (e.g., location, duration, cause).
- Construction activities (e.g., location, duration, possible diversion routes).
- predicted travel times (e.g., predictions based on the above information).

Once the TOC is operational, information requirements will be modified to reflect agency needs. This will ensure that timely and accurate information is communicated to the appropriate parties in a suitable format.

Required Communications Equipment

The interface requires the dissemination and sharing. of information between specific agencies and groups. Since the information provided is critical to agency response, the means of communication must convey the data in an appropriate fonat.

While each agency performs different functions, it is anticipated that many of the communications media will be quite similar. To determine final hardware and communications approaches in the detailed TOC design, the specified information needs and minimum requirements of participating agencies will be reviewed. Communications media that will be considered include:

- Audio Communication
  - dedicated auto-dial telephone
  - conventional telephones
  - two way radio systems
- Video Communication
  - real-time TV (CCTV connections)
  - captured frame TV
  - freeway congestion map
- Data Link Communication
  - incident reports
  - freeway congestion status reports
  - link travel times.

Once the TOC is operational, communications links will be expanded and upgraded over time to reflect specific agency needs and the implementation of new functions and services. Each agency will require information to be provided in a format that will allow

their response to be timely and efficient. The use of appropriate tools will enable this communication process to perform in the expected manner.

2.5 ATIS Functions

2.5.1 Introduction

The purpose of ATIS approaches is to provide travelers with information on congestion, traffic, weather and highway conditions, and navigation, location or routing advice. ATIS will also provide pretrip information, allowing travelers to plan their journey before leaving the home or workplace. This can support the selection of an optimal travel time, route or mode. Many ATIS technologies have the potential to be among the earliest fully-operational systems implemented as part of the Denver Metro Area IVHS program.

2.5.2 ATIS Short-Tern

Existing Conditions

An initial opportunity provided by implementation of the TOC will be the provision of a focal point for continued operation and expansion of existing information systems in the Denver Metro Area. Existing information systems which can-be considered in this area include:

. CSP and CDOT will continue to jointly operate the existing telephone hotline program to provide information on road conditions, weather, and freeway construction activities. Potential enhancements include real-time data updates.

Continuation and expansion of the highway advisory radio (HAR) services to provide advisories on real-time traffic conditions and freeway construction activities. Potential enhancements include the introduction of TOC-supported information updates for major traffic and weather events, with flashing roadside displays.

- The incorporation of existing VMS displays in or near the Denver Metro Area, particularly the North I-25 Bus/HOV project.

- Potential incorporation of a radio station within the TOC, similar to systems implemented elsewhere, allowing timely broadcasting of traffic news and information.

- Provision of TOC-generated traffic data to commercial traffic reporting services and radio and TV stations.

Information Broadcasting,

The next step of the ATIS short-term activities will address expansion and upgrading of the telephone hotline system, HAR network and VMS facilities. These areas will subsequently be complemented by the installation of additional data output media, producing an extensive integrated infonnation dissemination system. Technologies for consideration include:

- Radio Data System (RDS) broadcasting including a digital Traffic Message Channel (TMC).

However, the practicality of extending an incident detection system to the major arterials can also be assessed as part of the continuing TOC expansion effort.

At this time, the CIMC is actively pursuing opportunities in the area of incident management and response. Subjects under investigation include the use of cellular telephones for incident reporting, 800 MHz interagency communications, use of courtesy patrols and control of emergency services. The CIMC has developed a number of recommendations and held a conference in September, 1992 to summarize the group's progress during the first year of operation. Additional finding and recommendations from this group will be incorporated into an overall coordinated incident management and response plan, with suitable activities integrated into the TOC's functions and services.

All incident management programs depend on the successful management of the stages of an incident. These stages are:

- Detection and Verification.
- Response.
- Dissemination of Traveler Information.
- Clearance.
- Recovery.

The elements or stages of incident management do not occur in a prescribed order, however. Further increasing the complexity of this situation, particularly during peak periods in urban areas, is the fact that several incidents may need to be addressed at the same time. Therefore, a valuable component of an incident management system is a coordination center, where data from various locations can be gathered by computer and reviewed by trained personnel to form a wide-area picture of events as they occur. The TOC then becomes a support center for the incident response and clearance activities and a focal point for the dissemination of traveler information. Combination of these functions in the same location has the potential to improve the efficiency and consistency of incident response actions.

During the TOC design phase, various goals will be set for incident detection and response. For example, the soon-to-be-implemented TOC in San Antonio was designed to identify an incident within 2 minutes and respond within 30-60 seconds thereafter (Reference 1). Similar response levels may be appropriate for the Denver area.

2.6.2 Incident Management Short-Term

Detection and verification

Facilities at the TOC will be designed to handle incident detection reports from various sources. Incident detection algorithms will identify suspected problems for review and verification by TOC personnel. Potential data sources to be used at the TOC include:

- Ramp meters and other freeway sensors for automated speed data.

- Teletext and cable television information systems, including a color-coded speed and congestion map of the Metro Area freeway system.

  Traffic information paging systems.

- A videotex information system supporting interactive enquiry facilities.

- Public and commercial radio traffic reports.

- 800 MHz communication channel for interagency ATIS data transfer.

Computer Operations

Like ATMS, it is anticipated that coordination and control of the TOC's ATIS functions will require an advanced computer system. This will most likely be combined with the ATMS computer, since the two technology areas are so closely related. Software modules will then translate the ATMS data into formats useable in ATIS approaches. This could include, for example, automatic generation of messages for dissemination via RDS-TMC, teletext, cable TV or videotex, or production of data summaries for distribution to traffic reporting services and public and commercial radio stations.

2.5.3 ATIS Medium-Term

Enhancements and modifications to existing and earlier implemented systems will be addressed in the medium-term to take full advantage of emerging technologies. ATIS technologies and services will be reviewed and evaluated periodically with respect to their information compilation, display and network interface capabilities. Additional ATIS approaches will also be considered for integration into the TOC as the program continues. Options which may be evaluated include dynamic route guidance and high data-rate digital broadcasting.

2.5.4 ATIS Long-Term

At this stage of the design process, it is difficult to accurately predict the specific nature of ATIS projects and their role in the TOC in the long-term of the Denver Metro Area IVHS program. As technologies advance, new techniques supporting enhanced information dissemination and user interaction will be incorporated as they become available. Ongoing ATIS efforts will also be subject to continued refinement and expansion as the program continues.

2.6 Incident Management

2.6.1 Introduction

One of the most important functions that the TOC can support is a coordinated incident management program, capable of responding quickly and efficiently to a variety of incident types. The capability of the TOC to provide this function will be greatly enhanced by the multi-jurisdictional 800 MHz radio program being implemented by the CIMC, which will allow TOC operators to notify local enforcement and emergency response agencies of real-time conditions within their jurisdictions. Initial efforts will focus on the Denver area freeway system, where the impacts of incidents are most severe.

- Emergency phone call boxes. These, however, have not yet been proposed for widespread use by the CIMC or any other agencies.

. Cellular phones (911 or *77 incident reporting). The CIMC is currently investigating alternative methods of implementing a cellular call-in system. A recruited group of regularly commuting volunteers may be able to provide timely and accurate information required by the TOC operators at sufficient levels for success. This call-in strategy would also tend to keep TOC call-taking manpower requirements low, as opposed to a general public call-in system which could potentially overload the call-takers.

- CB radios.

- 800 MHz communication system.

- Aerial surveillance, for example performed by commercial traffic reporting firms or Denver area television or radio stations.

- CCTV potentially incorporating local television stations' traffic camera networks.

- CSP, CDOT maintenance, courtesy patrols, and transit personnel who can provide radio reports to the TOC of incidents, congestion, or other traffic problems.

Response

In terms of incident management, response is the initiation, coordination and management of the appropriate actions, including personnel and equipment, necessary to clear an incident. To achieve the appropriate response, TOC operators must confirm the incident, assess what needs to be done, and direct the corresponding remedial activities.

The initial task of the incident management team is the formulation of an incident response program. This should cover four essential areas:

- Emergency response plans for catastrophic (or potentially catastrophic) incidents, for example those involving hazardous materials. CSP maintains an Emergency Information System (EIS) which is used to track hazardous material carriers through the state.

- Traffic diversion plans for major incidents.

- Clearance and traffic management plans for routine or predictable incidents, such as traffic associated with sports events.

- Pre-event incident planning for other possible scenarios.

Another important area to address is the establishment of certain response criteria which determine the need for and level of involvement of the TOC-based incident management team. These should include:

- Number of lanes blocked.
- Estimated incident duration.
- Location of incident (jurisdictional boundary response).
- Minimum response time for clearance.

Too much or too little of a response can potentially make the duration and impact of an incident even worse that it was originally. A timely and coordinated response, on the other hand, can effectively and efficiently control an incident before it becomes a catastrophe. Facilities at the TOC should therefore provide sufficient information to support accurate detection and verification of incidents, as well as offering data analysis tools which enable precise response requirements to be determined.

Clearance

For an incident management program, clearance is the safe and timely removal or termination of the cause of the incident and restoration of the roadway to its full capacity. Priorities at the incident site should include:

- Preservation and protection of human life.
- Maintenance of safety for participants in the response-effort.
- Fulfillment of any legislative requirements.
- Minimization of delay to the motoring public.
- Minimization of damage to public and private property.

Incident management and responsible facilities at the TOC should be designed such that they allow these priorities to be addressed. For example, the equipment and reporting services should enable operators to assess hazards at the incident scene and disseminate appropriate warning messages.

An effective clearance effort will proceed from the incident management team's initial determination of what needs to be done and who needs to be involved. This information should be relayed to the appropriate agencies via the TOC's communications links. In addition, the TOC incident command system should define the lines of authority and responsibility at the incident site to ensure a high level of communication and coordination between all participating groups. Proper response vehicles without an "overkill" level of numbers of responding vehicles is also a great help in clearing an incident scene. The communications capabilities of the TOC will allow specific instructions to be issued to the appropriate agencies, minimizing the potential for "overkill."

Timely removal of an incident is accomplished by the implementation of quick clearance policies. Incident response and clearance strategies can include:

- Dedicated police freeway patrols.
- Vehicles equipped with push bumpers.
- Contracts with private towing companies.
- Courtesy service patrols.

- Future "quick response" vehicles which could be developed in conjunction with local fire departments.

Public agencies have a responsibility to provide a safe, efficient transportation system. Therefore, it is important that trained, experienced personnel who fully understand scene management, clearance options, specialized equipment, and other needs be available at an incident scene. Likewise, the TOCmust contain sufficient data collection, analysis and dissemination tools to allow its operators to support this effort in an efficient, coordinated manner.

Recovery

Recovery is the application of traffic control measures to manage traffic and restore normal conditions in the area affected by an incident Proper traffic management will reduce the impact of the incident and provide a safer environment for response teams and motorists. Traffic management recovery steps which potentially can be addressed by the TOC include:

- Redirection of traffic at the site of the incident.
- Prevention of more traffic from flowing into the area and increasing the upstream queue.
- Prevention of congestion from extending across the metropolitan traffic network.

Inadequate traffic management techniques can lead to excessive lane closures, extended delay and inconvenience for trapped motorists and possibly more secondary accidents. For these reasons, it is crucial that traffic management strategies be clearly understood by the incident management teams at the TOC and the incident scene. Strategies and techniques for use by the incident management teams could include:

- First-response units equipped with appropriate traffic control devices (roll-up signs, cones, portable message signs, etc.).
- Identification of alternate routes and appropriate signal timing adjustments (if a diversion is necessary).
- Timely and accurate traveler information dissemination (VMS, HAR, radio and TV reports, traffic reporting services, etc.).

Traffic management is an element of incident response activities that is sometimes given less attention than it deserves, perhaps because of the complexities of managing traffic under incident conditions. Since clearance activities generally take place in the face of high traffic demands, it is imperative that proper traffic management techniques be instituted within any incident response system. The TOC should therefore incorporate suitable equipment and facilities to address these traffic management needs.

2.6.3 Incident Management Medium- and Long-Term

Introduction

The components of IVHS can be thought of as tools for use in incident management. When viewed as individual technologies, they have little independent role in reducing the impacts of incidents or in managing responses. In combination, however, IVHS technologies can provide support in detection, identification, response and clearance activities, including increasing the speed and accuracy of remedial actions while improving the information provided to travelers. In the medium- and long-terms of the Denver Metro Area IVHS program, a variety of IVHS approaches have potential for integration with the TOC system to further enhance the region's incident management and response capabilities.

Detection and Verification

Significant time reductions can be realized in the incident detection and verification stage by a number of emerging technologies. Approaches which may be considered for medium- and long-term TOC operation include:

- Improved and advanced incident detection algorithms and expert systems.
- Video image detection (VID).
- VID algorithms and expert systems.
- Automatic vehicle identification (AVI) for link journey time monitoring,
- Infrared cameras (especially for night detection).
- Vehicles equipped with Mayday alert systems.
- Vehicles equipped with an onboard route guidance system (probe vehicles).

These approaches would require increased use of equipment in the external highway environment, including sensors and cameras for highway monitoring as well as in-vehicle systems. In addition, facilities at the TOC would need to be upgraded and enhanced to accommodate the new data available from these sources. Potential upgrade requirements include hardware and software modules to analyze and integrate the new data with information derived from existing systems.

Response

Incident response processes can also benefit from emerging IVHS technologies. These technologies can help to reduce reaction time and improve the appropriateness of the response. Approaches which may be considered for use in the TOC in the medium- and long-terms include:

- Expert systems and automated response plans, based on knowledge elicitation and operational experience.

- A geographically-coded information system network, allowing automatic identification of appropriate parties and agencies for participation in the response effort.

- Data communication links between the TOC and response vehicles (computer link-up).

- Creation of an incident record database, for analysis and integration with expert systems and artificial intelligence.

Clearance

IVHS technologies can further assist in the clearance activities of an incident management program. IVHS-based timesaving and assistance measures which can be considered for the TOC include:

- Response vehicles equipped with onboard computers supported by TOC data and communications, to provide response plan information and route guidance.
- AVI or Automatic Vehicle Location (AVL) technology to locate response vehicles, track progress and modify clearance efforts as required.
- Introduction of TOG-controlled automated systems and robotics for hazardous materials incidents.

Recovery

Most of the IVHS technologies that can assist in the traffic management recovery area concern traveler information systems. Options which may be considered for TOC control include:

- Real-time VMS displays and HAR broadcasts, including automated message generation based on operational plans and expert systems output.
- Advances in teletext and cable television services, providing rapid incident advisories and recommending alternative travel options.
- Videotex system enhancements, allowing users to interactively assess alternative travel options.
- Dynamic real-time route guidance systems, supporting TOC-controlled rerouting of vehicles away from the scene.
- High data-rate digital broadcasting approaches for increased traveler awareness.
- Traffic signal coordination timings along diversion or alternate routes.

2.7 CDOT Permitting and Traffic Control

Permitting and traffic control planning for maintenance and construction activities will also he housed in the TOC. CDOT currently issues access permits and construction permits (curb cuts, utilities, lane closures) for these activities along highway rights-of-way.

In 1990, as part of the traffic control efforts for the construction of the North I-25 Bus/HOV lanes and the reconstruction of the I-25/70 (Mousetrap) interchange, CDOT

created the Traffic Control Support Project (TCSP) to coordinate all lane closures and detour activities.

The TCSP currently occupies an office of 1,200 square feet with a staff of seven and operates 24 hours a day, five days a week. In addition to organizing over one hundred traffic control operations a week, the TCSP programs six stationary Highway Advisory Radios (HAR), one portable HAR, four portable variable message signs, and a 24 hour construction lane closure 'hotline" (573-ROAD). The TCSP also has established radio communications with CDOT maintenance, CSP, Metro Traffic Control, and the Denver area Courtesy Patrols.

Although the primary function of the TCSP is to support construction projects, it can use its HAR broadcasting equipment, construction "hotline" number, and portable message signs to provide information to the traveling public in the event of a major incident.

These permitting and coordinating functions will be consolidated at the TOC in order to have a comprehensive picture of potential disruptions on the regional arterial and freeway systems. Detour and lane closure status broadcast via the various ATIS measures will be able to be kept up to date in a much closer to real time fashion due to the presence of the permitting function within the TOC building.

3.0 TOC IMPLEMENTATION TIMEFRAME AND PHASING

3.1 Introduction

The design, construction and implementation of the Denver TOC will best be realized by an incremental program approach. These three aspects of the TOC should be divided into phases where activities and services can be incorporated over time as funding becomes available.

The intent of this chapter is to build upon the foundation established within the Denver Metro Area IVHS program's Early Action Plan and Strategic Plan. These documents identified activities and services which exhibit varying degrees of interdependency with the Denver TOC. A preliminary listing of some of these individual activities, their functional categorization and potential implementation timeframe were discussed in Chapter 2 of this document

This chapter investigates in more detail the Strategic Plan activities which are the most closely affiliated and interdependent with the TOC. The TOC timetable is broken down into four phases with the corresponding time periods as follows:

1) Start-Up Phase (January 1993 to December 1994; 24 months)

2) Short-Term Operational (January 1995 to December 1997; 36 months)

3) Medium-Term Operational (January 1998 to December 2001; 48 months)

4) Long-Term Operational (January 2002 and beyond).

Within each of these time periods, those activities which are most directly connected with the Denver TOC are discussed in terms of the following:

- scope of work to be accomplished;
- preliminary cost estimates:
- potential implementation locations; and
- preliminary staffing/personnel estimates.

Preliminary cost estimates for the Start-up Phase, Short-term and Medium-term Operational Periods are summarized in Table 3.1 and described in the following sections of this chapter. The preliminary staffing/personnel estimates for the Denver TOC and these associated activities are covered in more detail within Chapter 4. Where cost estimates are included, these should be considered as tentative in nature, with scope for refinement as functions and requirements are defined in more detail. At this time, efforts to establish a preliminary implementation timeframe for the TOC's functions and associated systems are needed to provide a focused approach as funding becomes available.

Table 3.1 - PRELIMINARY COST ESTIMATES

TOC Start-Up Phase Through Medium Term

Activity/Cost		**TOC Start-Up Phase (24 Months)** 1/93-12/94	**TOC Short-Term Phase (36 Months) 1/95 - 12197**	**TOC Medium-Term Phase (48 Months) 1/98 - 12/01**	**cost by Activity**
TOC Design Process	**	650,000			650,000
TOC Construction	**	3,000,000			3,000,000
TOC Start-Up Equipment	**	2000,000	2,000,000		4,000,000
Real-Time Volume/Speed	**	600,000	4,5000,000		5,100,000
Expanded Ramp Metering		1,500,000			1,500,000
Incident Detection/Management	**	1,123,000	1,400,000		2,523,000
Temporary Communications		500,000			500,000
Preplanned Incident Diversion Routes		1,000,000			1,000,000
TOC Database Integration	**		300,000	200,000	500,000
Cooperative Exchange TV/Radio	**		350,000		350,000
Public/private Dispatch	**		200,000		200,000
Data Fusion	**			500,000	500,000
TOC Expert System	**			1,500,000	1,500,00
Permanent Communications Netork	**		3,000,000	3,000,000	6,000,000
VMS			2000,000		2,000,000
Teletext/CATV	**		700,000		700,000
RDS/Broadcasting	**		500,000		500,000
Videotex	**			425,000	425,000
Dynamic Route Guidance	**			500,000	500,000
		10,373,000	14,950,000	6,125,000	31,448,000

* Start-up activity is design; short-term activity is equipment procurement and construction.
\- Activity represents opportunity for private sector participation.
@ Costs from CIMC Final Report (Reference 5).

NOTE: Right-of-way costs are not included in this estimate.

3.2 TOC Start-up Phase

3.2.1 Introduction

The 24-month start-up phase extends from January 1993 to December 1994. The TOC start-up phase will focus primarily on the design and construction of the TOC itself. In addition, this period will include the design process required for the equipment necessary for initial TOC operations. It is anticipated that a few strategic staffing positions will be required for involvement in the TOC implementation and commissioning process.

3.2.2 TOC Design Process

Presently, the CEI/CRC team is providing concept-level planning for the Denver TOC. In addition, the CEI/CRC team is responsible for the TOC's detailed design and planning efforts as an extension to the initial planning work. Efforts within this activity focus on the design documents, plans, strategies and an integrated system architecture for the TOC. In addition, a TOC building architectural and civil/site design will be prepared within the identified corridor location. The work within this activity will be complete at the end of 1993 with a total cost of $650,000.

3.2.3 TOC Construction

This activity will cover the scope of work necessary to physically construct the Denver TOC. After review of the building architectural and civil/site design, a contractor will be selected to construct the TOC. It is anticipated that this activity will begin in early 1994, with completion in early 1995. Construction costs within this time period are tentatively estimated at $3,000,000. The actual cost will depend on a number of factors, including location and the choice of using a new facility versus an existing building.

3.2.4 TOC Start-up Equipment

This activity will involve the equipment (hardware and software) procurement for the Denver TOC's initial functions. It is anticipated that this activity will begin in early 1994. Within this time period, the funds to be expended on purchasing the first systems and components are estimated to be in the region of $2,000,000. This activity represents equipment and materials to be used "in-house" at the TOC to manage and complement the IVHS-related field equipment and communications links. It is anticipated that equipment initially installed in the TOC, particularly its computer systems, will be capable of accommodating significantly more than the start-up field equipment, to account for expansion in the future. In addition, funds will be utilized to purchase the necessary office furniture, operator consoles and other equipment required in the TOC.

3.2.5 Collection of Real-Time Traffic Volume and Speed Information

This activity will involve deployment of freeway-related vehicle detection technologies meeting the Denver Metro Area's specific needs. In particular, this activity will ultimately implement a comprehensive, network-wide, real-time traffic information collection system. As a first step, in the start-up phase it is anticipated that functional requirements and integrated system designs will be accomplished, at a cost of around $600,000. The main focus at this time will be to determine the most appropriate detection

equipment designs and locations for the Denver Metro Area freeway system. It is anticipated that this activity will begin in early 1994.

3.2.6 Expanded Freeway Ramp Metering System

CDOT is currently in the process of expanding its freeway ramp metering system at a number of locations throughout the Denver Metro Area. At this time, CDOT is in the process of developing performance specifications for the ramp metering computer system to obtain greater control and monitoring flexibility and to provide improved software for graphical displays of freeway speeds. Building on this, within this initial start-up phase, it is anticipated that approximately $1,500,000 could be applied to expand the ramp metering system.

3.2.7 Incident Detection and Management

This activity will implement a coordinated incident management program in the Denver Metro Area. At this time, the CIMC is actively pursuing opportunities in the area of incident management programs, and published its recommendations report in September 1992. It is anticipated that the CIMC's incident management recommendations will be pursued in 1993. Activities and costs listed below have been taken from the CIMC's final report (Reference 5). Major emphasis within this time period will focus on the establishment of the following initiatives:

1) interim TOC - $547,000

2) organized cellular phone call-in system - $200,000

3) reference working system - $100,000

4) consensus jurisdictional maps - $50,000

5) common communication system - $85,000

6) total station equipment - $91,000

7) enhanced HAR system - $50,000

These CIMC figures estimate that the cost to implement these activities will approach $1,123,000 (Reference 5).

3.2.8 Create Temporary Communications to Key Locations

This activity will focus on the design and installation of a temporary communications network to key locations in the Denver Metro Area. The activity will investigate those technologies which could provide the necessary communications capabilities, as well as identify those key locations which will provide the foundation for a permanent communications network. It is anticipated that most of this activity's work will be completed as part of other individual ATMS, ATIS and incident management efforts. However, it is important that this activity serve as the coordinating entity to fuse the

individual components into a comprehensive structure. Within this start-up phase, it is estimated that costs will approach $500,000 and work will get underway in mid-1993.

3.2.9 Preplanned Incident Diversion Routes

This activity will focus on the establishment of traffic diversion routes for use when freeway lanes within the Denver Metro Area must be closed for an extended period of time. Preplanned incident diversion routes can provide significant benefits by reducing the potential for delays and secondary accidents in the event of a major incident. In addition, tbis activity provides an excellent opportunity for interjurisdictional cooperation, which should establish the foundation for further freeway and arterial coordination. However, diversion routes must be established in a manner that assures the participating agencies that the arterial roadways can accommodate the additional traffic at an acceptable level of service. Within this start-up phase, it is anticipated that work will get underway in mid- 1993 and costs will approach $1 ,000,000, potentially including signal timing plans for diversion scenarios and new equipment.

3.2.10 Variable Message Signs

The VMS sysstem operated by Region 1 along I-70 west of Denver will be incorporated into the TOC as a start-up activity. The North I-25 bus/HOV VMS system will also be interfaced with the TOC if it is completed during this time period. Costs of these activities are negligible or are being paid for by other agencies.

3.3 TOC Short-Term Operational Phase

3.3.1 Introduction

Within the TOC short-term operational phase, the focus will primarily be on activities which will complement the Denver Metro Area's existing conditions, as well as the continuation of some of the start-up activities. This 36-month time period extends from January 1995 to December 1997.

3.32 TOC Start-up Equipment

This activity's implementation schedule continues on from the initial start-up phase. The purchase and installation of the Denver TOC's start-up equipment is expected to continue through late 1995. It is anticipated that approximately $2,000,000 will be allocated during this period.

3.3.3 Collection of Real-Time Traffic Volume and Speed Information

This activity continues on from the start-up phase. Activities within this time period should approach completion in late 1997. Costs to procure, install, and commission the selected vehicle detection equipment for widespread system implementation are estimated at $4,500,000.

3.3.4 Incident Detection and Management

Incident management activities continue from the start-up phase. It is anticipated that work in this area will be completed in late 1997. The CIMC estimates that the following functions and their associated costs will be included within this activity:

1) complete reference marking system - $100,000

2) CCTV coverage - Sl,000,000

3) accident investigation sites - $300,000

The cost to implement these activities will therefore be approximately $1,400,000 (Reference 5).

3.3.5 TOC Database Integration

This activity will focus on the functional integration of the TOC's in-house and distributed database systems. Many of the ATMS, ATIS and incident management projects included within the Denver Metro Area IVHS program will ultimately use common databases associated with the TOC facility. This activity will implement the necessary database structure for both current and planned systems. These may include the ramp metering system, freeway vehicle detection efforts, environmental monitoring systems, fleet management and dispatch systems, incident management efforts, and various ATIS ventures. An appropriate database format will include central and distributed information processing needs, data communications requirements, and necessary redundancy efforts. Since database integration relies on other system implementations, this activity will proceed in parallel with TOC component deployments. It is proposed that $100,000 per year be set aside to cover this activity's scope of work, totalling about $300,000 over 36 months. This would begin in early 1995 when the TOC is commissioned, continuing throughout this time period.

3.3.6 Develop Cooperative Exchange System With Television and Radio Traffic Information Services

The purpose of this cooperative exchange system is to develop an interface to share relevant information between the Denver TOC and all participating media agencies. In addition to these data sharing capabilities, this cooperative exchange system has the potential to serve as an important tool for the dissemination of traffic information to the public. It is anticipated that costs to implement this activity will approach $350,000. Implementation of this cooperative exchange system will begin in early 1995 when the Denver TOC is commissioned. Completion of this activity should occur in late 1996. This activity represents an opportunity for partial or substantial private sector participation.

3.3.7 Public and Private Dispatch System

This coordinating activity will provide an additional source of field data for incident detection and verification efforts. In particular, this activity would utilize the various public agency and private sector dispatch systems for this information. Public agency participation could include the numerous city and county public work department vehicle fleets as well as the local police departments. Private sector participants could include delivery trucks, taxis, utility maintenance vehicles and rental agency shuttle vehicles. It is anticipated that costs to cover this activity's scope of work will approach $200,000. Work should get underway in early 1995 and continue through the entire time period. Again, this activity is an opportunity for substantial private sector participation.

3.3.8 Develop Permanent Communications Network

This activity will involve the planning and deployment of a permanent communications network to integrate the various IVHS elements and activities in the Denver Metro Area. Evaluation of competing technologies will provide the basis for a permanent state-of-the-art communications network. This activity will build upon the temporary communications network, beginning in early 1995 and continuing throughout the entire period. Costs devoted to this communications infrastructure during this time frame backbone are tentatively estimated at $3,000,000. It is recognized that this activity's schedule and cost will depend largely on the individual activities selected for implementation.

3.3.9 Variable Message Signs

This activity will involve detailed design and deployment of a VMS system within the Denver Metro Area. VMS offers a valuable technique to provide motorists real-time traffic information and, if desired, alternate route selection advisories in advance of key decision points along the freeways. An initial objective of this task is to determine the appropriate VMS equipment (e.g., flip disk, LED cluster, fiber optic, etc.) and appropriate deployment locations. In addition, message generation capabilities and message display type need to be investigated. Detailed design and deployment will then follow. It is anticipated that this activity will begin in early 1995 and approach completion in late 1997. The CIMC has estimated a cost of around $1,000,000 for VMS activities, although an expenditure of $2,000,000 would allow for increased system coverage. It is recognized that the actual cost will reflect the VMS technology selected and the number of signs installed. The Region 1 VMS system along I-70 west of Denver and the North I-25 bus/HOV VMS system will likely be interfaced with the TOC during the start-up phase.

3.3.10 Teletex and Cable Television Information Systems

This activity will aim to design and implement a television-based traffic information service for the Denver Metro Area. Review of this information by travelers will be possible through a teletext service and a dedicated cable television channel. The cable channel will present a color-coded speed map of the entire freeway system in a format suitable for relay into homes in the Denver Metro Area, as well as for display on terminals in downtown office buildings. In addition, the cable channel will include a picture insert window capable of broadcasting live images of major incidents from the CCTV camera system. The teletext service will be interactive and will supplement the cable channel, offering a number of pages of traffic information, selectable by area or information type. It is anticipated that this activity will begin in early 1995 and approach completion in late 1997 at a cost of $700,000. Private participation in this activity should be actively pursued by CDOT.

3.3.11 Radio Data System (RDS) Broadcasting

RDS is a subcarrier system which provides a silent, digital data channel on existing FM radio programs. This activity will equip participating radio stations with RDS encoding equipment, or implementation of a similar wireless digital communications service. The project will also establish a Traffic Message Channel (TMC) message generating facility at the TOC with a data link to the broadcasting station. It is anticipated that this activity will begin implementation in early 1995 with completion in early 1996, at a cost near $500,000. Over the course of the program, full system implementation will occur when

portable or in-vehicle TMC receivers are purchased by private consumers in me Denver Metro Area. CDOT should actively pursue opportunities for public/private partnerships to implement this activity.

3.4 TOC Medium-Term Operational Phase

3.4.1 Introduction

The TOC medium-term operational phase will focus on those activities which possess advanced IVHS features. It is expected that most of these systems and technologies will be proven and available for implementation by this time. In addition, some activities within this phase are a continuation of work started in earlier stages. This 48-month period begins in January 1998 and extends to December 2001. The actvities detailed in this section generally have high potential for private sector participation

3.4.2 TOC Database Integration

This activity continues the work initiated during the short-term phase. TOC database integration will continue on in early 1998 and approach completion by late 1999. Further costs within this activity are estimated at around $200,000.

3.4.3 Data Fusion

TOC data fusion will build upon the initial foundation established within the TOC database integration efforts. This activity will involve fusion of appropriate data received at the TOC to produce a single, reliable database. The data fusion process will assign reliability and longevity weightings to alternative data sources (e.g., inductive loops, dial-in reports, CCTV images, etc.) to assist the TOC operators in resolving data conflicts and assessing traffic conditions. It is anticipated that this activity will begin in early 1998 and extend through late 2000 at a cost of approximately $500,000.

3.4.4 TOC Expert System

Directly interdependent with both the TOC's database integration and data fusion efforts, this activity will focus on the development of individual expert systems for appropriate TOC functions. The ongoing expansion and enhancement of the TOC will ultimately entail functions of such variety and complexity that they are beyond the scope of unaided human management and control. Among the areas that can be assessed for expert systems are traffic control, demand management, and traveler information message generation. TOC expert systems will initially provide advisory output and will be refined to provide fully-automated responses. It is anticipated that this activity will begin in early 1998 and extend throughout the entire period, at a cost of around $1,500,000.

3.4.5 Develop Permanent Communications Network

This activity will continue work initiated within the short-term phase. Although it is anticipated that some of this project's workscope will be completed within other individual ATMS, ATIS and incident management activities, this activity will fuse the individual components into a comprehensive communications structure. It is anticipated that this activity will be concluded during this time period at a cost of $3,000,000.

3.4.6 Videotex Information Systems

This activity will implement an interactive videotex information service within the Denver Metro Area based on the TOC's integrated information database system. The videotex system will offer traffic and traveler information, weather conditions, route planning facilities and transit service enquiries through computer and video terminals linked to the TOC via telephone lines. These data will be available in private homes, office buildings, public activity centers, parking garages or gas stations. It is anticipated that this activity will begin in early 1998 and near completion in late 1999 at a cost of $425,000. It is recognized that private sector initiatives may already have introduced videotex by this time. In this case, the emphasis will be placed on providing consistent travel data through an interface with this system.

3.4.7 Dynamic Route Guidance

This activity will implement a dynamic route guidance system in the Denver Metro Area. This activity should substantially build upon the major route guidance demonstration projects currently underway elsewhere in the U.S. In addition, tasks within this activity should reflect the efforts of FHWA to establish a national IVHS systems architecture. It is anticipated that most of the costs within this effort will be borne by the private sector in producing and marketing in-vehicle navigational equipment. However, the Denver TOC will need to collect and format appropriate data, such as link journey times, to support these private sector initiatives. Software modifications to assemble the TOC-collected data in the appropriate format are expected to be addressed in 1998, at a cost of approximately $500,000.

3.5 TOC Long-Term Operational

As technologies advance, new techniques concerning traffic operations and management, traveler information dissemination and incident management activities will be evaluated for inclusion within the Denver TOC. The most appropriate approaches will be incorporated as they are proven. In addition to any new identified systems and technologies, it is anticipated that an ongoing enhancement of the communications network will be established to complement these new technology opportunities.

At this point of the TOC project, the potential exists for a variety of programs to be integrated with the TOC's initially implemented and planned functions. Funding requirements in the long-term will reflect the activities selected for implementation As an initial estimate, $1 ,000,000 per year could be allocated for TOC enhancements during this time frame.

4.0 STAFFING REQUIREMENTS

4.1 Introduction

It is anticipated that operations at the Denver area TOC will be performed by a variety of staff personnel with a range of functions and responsibilities. The TOC will be a regional, multi-jurisdictional and multi-agency facility. Space will be provided for CDOT and CSP personnel, as well as for public/private sector staff including traffic engineers from cities and counties in the Denver Metro Area, media organizations, enforcement agencies and emergency medical response organizations. In addition, certain aspects of the TOC's traffic management, incident management and traveler information dissemination strategies will require their own, individual staffing positions.

Staffing requirements should reflect the support needs identified for every hour of the TOC's operations. The TOC will operate 24-hours-a-day, 7-days-a-week. CSP will have dispatch and call-taking stations manned throughout this time period within the TOC.

The most important time of day for the TOC's traffic management, incident management, and traveler information dissemination activities to be fully operational is between the beginning of the a.m. peak hour and the end of the p.m. peak hour of every weekday. This time period (approximate range: 6:00 a.m. to 7:00 p.m.) is critical due to the high number of vehicle miles traveled in the region during daylight hours. Staffing requirements should reflect support needs during these hours, as well as providing adequate personnel during off-peak and weekend time periods. In addition, staffing requirements should be able to accommodate the demands associated with atypical periods such as sporting events, major incidents and inclement weather conditions.

A key objective of the Denver area TOC is to provide an integrated multi-function facility. The intent is to combine traffic operations with a region-wide communications/dispatch center. Primarily, these traffic functions will relate to all aspects of the ATMS and incident response programs, along with their associated ATIS efforts. The communications/dispatch functions should provide full communications support for CSP, CDOT and other state agencies as described in Chapter 2.

In addition, the potential exists to form private partnerships in the area of commercial ATIS communications functions. In particular, the TOC could incorporate a privately-run broadcast service or radio station on a franchise basis. This could support digital traffic information broadcasting and, in the longer term, dynamic route guidance.

It is not the intent at this stage to make any firm determination of staffing requirements, since this will be dependent on the final functions and services selected for the TOC. However, it is possible to provide a preliminary listing of some probable positions and their associated roles, based on the experience of similar facilities elsewhere in the U.S. and the Denver area's specific needs. TOC staffing requirements are investigated below in the following areas:

- position/title.

- functions/responsibilities.
- status (e.g., new hire, full-time employee, existing position, etc.).
- probable starting date.
- potential staffing source.

These tentative staffing requirements relate to the TOC's traffic and communications applications outlined within this document. Additional staff may be required to cover any future functions or services which may be incorporated at a later date. Staffing should be organized to integrate personnel functions to the extent possible and to address the concept of a career path for TOC employees to allow for personal growth and opportunities for advancement.

4.2 TOC Participants

4.2.1 Participant Identification

The Denver Metro Area TOC has the potential to become-the first facility in North America to integrate traffic management, incident management and public safety communications into one combined operation. This will establish the multi-jurisdictional, multi-agency facility which the participants in the Denver Metro Area IVHS study and TOC design are striving to achieve. Within the TOC, space will be provided for a multitude of public agencies as well as for the private sector. Public agency participants will likely include, but are not limited to, the following:

- CSP.
- CDOT (Region 6).
- CDOT (Region 1).
- CDOT Headquarters (HQ).
- City and County of Denver (Traffic Engineering, Police, and Fire Departments).
- RTD.
- DRCOG.
- CIMC.
- Other City and County Traffic Engineering, Police and Fire Departments.

Private sector participants could include, but am not limited to, the following:

- Commercial traffic reporting services.
- Television stations (regular and cable).
- Radio stations.
- Emergency services (e.g., hospitals/ambulances, paramedics).
- Authorized towing companies.

Since the TOC has the potential to incorporate so many different organizations within one facility, it is important to promote a team approach in running the center. At the same

time, the organizational independence of CDOT HQ, CDOT Region 1, CDOT Region 6, CSP, the various cities and counties, media organizations, emergency service groups and any other participants needs to be recognized. The intent of combining all of these organizations under one roof is to promote the idea that sharing facilities, coordinating activities and cooperating together will prove to be a better and more efficient way of serving the Denver Metro Area than isolated and uncoordinated activities.

4.2.2 Private Sector Participation

It is anticipated that most, if not all, of the public agency and private sector participants will have space allocated for their representatives within the TOC building. Some will also have space in the TOC control center room. In addition, certain aspects of the TOC's traffic management, incident management and traveler information dissemination strategies will require their own, individual staffing positions. For each of these positions, questions concerning the appropriate level of involvement by the public and private sector must be addressed. For example, should the TOC be consultant-operated (like the INFORM center on Long Island) or staffed in-house (like Toronto and San Antonio), or should it be a combination of both approaches? Input as to the private sector's desired role in IVHS in the Denver Metro Area is currently being sought. It is recommended that CDOT should be involved at a high level of detail within either approach, whether it be operating the TOC or providing continuing management oversight and support.

At this stage, TOC staffing is anticipated as a combination of both public agency and private sector involvement. This combination is an excellent opportunity to promote a public/private team approach in operating the TOC. It may be desirable to contract selected services out to a private sector firm when the TOC is first commissioned. This could be done on an interim or trial basis to evaluate the effectiveness and acceptability of this approach. If this initial private sector staffing does not fulfill its desired expectations, it should prove easier to switch these positions to a public agency at a later date. In contrast, it may prove difficult to change jobs to the private sector after they have been established as regular state positions.

Where staffing positions are involved, there are many concerns and issues that should be addressed. The following discussions highlight these issues:

- Expertise/Knowledgeability. Private sector involvement must be considered carefully, especially where these positions will involve traffic and incident management and control applications. CDOT has expressed concern about a high level of privatization because of the potential for loss of in-house expertise. CDOT has also expressed a desire to retain staff within both the TOC system design and operations processes, to obtain specific knowledge and to ensure program continuity.

- Morale. CSP dispatchers and call-takers are public employees. There could be concerns if private employees work side-by-side with public employees. Integration of staffing between the public and private sectors would be at best a difficult proposition.

- Incident Management. It may be inappropriate for the private sector to perform some functions in the TOC. In the privately-operated Westchester County facility, for example, incident management is retained as a public sector responsibility.

Other issues include:

- Entry-Level Positions
- Employee Wages
- Employee Benefits
- Employee Termination

4.3 TOC Staffing Functions/Positions

4.3.1 Introduction

The Denver TOC has the potential to be more multi-functional, broader-based and varied in scope than any other center in the country. In fact, Denver's center will combine traffic operations with communications and dispatching. This integration of public safety, communications, and traffic management will create multi-function positions and responsibilities within the TOC and will probably reduce the overall number of staff needed.

At this time, the Denver Metro Area's CSP dispatch unit is responsible for the timely dispatch and monitoring of CSP vehicles in the area. The local dispatch unit's responsibilities will be expanded to cover all of north-central and northeast Colorado in the future. This presents the unique opportunity of utilizing CSP communications for fundamental IVHS elements.

When the CSP's dispatch unit moves into the TOC, an excellent opportunity for an unprecedented level of cooperation between state agencies will be created. With the advent and implementation of the proposed CSP Computer Aided Dispatch (CAD) system and the Statewide Digital Radio System (800 MHz Trunking a core group of system users should be established to discuss needs, resources, and cooperation for the most efficient use of this new resource. CSP is a logical candidate to lead this effort.

Within the TOC, the CSP dispatch unit should provide full communications support for CDOT Region 1, CDOT Region 6, CDOT Region 4, CDOT Region 3, and other state public safety agencies. CSP will ensure that CDOT's maintenance dispatching needs are met by assigning specific dispatchers to respond to CDOT needs in the three zones discussed in Chapter 2--namely the Denver area, mountains, and eastern plains. CSP should not simply move its existing operations to a new facility, nor should it be expected to provide these expanded communications coverage and support services with existing FTEs (full time employees) and equipment.

A key issue affecting the success of the TOC is the extent to which voice communications needs are met and integrated for all agencies involved. This proposed combination of resources between CSP, CDOT and other state public safety agencies must address every agency's requirements and the procedures necessary to meet them. The arrangements between these agencies should have built-in safeguards to ensure that each agency's needs are addressed, that user groups and agreements are non-threatening politically, do not impact management prerogatives, and will work over a long period of time. However, many issues, such as number of personnel required, funding, equipment, management, etc., will need to be resolved before this concept can fully go-into effect.

Within this section, the TOC's staffing requirements am investigated in more detail. This includes an assessment of alternative sources of personnel for each position indicated. Where potential private sector positions are identified up front, it may be easier to obtain funds to staff the TOC if a good balance of public and private employees is initially determined. The various relationships between these participants (and required staffing positions within the TOC) are graphically displayed in Figure 4.1 - "Essential" Position Interrelationships. Figure 4.2 - Conceptual Functional TOC Organization Chart displays a concept for the organization of the various functions/positions within the TOC.

4.3.2 TOC Management Team

The TOC will consist of employees from several different jurisdictions. This fact could result in complex "chain-of-command" structures. The solution to this potential problem is envisioned as a separate TOC management "team", directly responsible for (and having authority over) all aspects of TOC operations. This team could consist of a board of representatives from the participating jurisdictions, one individual appointed by the participating jurisdictions (possibly a rotated position), or management by a private sector individual or group of individuals.

4.3.3 TOC Administration/Supervision

4.3.3.1 INTRODUCTION

The administration, scheduling, and budgetary concerns of the TOC will be dealt with by various supervisors or managers. These managers will be required to supervise several TOC employees in addition to these administrative functions, as several positions/functions within the TOC require direct supervision. These positions are described in the remainder of this section.

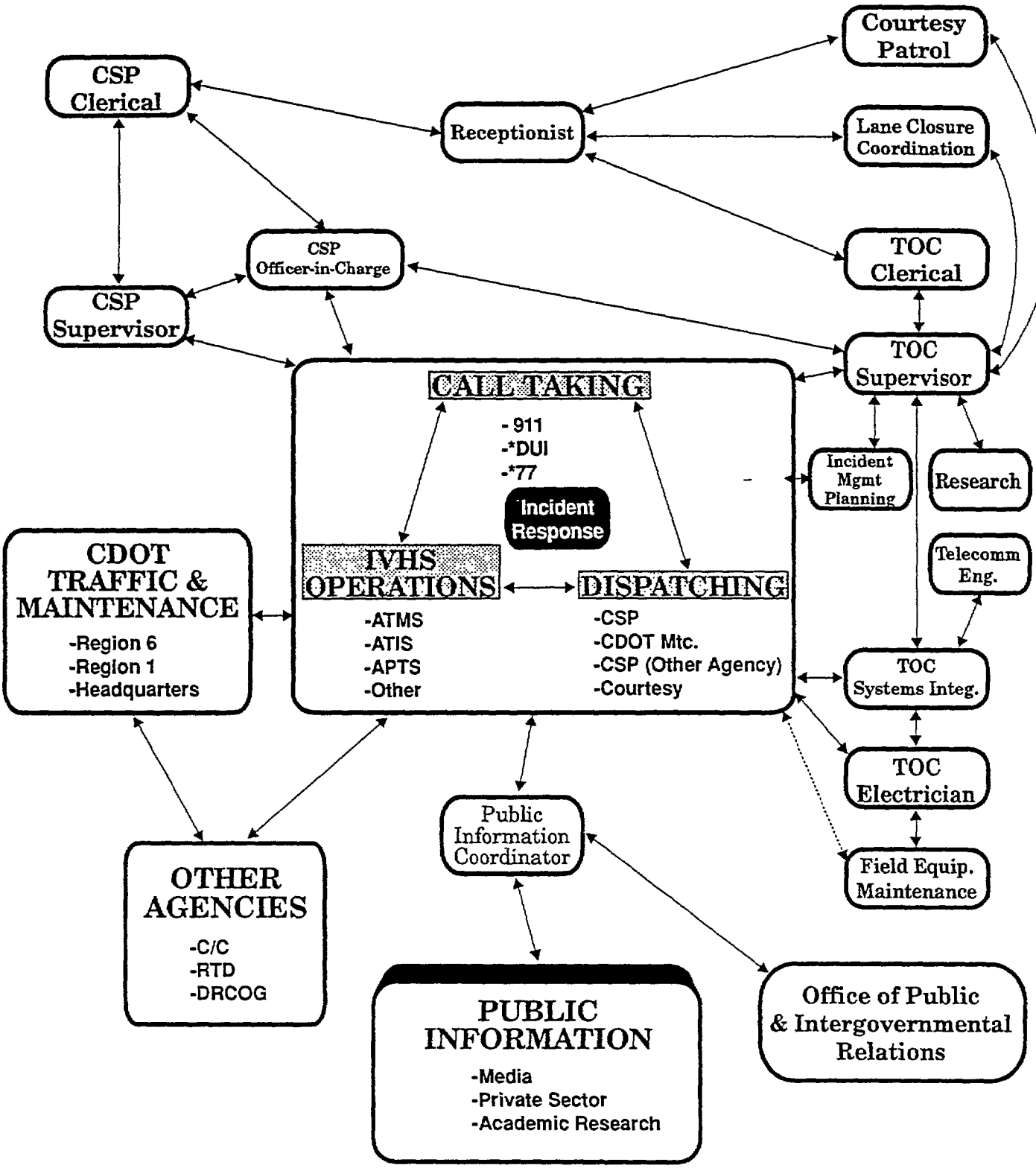

Figure 4.1 "Essential" Position Relationships

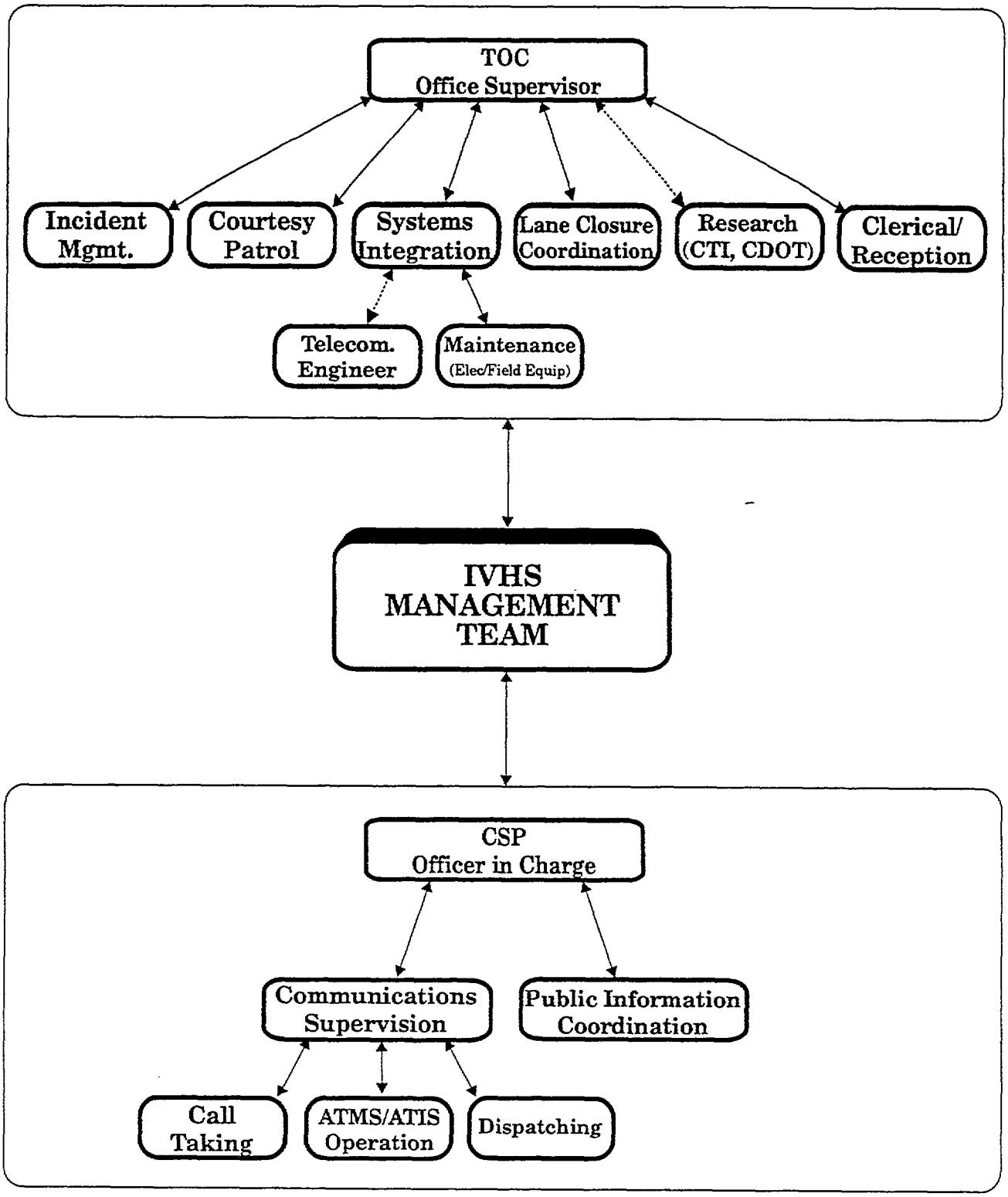

Figure 4.2 Conceptual Functional Organization Chart

4.3.3.2 CSP OFFICER-IN-CHARGE

Position/Title: CSP Officer In Charge

Functions/Responsibilities: The CSP Officer-In-Charge is typically a CSP Captain and is responsible for overseeing all facets of the CSP Communications and dispatch unit. This includes day-today operations, budget, personnel supervision and administration. The Officer In Charge directs the CSP Communication Supervisors and is regularly forced to make quick decisions regarding officer deployments or responses to incidents.

Position Interrelationships: TOC supervisor, CSP communications supervisors, CSP dispatchers, ATMS/ATIS systems operators, systems engineer, media and traffic reporting services, CSP call takers, TOC electronic technician, CDOT Region 1 TOC Representative, CDOT Region 6 TOC Representative.

Status: Existing CSP employee.

Start Date: Early 1993; involved in TOC planning and design.

Staffing Sources: CSP.

4.3.3.3 TOC OFFICE SUPERVISION

Position/Title: TOC Office Supervisor

Functions/Responsibilities: The primary responsibility of this position is to provide overall management, balance and coordination between all participating public agencies and private organizations within the TOC. The TOC office supervisor will be the primary liaison point between cooperating agencies, both internal and external to the TOC. This position will also be responsible for overall office management. In addition, the TOC office supervisor will serve as the statewide liaison representative in future years as the TOC becomes the central point of Colorado's IVHS operations network, as outlined in the C-Star plan.

Position Interrelationships: The TOC office supervisor will interact with all other facility personnel.

Status: New hire; full-time employee.

Start Date: Early 1993; involved in TOC implementation and commissioning process.

Staffing Sources: CDOT Region 1, CDOT Region 6, CDOT HQ, CSP, joint CDOT/CSP hire, private sector consultant (Executive Director).

coverage could also be extended to include display terminals in office buildings or additional public activity center kiosks.

In the longer term, public/private cooperation could be beneficial in the area of dynamic route guidance. Here, the TOC would maintain a database of link journey times. This could be used to support private sector route guidance system deployments in the region.

The public information coordinator position offers a good opportunity to form a number of public-private sector partnerships within the TOC's operations. Early involvement by the private sector in the TOC implementation process will produce better feedback concerning the media's role in traveler information dissemination activities. If this involvement is delayed, input may be too late to incorporate. At this time, every idea or opportunity which establishes better relations between the TOC and the private sector media and traffic information services is valuable.

Position/Title: Public Information Coordinator

Function/Responsibility: This position will be the primary liaison point for communicating all ATMS and incident management efforts to the media. Major emergencies would require coordination with the OPIR. These reports could include link-travel times, incident site locations, congestion areas, possible alternate routing schemes and other pertinent information. This position would be complemented by various automatic information dissemination systems. The media liaison position will be responsible for planning, organizing and editing a variety of publications and programs for broadcast over these systems, including updating road and weather information, or perhaps over the TOC's associated radio station. Along with preparing and compiling all pertinent information for distribution to the media, this position would serve as the primary contact between the TOC media and motoring public when clarification of the TOC's reports and activities is required.

Position Interrelationships: CSP dispatching, ATMS/ATIS system operators, all CDOT Region TOC Representative, systems engineer, city and county traffic engineers, TOC office supervisor, OPIR.

Status: Reassigned personnel or new hire; full-time employee.

Start Date: Early 1994, involved in TOC implementation process.

Staffing Sources: CSP, CDOT, CDOT/CSP joint hire, private sector consultant

4.3.5 *Incident Management*

4.3.5.1 INTRODUCTION

The establishment of Denver Metro Area TOC will provide improved response to incidents which affect the traffic operations on area roadways. The Denver TOC will also house CSP operations which providing law enforcement functions for a large area in Colorado.

Improved incident response will be accomplished by the formation of incident management teams, consisting of three positions in the Denver Area TOC, as follows:

- Call Takers.
- ATMS/ATIS Operators.
- Dispatchers.
- Incident Management Engineer.

Effective incident response, as well as law enforcement functions, involves the coordinated effort of each of these positions. The incident response team staffing positions are envisioned to form a career path for several of the TOC employees. This career path is described below:

Call Taker »» ATMS/ATIS Operator »» Dispatcher

To advance beyond an ATMS/ATIS Operator, an individual must become a CSP employee. This requirement stems directly from the sensitive (criminal) information processed routinely by the Dispatcher position. Implicit in this career path is the fact that ATMS/ATIS Operators can perform the functions of Call Takers and that Dispatchers can perform all tasks within the Incident Response team. This career path, or cross-training, will allow the on-duty staff size of the TOC to be reduced during off-peak time periods, as one individual (a dispatcher) will be able to perform all required functions.

Each of these positions, including titles, status, functions/responsibilities, relationships with other TOC positions, phase of TOC development the position is required, and possible staffing sources, are described in the remainder of this section.

4.3.5.2 CALL TAKING

Position/Title: CSP Call-Takers

Functions/Responsibilities: The primary responsibility for these positions will be to answer the TOC's emergency phone system (e.g., cellular phone call-in *77 and *DUI, emergency phone call box stations if any, overloaded 911 calls, etc.). This position will also monitor TOC building security, intercom communications with the receptionist and TOC control room entrances and exits.

Position Interrelationships: CSP dispatchers, ATMS/ATIS system operators, CSP communications supervisors.

Status: New hire or reassigned CSP personnel; full-time employee.

Start Date: Early 1995, when TOC is commissioned.

Staffing Sources: CSP, private sector consultant, CDOT Region 1, CDOT Region 6, CDOT HQ, CDOT/CSP joint hire.

4.3.5.3 ATMS/ATIS OPERATION

Position/Title: ATMS/ATIS System Operator

Functions/Responsibilities: The ATMS/ATIS system operator will be responsible for overseeing all monitoring and control functions of the TOC's ATMS/ATIS facilities. System operators would monitor traffic conditions via software graphical displays, incident detection algorithms and CCTV camera images. These positions would also be responsible for the generation or confirmation of VMS, HAR, RDS-TMC and telephone hotline advisory messages. In addition, the ATMS/ATIS operator will be responsible for monitoring the Denver area's weather information systems. During incident scenarios, the operators will assist in the detection, verification and response stages as well as in the selection of the appropriate alternate routing schemes.

Position Interrelationships: Media and traffic reporting services, CDOT Region 1 TOC Representative, CDOT Region 6 TOC Representative, city and county traffic engineers, TOC office supervisor, system engineer, RTD, CSP communication supervisors, CSP dispatchers.

Status: New hire; full-time employee

Start Date: Early 1995, when the TOC is commissioned.

Staffing Sources: CDOT Region 1, CDOT Region 6, CSP, CDOT/CSP joint hire, private sector consultant, private sector traffic information service.

4.3.5.4 DISPATCHING

Position/Title: CSP Communications Officer (Dispatcher)

Functions/Responsibilities: Each dispatcher is responsible for many activities. These include answering telephone calls from the public and other agencies, updating and maintaining information logs, operating the CCIC/NCIC criminal information computers, management of warrant records, abandoned vehicle records management, collection and dissemination of road/weather information, updating traveler information tapes, dispatching officers, dispatching wreckers, dispatching emergency response, operating the EIS computer, providing emergency or mutual aid communications with other agencies, acting as liaison between field officer and citizen, provision of news releases,and determination of appropriate jurisdiction and notification thereof for responses to various conditions.

Position Interrelationships: CSP officer in charge, CSP communications supervisors, ATMS/ATIS system operators, CSP call takers, TOC electronic technician.

Status: Existing CSP Employee.

Start Date: Early 1995; when TOC is commissioned. Continue in existing duties at existing locations until that time.

4.3.5.5 ENGINEERING

Prior to full TOC operations, an incident management engineer (IME) will be required to establish effective reactions to various types of incidents occurring at different locations and during different times of the day. Responses may include alternative diversion routes, required number and type of emergency vehicles, type and locations of VMS and HAR messages, and various other traffic control functions. These established responses will allow for the instant and proper response by an incident response team member, or eventually an expert system.

Position/Title: Incident Management Engineer (IME)

Functions/Responsibilities: This position's primary responsibility will be the organization and operation of the Denver Metro Area's incident management program. Functions of the IME should include pre-event incident planning and coordination with CSP, CLOT, city and county traffic engineering and police departments, as well as incident response teams (including courtesy patrols, corridor management teams, etc.), equipment procurement, and documentation of incident response plans and efforts for future evaluation. This position will be involved in all aspects of the incident management decision-making process within the Denver Metro Area.

Status: Reassignment or new hire, full-time employee

Start date: Early 1994; involved in TOC implementation process and incident management strategy formation.

Staffing sources: CDOT Region 1, CLOT Region 6, CLOT Headquarters, CSP, CDOT/CSP joint hire, private sector consultant

4.3.6 Courtesy Patrol

An individual responsible for management of the courtesy patrol functions should be permanently stationed at the TOC. This position will provide coordination between the Courtesy Patrol and incident management team, as well as administering the operations of the courtesy patrol field personnel (private contractors). This position is not envisioned to be a separate, full-time position, but instead will be within the functions/responsiblities of the incident management engineer.

4.3.7 Systems Integration

4.3.7.1 INTRODUCTION

Systems integration will be responsible for the proper operation of the hardware and software necessary to perform the functions of the TOC. This will include not only the effort required for initial TOC start up but ongoing equipment maintenance and software modifications.

4.3.7.2 SYSTEMS INTEGRATOR

Position/Title: TOC Systems Integrator

Functions/Responsibilities: This position would be responsible for developing and maintaining software to support data processing, traffic analysis and prediction, and traveler information aspects of TOC operations. The position would also be in charge of developing and integrating software and hardware systems which enhance information interface capabilities between control consoles, field equipment and other facilities such as distributed jurisdictional TICs and satellite TICS.

Position Interrelationships: ATMS/ATIS system operators, CSP dispatchers, call takers, CSP call takers, city and county traffic engineers, media and traffic reporting services, TOC office supervisor, CSP officer in charge, CSP communications supervisors.

Status: New hire; full-time employee.

Start Date: Early 1994; involved in TOC implementation and commissioning process.

Staffing Sources: CDOT Region 1, CDOT Region 6, private sector consultant.

4.3.7.3 TELECOMMUNICATIONS ENGINEER

The Division of Transportation Development within CDOT is hiring a telecommunications engineer to provide the expertise needed for the TOC and the statewide telecommunications support needed CDOT's IVHS program. This position will initially apprentice with the Division of Telecommunications prior to permanently occupying space within the TOC. After six to nine months of apprenticing, a permanent location will be needed in the TOC.

Position/Title: Telecommunications Engineer

Functions/Responsibility: The TOC will serve as the major communication hub for the state highway system within Colorado. It is essential that the communications engineer actively participate as an integral component in the development and expansion of the future CDOT statewide communications architecture. The communications engineer will be responsible for coordination with the Division of Telecommunications, establishing statewide IVHS communication links, and providing communications expertise to the TOC supervisor and Department personnel.

Position Interrelationships: TOC supervisor, CTI Researcher, CDOT Research Engineer, private sector personnel, TOC receptionist, CSP Communications Supervisor.

Status: In the process of being recruited.

Start Date: Opening day of TOC

Staffing Sources: CDOT

4.3.7.4 TOC ELECTRICIAN

Position/Title: TOC Electronic Technician

Functions/Responsibiities: This position would be responsible for maintenance and upkeep of the TOC computer system, communication/information interface system, operator consoles, power supply and any other electronic equipment or communication devices. It may be appropriate to staff this position during the TOC design and construction process to facilitate the transition from the interim to the permanent TOC.

Position Interrelationships: Systems engineer, TOC office supervisor, CSP communications supervisor, TOC field equipment maintenance, CSP dispatchers.

Status: Reassigned CDOT Region 1 or CDOT Region 6 personnel or potential new hire; full-time employee.

Start Date: Early 1994; involved in TOC implementation and commissioning process.

Staffing Sources: CDOT Region 1, CDOT Region 6, CDOT/CSP joint hire, private sector consultant.

4.3.7.5 EQUIPMENT MAINTENANCE

It is anticipated that CDOT will maintain the IVHS-related equipment associated with the TOC. This includes both in-house TOC computer systems and consoles (with services provided by the systems engineer and TOC electronics technicians} as well as its associated field equipment, hardware and software components and communications network infrastructure. While it is recognized that this is a significant undertaking, it is felt that CDOT should retain a high level of involvement within this area.

As the Denver Metro Area's IVHS program introduces new technologies and systems, they will require the necessary staff to support their correct maintenance. Additional training will therefore be required for CDOT maintenance personnel to perform these tasks. Initial support for these activities should be written into the equipment supply contracts for each system or technology selected. In turn, CDOT personnel will pass their knowledge to their colleagues with continuing support from the supplier.

This maintenance training will initially be time consuming and costly. However, familiarity with the system components and new technologies should develop over time for CDOT employees. In-house maintenance efforts should increase response time, provide more coordinated repair efforts and decrease maintenance costs. If the state retains maintenance responsibility from the program's inception, CDOT will be

able to progress and develop its region-wide operations with a regulated level of stability and quality. In addition, increasing the knowledge of its maintenance crews will enhance CDOT's role and reputation as a technology leader in the IVHS arena.

Position/Title: TOC Maintenance.

Functions/Responsibilities: This position will upkeep and maintain the Denver Metro Area's M-IS-related field equipment. This includes all signs, controllers, radio receivers and other hardware equipment, software and control operations as well as the associated communications infrastructure and other electronic field equipment or communications devices.

Position Interrelationships: CDOT Region 1 TOC Representative, CDOT Region 6 TOC Representative, CSP dispatch.

Status: Existing CDOT Region 1 and CDOT Region 6 maintenance crews with additional training.

Start Date: Early 1994; IVHS training and involvement in IVHS deployment process.

Staffing Sources: CDOT (note there is also potential for this position to be staffed by a private sector consultant).

4.3.8 Lane Closure Coordination

Roadway construction can have a significant adverse impact on traffic operations. For this reason, CDOT has long required permits to be issued for any construction on the roadway network. Lane closure coordination/permitting should be performed at the TOC to allow these "planned incidents" to be coordinated with the incident management team. This function will require two different positions as shown below.

4.3.8.1 LANE CLOSURE COORDINATOR

Position/Title: Lane Closure Coordinator

Function/Responsibility: This position will consist of three CDOT inspectors. Responsibilities will include reviewing/issuing construction and access permits (the same individuals are currently responsible for both types of permits).

Position Interrelationships: Incident Management Team, CDOT Region 6 Supervisor, CDOT Region 6 Scheduling Coordinator, TOC Receptionist

Status: Existing CDOT Region 6 employees, relocated to the Denver Metro Area TOC; full-time employee

Start Date: Not applicable (these are existing employees)

Staffing Sources: CDOT Region 6

4.3.8.2 LANE CLOSURE SUPERVISOR

Position/Title: Lane Closure Supervisor

Function/Responsibility: The responsibilities of this position will include coordinating all of the Denver Metro Area construction zone activities, scheduling with ATMS/ATIS operators and public information coordinators, and updating the CDOT construction telephone "hotline" and HAR messages.

Position Interrelationships: Incident Management Team, Lane Closure Coordinators, TOC Receptionist

Status: Existing CDOT Region 6 employees, relocated to the Denver Metro Area TOC; full-time employee

Start Date: Not applicable (these are existing employees)

Staffing Sources: CDOT Region 6

4.3.9 Research

4.3.9.1 INTRODUCTION

Representatives from the Colorado Technology Institute and the Colorado Department of Transportation Research Branch should have a permanent, unique station at the TOC for on-site transportation research and educational activities. The TOC will be a state-of-the-art traffic management facility which will be capable of integrating both research and operational functions in the same location. Immediate access to the TOC's information flow and state-of-the-art equipment is essential to the success and credibility of CTI as a nationally recognized research institute as well as the CDOT's IVHS development program.

4.3.9.2 CTI

Position/Title: CTI Researcher

Function/Responsibility: CTI will serve as a forum partner with academia to expand its existing research program by inviting expertise outside of CDOT to participate. CTI will also provide a training ground to educate students in traffic operations and possibly provide hands-on experience with traffic control systems. A position at the TOC will enhance CTI's ability to capture federal research funds in the growing field of IVHS research.

Position Interrelationships: TOC supervisor, TOC receptionist, private sector personnel.

Status: Personnel from CTI as projects in the area of IVHS/Traffic operations develop

Start Date: Opening of TOC

Staffing Sources: CTI

4.3.9.3 CDOT

Position/Title: CDOT Research Engineer

Function/Responsibility: CDOT Research personnel will expand their involvement in urban traffic modeling studies, traffic data collection, and the evaluation of systems technologies for improving transportation. On-site office space is essential to the development of a progressive research and development program in the area of IVHS and traffic control systems.

Position Interrelationships: TOC supervisor, TOC receptionist, private sector personnel.

Status: Personnel from the existing CDOT Research Branch personnel as projects in the area of IVHS/Traffic operations develop

Start Date: Opening of TOC

Staffing Sources: CDOT

4.3.10 Clerical/Reception

4.3.10.1 TOC RECEPTIONIST

Position/Title: TOC Receptionist

Functions/Responsibilities: This position will be responsible for all clerical duties at the TOC. These could include typing, filing, word processing, initial contact with visitors and communication with personnel in the TOC control room. An additional clerical/receptionist position would be required for CSP.

Position Interrelationships: TOC office supervisor, CSP supervisor, CSP officer-in-charge, CSP call takers.

Status: Reassigned CDOT (Region 1,6 or HQ) personnel, reassigned CSP personnel, or potential new hire; full-time employee.

Start Date: Early 1995, when TOC is commissioned.

Staffing Sources: CDOT Region 1, 6 or HQ, CSP, private sector consultant or temporary service.

4.4 Other Jurisdiction Participation

4.4.1 Introduction

In addition to the TOC staff discussed in the previous sections, other jurisdictions will have a presence, through electronic connection, physically, or a combination of the two, in the TOC. Electronic connections can be provided between City and County Traffic Engineering offices via means as simple as telephone drops allowing for voice and/or data transmission only or as complex as fiber optic or coaxial cable networks allowing for video, voice and data transmission. Presence, either electronically or physically, will allow the participation of any jurisdictions which may be affected by traffic incidents or the response to these incidents.

4.4.2 CDOT Region 1

Position/Title: CDOT Region 1 TOC Representative

Function/Responsibilities: This position will be responsible for coordinating CDOT Region 1 maintenance scheduling with CSP personnel, coordinating construction zone activities and scheduling with the ATMS/ATIS operators and public information coordinators, monitoring ramp metering and traffic control strategies (within their jurisdiction) and making adjustments when required, and monitoring the status of all field equipment within their jurisdiction. This position will also assist in the selection of alternate routing schemes, when appropriate. In addition, the position will handle dispatching efforts when CSP is unable to due to inclement weather or other circumstances.

Position Interrelationships: CSP dispatching, ATMS/ATIS system operators, private sector information services, CDOT Region 6 TOC Representative.

Status: Reassigned personnel from CDOT Region 1; full-time employee.

Start Date: Early 1995, when TOC is commissioned.

Staffing Sources: CDOT Region 1.

4.4.3 CDOT Region 6

Position/Title: CDOT Region 6 TOC Representative

Function/Responsibilities: This position will be responsible for coordinating CDOT Region 6 maintenance scheduling with CSP personnel, coordinating construction zone activities and scheduling with the ATMS/ATIS operators and public information coordinators, monitoring ramp metering and traffic control strategies (within their jurisdiction) and making adjustments when required, and monitoring the status of all field equipment within their jurisdiction. This position will also assist in the selection of alternate routing schemes, when appropriate. In addition, the position will handle

dispatching efforts when CSP is unable to due to inclement weather or other circumstances.

Position Interrelationships: CSP dispatching, ATMS/ATIS system operators, private sector information services, CDOT Region 1 TOC Representative.

Status: Reassigned personnel from CDOT Region 6; full-time employee.

Start Date: Early 1995, when TOC is commissioned.

Staffing Sources: CDOT Region 6.

4.4.4 City and County Traffic Engineers

Position/Title: Traffic Engineer

Functions/Responsibilities: These positions will be responsible for monitoring all signal system operations (e.g., in-effect dial, system status, etc.) for arterial, corridor and grid networks within their jurisdiction. Responsibilities would include optimizing and implementing the necessary traffic control strategies, monitoring the status of all field equipment and coordinating maintenance efforts. This position will also assist in the selection of alternate routing schemes, when appropriate.

Position Interrelationships: ATMS/ATIS system operators, CSP dispatchers, media and traffic reporting services, system engineer.

Status: Full-time employee; potentialy reassigned from participating jurisdictional agency as determined by agency.

Start Date: Early 1995, when the TOC is commissioned. Some local authorities may choose to relocate traffic engineers into the TOC at a later date.

Staffing Sources: Participating jurisdictional agency, private sector consultant.

4.4.5 RTD

Position/Title: RTD Representative

Functions/Responsibilities: This position will act as a liaison between the TOC and RTD. Duties may include coordinating transit scheduling information, the RTD audiotex system and other transit project information. This position will be responsible for incorporating APTS technologies and methods into RTD's service, as well as integrating these with other regional IVHS initiatives. In addition, the position will be responsible for coordinating RTD's GPS system with the TOC so that the express bus service's AVL capabilities can be used as probes. This position will build on initial coordination efforts begun earlier in 1992 between RTD and CDOT.

Position Interrelationships: ATMS/ATIS system operators, private sector traffic information services, TOC office supervisor.

Status: Potentially reassigned personnel from RTD as determined by RTD; full-time employee.

Start Date: Early 1996.

Staffing Source: RTD.

4.4.6 DRCOG

Position/Title: DRCOG Representative.

Functions/Responsibilities: This position will be responsible for coordinating the TOC's various interjurisdictional projects and efforts. This will include coordinating traffic control strategies between CDOT and city and county traffic departments. The position will be instrumental in the development of preplanned incident diversion routes and other incident routing schemes.

Position Interrelationships: CDOT Region 1 TOC Representative, CDOT Region 6 TOC Representative, city and county traffic engineers, TOC office supervisor.

Status: Potentially reassigned personnel from DRCOG as determined by DRCOG.

Start Date: Early 1994; involved in incident management program design efforts.

Staffing Source: DRCOG.

4.5 TOC Training

The Denver TOC will contain a multitude of staffing positions with various functions and responsibilities. Therefore, these staffing positions will need adequate training in order to perform their jobs in a capable manner. The control center staff should be knowledgeable of every system and console within the facility. This will be necessary to provide adequate back-up and redundancy levels in case of emergency situations, holidays, vacations, sick leave and employee departures. This philosophy could be expanded to include a merger of CSP-related positions and IVHS-related positions to create a fully integrated TOC staff.

Initially, all new employees and reassigned employees will start their training at a similar level of understanding. The training program will instruct these employees on all aspects of the appropriate dispatching, call taking, ATMS/ATIS, incident management and ATIS operating equipment in case an emergency or system failure requires their attention. This cross-training technique will produce multi-talented employees who can handle various functions of the TOC's operations. In addition, this cross-training should create

operational efficiencies as the employees become more familiar with their equipment and duties. Some staff savings may be achievable through this synergy.

To allow for the development of career paths, it is proposed that some positions utilize a rotational staffing scheme. This job-switching, say every four months, should keep employee interest and efficiency high, as well as reinforcing previously learned applications. The TOC should provide opportunities for career advancements within the facility. In addition, as new technologies and systems are brought on-line, existing TOC staff should be trained on their usage as well as considered for any newly-created positions. The Denver TOC should be cognizant of its employees' desires and seek to retain and promote highly motivated and skilled employees.

Overall, all TOC staff members should coordinate their activities to ensure an effective, efficient and seamless operation TOC staff should work together to learn from each other's individual responsibilities and requirements. This involvement and interaction between employees and staffing positions should develop better plans and procedures for the TOC's operations and prepare the way for future applications. If every member of the TOC staff feels that they are useful and important, a coordinated team approach will have been established.

4.6 TOC Implementation Phasing

4.6.1 Introduction

As noted previously, the Denver TOC should ideally operate 24-hours-a-day, 7-days-a-week. However, the ability to operate the TOC continuously is dependent in part on the size. of its staff, implementation phasing schedule and the availability of funds to cover their salaries. It is anticipated that the staff of the Denver Metro Area TOC will be built up over a period of time. This will allow staffing levels to be increased as new functions and services are implemented.

4.6.2 Interim

The TOC start-up phase (1993-1994) will include twelve new full-time employee positions, plus five reassigned full-time employees. Interim TOC positions will include two Incident Management Engineers - required to establish a good base of incident response plans, three Public Information Coordinators, a Systems Integrator, and eight dispatchers - to provide improved dispatch for CDOT maintenance. The systems engineer position will be filled toward the end of 1993 to assist in the equipment (hardware and software) and communications implementation, as well as the commissioning process. All positions required for the implementation of an interim TOC are shown in Table 4.1 - Interim TOC Staffing.

4.6.3 Short-Term

In early 1995, it is anticipated that the TOC's construction activities will be completed and most of the initial start-up equipment installed. It is assumed that the entire CSP consolidation will be complete, and ready to enter the TOC, at this time. Therefore, the TOC short-term operational phase (1995-1997) will include a total of 98 full-time

employees (17 of which were a part of the interim TOC). A breakdown of TOC staff positions are shown in Table 4.2 - Short-Term TOC Staffing.

Table 4.1 - Interim TOC Staffing

Position/Function	Total FTEs	Peak FTEs
Supervisors		
CSP Officer in Charge		
TOC Office	1	
CSP Communications		
Incident Management		
Call Taker		
Dispatcher	8 [2]	3
ATMS/ATIS Operator	-	-
Engineer	2	2
Public Information Coordinator	3	1
Systems Integrator	1	1
Telecommunications Engineer		
Electronics Maintenance		
Lane Closure Coordinator	1	1
Clerical		
CSP Clerk	-	-
TOC Clerk/Receptionist	1	1
TOTAL	**17** [3]	**10**

"Peak FTEs" is defined as the maximum number of FTEs present in the center(s) at any given time.

2 These employees are assigned to dispatch for CDOT maintenance only.

3 Twelve of these seventeen employees are new FTE's. Of the five existing FTE's. two (both maintenance) are from CDOT Region 1 and three (one maintenance, two traffic) are from CDOT Region 6.

Table 4.2 - Permanent TOC Staffing (Short Term)

Position/Function	Interim TOC Total FTEs	Existing CSP FTEs	Additional FTEs	TOTAL	Peak FTEs [1]
Supervisors					
CSP Officer in Charge	-		1	1	1
TOC Office	1	1 [2]		2	1
CSP Communications	-	9 [2]		9	3
Incident Management					
Call Taker	-	14 [2]		14	5
Dispatcher	8	34 [2]		42	12
ATMS/ATIS Operator	-		11	11	4
Engineer	2		2	4	2
Public Information Coordinator	3		-	3	2
Systems Integrator	1		1	2	2
Telecommunications Engineer	-		1	1	1
Electronics Maintenance	-		2	2	1
Lane Closure Coordinator	1		2	3	3
Clerical					
CSP Clerk	-	2 [2]		2	2
TOC Clerk/Receptionist	1		1	2	2
TOTAL	**17**	**60**	**21**	**98**	**42**

[1] "Peak FTEs" is defined as the maximum number of FTEs present in the TOC at any given time.

[2] These employees are existing CSP in Lakewood, Limon, Greeley, Sterling, and Hot Sulphur Springs.

[3] These FTEs will be added as required.

In addition, there are other potential TOC positions whose staffing levels have not been identified. These include the city and county traffic engineers, CDOT Region 1 representatives, CDOT Region 6 representatives, RTD personnel and the DRCOG representative. In most cases, however, it is anticipated that each position will require one reassigned full-time employee.

4.6.4 Medium-Tern

By the medium-term operational phase (1998-2001), it is anticipated that the majority of the TOC's initial features will have been commissioned and the appropriate staff employed. Since the TOC's functions will be built up over a period of time, staffing levels will need to be increased to reflect the expanding service base and additional technologies.

Within the medium-term operational phase, the newly-created TOC full-time employee positions outlined in the previous sections will expand their roles and responsibilities along with their scope of coverage. A breakdown of TOC staff positions are shown in Table 4.3 - Medium-Term TOC Staffing.

4.6.5 Long-Term

The long-term operational phase (2002 and beyond) holds many possibilities for implementing new systems and technologies. However, it is anticipated that a number of automated functions and expert systems will be fully operational within this time period. These automated support functions will potentially decrease the need for additional staff, and may even reduce the total staffing requirement. In addition, the TOC's cross-training and rotational schemes will produce an efficient and multi-functional staff. Therefore, no significant staffing increases are expected for the TOC's long-term operations.

Table 4.3 - Permanent TOC Staffing (Medium-Term)

Position/Function	Short-term TOC Total FTEs	Additional FTEs	Other FTEs[3]	TOTAL	Peak FTEs [1]
Supervisors					
CSP Officer in Charge	1			1	1
TOC Office	2			2	2
CSP Communications	9	-	-	9	3
Incident Management					
Call Taker	14	2 [2]	18 [3]	34 [3]	12 [3]
Dispatcher	42	-	31 [3]	- 73 [3]	22 [3]
ATMS/ATIS Operator	11	6 [3]	-	17 [3]	6 [3]
Engineer	4	-	-	4	2
Public Information Coordinator	3	1	-	4	2
Systems Integrator	2			2	2
Telecommunications Engineer	1			1	1
Electronics Maintenance	2	2		4	2
Lane Closure Coordinator	3	-		3	3
Clerical					
CSP Clerk	2			2	2
TOC Clerk/Receptionist	2	-		2	2
TOTAL	98	11	49	158	51

[1] "Peak FTE's" is defined as the maximum number of FTEs present in the TOC at any given time.

[2] Two of these additional call takers are dedicated to CDOT *77 and *DUI.

[3] These FTE's are based on estimates of the level of participation from wildife, revenue, corrections, and other local Jaw enforcement agencies. If this level of participation is not achieved, this number of people will not be required. (Note: These FTEs may be reassigned from the participating agencies.)

5.0 SYSTEM ARCHITECTURE

5.1 Introduction

One major issue in planning and design of a TOC is the need for a system architecture to guide development, decision-making, construction, and implementation. An architecture provides the framework around which the detailed system design, specifications, and interfaces can be defined. All M-IS systems have an architecture, whether or not this was defined prior to implementation. Complex systems developed without a predefined architecture have been shown to be difficult to maintain, difficult to modify, and inflexible.

FHWA has initiated studies to develop a nation-wide systems architectun for operations centers of this kind. The outcome of these studies will likely result in the institution of various Federal regulations and guidelines which CDOT should be prepared to address. CDOT should maintain close coordination with FHWA during the TOC design to ensure compatibility with the future national architecture.

Through the course of this study, CDOT has consistently indicated the desire for flexibility and modularity within the TOC so that system growth or changes in technology can be accommodated in the easiest possible manner. Since growth and technological change have been constant during the short history of IVHS, the flexibility component of the TOC should be considered a critical and mandatory requirement for the Denver area facility. A well developed system architecture will provide a TOC with the necessary flexibility.

5.2 "Open" Configuration

The Denver area is pursuing the deployment of a TOC relatively early in the development of IVHS systems in the United States. As a consequence, the system architecture defined for the Denver TOC will almost certainly require updating over the course of the upcoming decade. One key factor in minimizing the difficulties inherent in system modifications or upgrades is the standardization of system operating parameters and interfaces in order to have the capability to change various modules of the system without having to replace or adjust other non-related modules at the same time.

Open architecture defines non-proprietary standards for various system operating parameters and interfaces. Not only does the open system encourage a more flexible TOC (also encouraging a competitive bidding process as most system components can be supplied by a variety of manufacturers), it also helps to maintain modularity. Use of the appropriate standards will allow compatibility with new products and services in the future, ensure the quality level of the product, and will allow easy links to other TOCs which use the same standards. Although additional standards will likely be developed over time, CDOT will use, as a minimum, the following in planning the Denver area TOC.

5.2.1 Standards

Whenever possible, CDOT will apply existing standards to guide the development of the Denver area IVHS systems. These will include standards in:

- Telecommunications.
- Video equipment.
- Software.

FHWA anticipates that numerous other standards will be influenced by or specifically defined for IVHS applications in the United States (Reference 4). These might include standards for:

- Map database formats.
- Mobile communications standards.
- IVHS-specific frequency assignments.
- FM subcarrier data formats.
- AVI standards.
- Safety standards for in-vehicle human interface.
- General AVCS applications.
- Message formats between IVHS subsystems.

Several general communications standards already exist and will definitely be used to guide the development of the Denver area TOC's architecture. These are described in the following sections.

5.2.2 OSI

Open Systems Interconnection (OSI) is a standard hierarchy of communications protocols developed to promote standardized interfaces between otherwise incompatible systems. Advantages of OSI include the support of inter-operation of diverse equipment designs and manufacturers and the allocation of functions to separate system layers, allowing easier software development and maintenance (Reference 4). OSI is really meant to apply to computer-to-computer needs within the TOC.

OSI defines a common set of rules and procedures to facilitate efficient data communications, and avoid communication incompatibilities between subsystems. OSI was originally developed as a cost saving measure to reduce development, procurement, support, and maintenance costs for computer systems. Advantages of OSI include widespread support in industry and government, off-the-shelf hardware and software, and "layered" architecture allowing insulation of various functions so that individual layers can be updated without affecting other layers and functions.

5.2.3 POSIX

Portable Operating System Interface (POSIX) describes a standardization effort to define a buffer between the mainframe computer and the system operating software. Simply stated, application of the POSIX guidelines in the design would allow CDOT the future flexibility to change out the TOC mainframe computers without facing the added expenditure of new software if the new mainframes were manufactured by a different

company than the originals. Multiple hardware and software vendors can be brought into the implementation process while future compatibility is achieved.

POSIX does not at present describe an accepted standard but a standardization effort. CDOT should closely monitor the currently developing POSIX standards and their potential incorporation into the TOC. At present, there is no guarantee that POSIX will achieve the goal of acceptance as a universal standard.

5.2.4 SONET

Synchronous Optic Network (SONET) provides standards for fiber optic communications. Primary IVHS applications are for transmission of real time video. Advantages of using the SONET standards include compatibility with multiple vendors, lower costs, hardware interchangeability, redundancies, easier maintenance, simplified multiplexing, and standardized optical rates and formats (Reference 4), and true interconnectivity between fiber vendors.

Other benefits of SONET include a virtually unlimited capacity for switching voice, data, video, and image traffic; synchronization of all signals to the same clock source; efficient multiplexing and demultiplexing; lower costs and redundancies. Hardware interchangeability allows for multiple vendors. Widespread use of SONET equipment is not expected until 1994, however SONET-ready equipment is currently available.

5.3 Architecture Development

FHWA suggests that the development of a system architecture is an iterative process (Reference 3). The initial steps include definition of IVHS goals and identification of potential solutions to address the goals. This process has already been completed for the Denver area IVHS program and the results are summarized in the Strategic Plan document. Potential solutions are then organized into functional groups, in order to evaluate the interrelationship between the various activities. FHWA has identified the following functions as typical for IVHS programs:

- Surveillance.
- Communications.
- Traveler interface.
- Control strategies.
- Navigation/guidance.
- Data processing.
- In-vehicle sensors.

Some of the strategic plan activities identified did not appear to be appropriate for any of the above categories, so four additional project functions were added to specifically interface with the Denver Area Strategic Plan. These were:

- Incident management.

- Alternate mode interface.
- Dispatching.
- Program management.

The strategic plan activities have been summarized and compared to the list of functions in Table 5.1. Timeframes for the implementation of these activities are discussed in Chapter 3 of this document, as well as in the Strategic Plan and Master Plan.

The next step would be to consider all of the activities within a certain functional group, such as the surveillance category. The surveillance group would be analyzed to determine TOC requirements, field requirements, communication requirements, computing requirements, and so on. Thus an "Architecture" for the surveillance function is initially formed. Iterations to fine-tune the requirements are carried out as often as needed to achieve an acceptable result. Similarly, the process is also carried out for traveler interface and the remaining functional categories, and gradually an overall system architecture begins to take shape.

System architecture should be 'completely analyzed and discussed as an early action activity in the preliminary design process for the TOC.

PROJECTS	FUNCTIONS										
	Surveillance	Communications	Traveler Interface	Traffic Control	Navigation/Guidance	Data Processing	In-Vehicle Systems	Incident Management	Alternate Mode Interface	Dispatching	Program Management
5.1 Objective #1 - Provide Focal Point											
5.1.1 TOC	●	●	●	●	●	●	●	●	●	●	
5.1.2 Demonstration Corridor	●	●	●	●	●			●	●		
5.1.3 TOC Expert System						●		●			
5.2 Objective #2 - Improve Data Collection											
5.2.1 Real-Time Volume/Speed	●			●				●			
5.2.2 Advanced Arterial Surveillance	●			●							
5.2.3 Dial-in Data Collection	●							●			
5.2.4 CCTV Coverage	●							●			
5.3 Objective #3 - Develop Computerized Systems											
5.3.1 TOC Database Integration						●		●			
5.3.2 TOC Data Fusion						●		●			
5.3.3 Maintenance Fleet Management	●									●	
5.4 Objective #4 - Improve Incident Detection/Response											
5.4.1 Incident Detection/Management	●	●		●				●			
5.4.2 Cooperative TV/Radio Exchange	●		●					●			
5.4.3 Public/Private Dispatch	●							●		●	
5.4.4 Pre-Planned Diversion Routes								●			
5.4.5 Emergency Service Dispatch					●			●		●	
5.5 Objective #5 - Region-Wide Communications Network											
5.5.1 Temporary Communications		●									
5.5.2 Permanent Communiations		●									
5.5.3 Communication Links to Other Centers		●			●			●		●	
5.6 Objective #6 - Disseminate Travel Information											
5.6.1 HAR			●		●		●	●			
5.6.2 VMS			●		●			●			
5.6.3 RDS			●		●		●	●			
5.6.4 Teletext/CATV			●		●				●		
5.6.5 Videotex			●						●		
5.6.6 Audiotex			●						●		
5.6.7 Dynamic Route Guidance			●		●		●	●			
5.6.8 Electronic Signage			●		●		●	●			
5.6.9 Automatic Speed Control			●	●	●		●	●			

PROJECTS	FUNCTIONS: Surveillance	Communications	Traveler Interface	Traffic Control	Navigation/Guidance	Data Processing	In-Vehicle Systems	Incident Management	Alternate Mode Interface	Dispatching	Program Management
5.7 Objective #7 - Traffic Control System											
5.7.1 Expanded Ramp Metering	●			●							
5.7.2 Advanced Isolated Control				●							
5.7.3 Reversable Lanes				●							
5.7.4 Adaptive Control				●				●			
5.7.5 Air-Quality-Responsive Control				●							
5.7.6 Fourth Generation Control				●							
5.8 Objective #8 - Reduce Demand/Alternate Modes											
5.8.1 Rideshare Management									●		
5.8.2 HOV Occupancy Vertification							●		●		
5.8.3 Demand Management									●		
5.8.4 Smart Cards									●		
5.8.5 Transit Vehicle Status							●		●		
5.8.6 CDOT/RTD/DRCOG Partnership			●					●	●		●
5.9 Objective #9 - Project Management System											
5.9.1 Program Management											●
5.9.2 Marketing/User Acceptance			●								●
5.9.3 Standardization		●			●	●	●				●
5.9.4 Program Review/Redirection											●
5.9.5 Public/Private Partnerships	●	●			●		●				●

6.0 TOC LAYOUT

6.1 Functional Requirements

The TOC should be designed to operate as a multi-use, multi-jurisdictional information complex with sufficient building space available for expansion and growth. This will involve areas for system control and dispatch, maintenance of electronic equipment, and general office space. Functional and spatial requirements for the TOC can be based upon the following operations and characteristics:

- Freeway traffic management.
- Incident management.
- City and County traffic management.
- Signal system interface with distributed traffic information centers,
- Media (TV, radio) interface and public relations.
- Integrated dispatch functions (CSP, CDOT, Courtesy Patrols, etc.).
- 911, *DUI, and *77 call takers.
- Other enforcement and emergency response functions.
- Equipment and communications maintenance.
- Office and visitor area.
- Maintenance and construction permitting area.
- Nor&h I-25 Bus/HOV TMS.
- Ramp metering system.
- Data processing requirements.
- Interface with RTD systems.
- Weather information systems.
- RTD/other transit/rideshare databases.
- Communications with other jurisdictions.
- Communications with other centers.
- Traveler information systems.
- Requirements for in-vehicle systems.
- TOC administrative requirements.
- Denver area IVHS program management.

A primary objective in considering the TOC layout is to provide a location of sufficient size and utility to allow participating agencies to coordinate and manage all aspects of the system's ATMS, incident management, and ATIS functions. A more comprehensive list of TOC functions appears in Figures 1.1 and 1.2. During the TOC design process, CDOT should work with other Denver area agencies to define these functions in greater detail.

6.2 TOC General Layout

6.2.1 Introduction

A fully-functional TOC must be designed to incorporate all proposed traffic-related services as well as addressing managerial, business and personal requirements. Some

specific areas or rooms that can be considered for inclusion in the Denver Metro Area TOC include:

- TOC control center (dispatch, call taking, ATMS monitoring and control, etc.).
- Computer room.
- Conference rooms.
- General office space.
- Reception area.
- Kitchen area.
- Restrooms, locker, and shower facilities.
- Storage area.
- Visitor viewing area.
- CSP command center, including a "war" room.
- CSP EIS area.
- Maintenance and construction permitting area.
- Media liaison office and meeting area.
- Road and weather information center (including HAR, telephone hotlines).
- Garage area for storage of CSP command vehicles.
- Building/grounds maintenance area.

A key consideration in the development of the Denver TOC's overall floorplan layout is the determination of the interrelationships between the various areas or moms listed above. Figure 6.1 provides a graphical depiction or "bubble diagram" which shows these physical interrelationships for the entire TOC family. Within Figure 6.1, each circle (or bubble) represents a physical area, mom or group of rooms that should be considered for inclusion within the Denver TOC. In addition, each arrow in Figure 6.1 highlights a physical interrelationship between these areas.

Figure 6.1 provides a preliminary overview of the Denver TOC's physical interrelationships as they apply to the facility's overall, day-to-day operations. It should be noted that this has been included only for purposes of illustration and discussion, and is one of several approaches that could be used for the TOC. To further this bubble diagram concept (as well as the TOC's overall floor plan layout), a questionnaire has been developed which addresses the space, functional and environmental needs for the Denver TOC as a whole.

Successful arrangement of the areas shown in Figure 6.1 will allow a smooth flow of operations to proceed in and from the TOC. The final floor layout will be determined during detailed design work as the effort progresses. Some of the rooms listed, particularly those associated with CSP, will need to be in a secured area so that the public and media cannot routinely access them. Again, sufficient floor space needs to be provided to allow for expansion and growth.

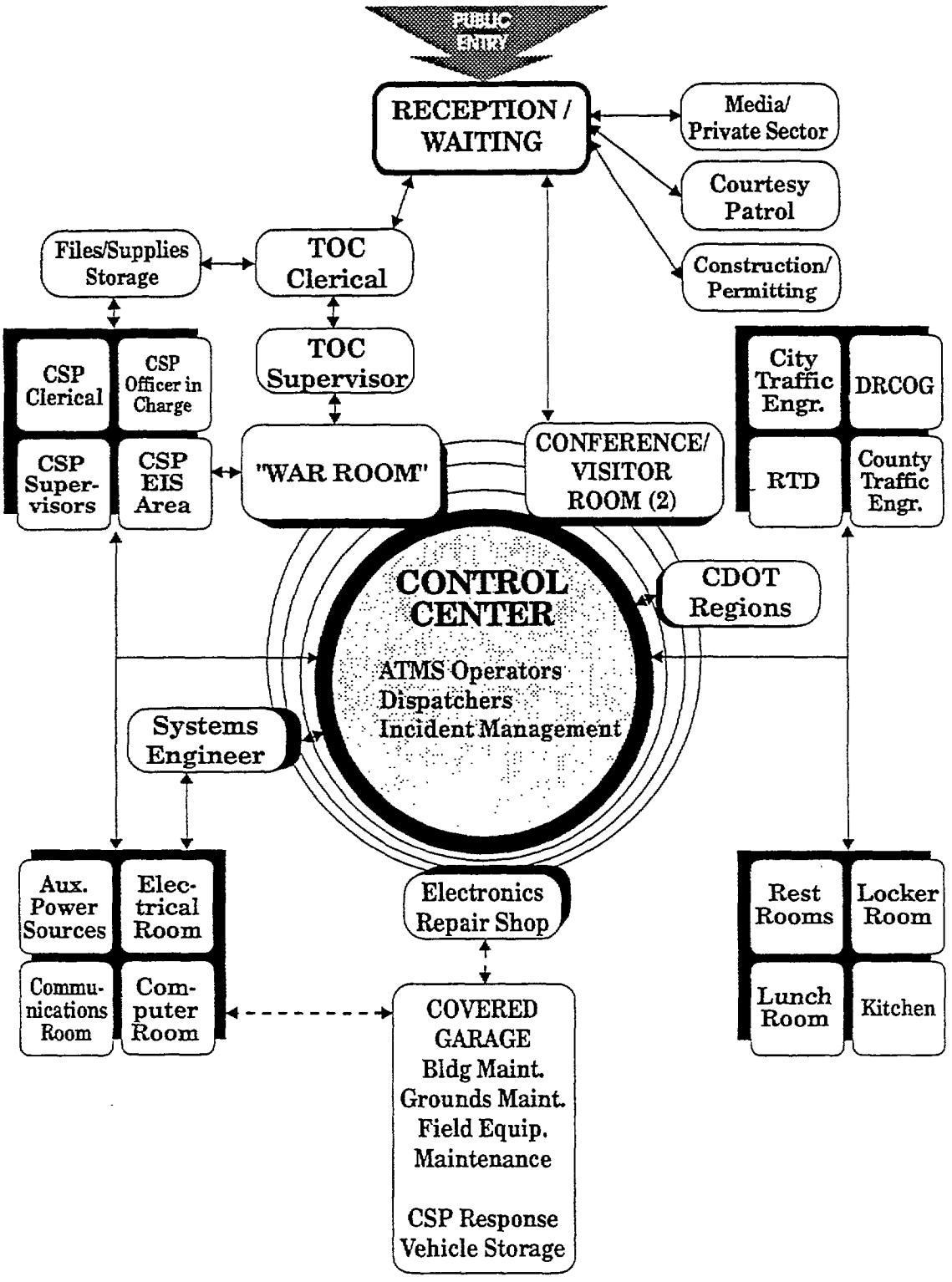

Figure 6.1 TOC Conceptual Layout

6.2.2 TOC Control Center

Control Center Layout

The TOC control center is expected to become the hub of the Denver Metro Area's ATMS operations and CSP's dispatching operations, as well as supporting dissemination of traveler information. Since the control center is concerned with all traffic-related activities, its layout and associated functionality is a particularly important aspect of the TOC design. Some areas that the control center could provide include:

- ATMS/ATIS operator consoles.
- CSP dispatch consoles.
- Emergency telephone consoles.
- CCTV camera displays.
- Large-scale projection screen display.
- Space for independent micro-computers.
- Printer, fax and photocopying area.

An important consideration in the development of the Denver TOC's control center layout is the facility's functional interrelationships between the various identified personnel positions. Figure 4.1 provided a bubble diagram which showing the essential position/functional interrelationships with the TOC's control center, while Figure 4.2 provided a conceptual organization chart for positions within the TOC in general.

Consideration is given within Figure 4.1, Figure 4.2, Figure 6.1, and the questionnaire to the need to support each position/functional interrelationship between personnel working at the various consoles through close, personal interaction or through electronic communications. Visual, voice, and electronic communications during routine operations, and most importantly during incident responses, will be enhanced by a well thought out and efficient allocation of space and positioning. In addition, this process will identify the informational exchanges (inputs and outputs) between each position or console.

Another key issue to address concerns the type of equipment to be selected for each controller's console. This selection process must be closely coordinated throughout the control center's operational area, to allow users to switch between consoles if required.

At this early stage of the planning process, it is not appropriate to finalize either the number of control stations or their arrangement. As the detailed TOC design effort proceeds, a more comprehensive analysis will be performed to determine final recommendations in this area. However, options for control center consoles and their associated operations are presented in general terms in the following sections.

ATMS/ATIS Operator Consoles

Consoles that support the ATMS/ATIS functions of the TOC should be similar for all the ATMS/ATIS operator stations. These interface subsystems would support review and control of the interaction between the main computer system and all field operations. The ATMS/ATIS operation consoles will likely be custom-built for the Denver Metro Area TOC, providing dedicated work stations to incorporate all of the required functions and services.

Each ATMS/ATIS operation console could include:

- Interactive keyboard communication with the main computer for ATMS/ATIS control.
- CCTV control and video switching.
- Telephone panel and dedicated hotlines.
- Radio transmitter and receiver control panel.
- Automatic incident detection alarm.
- VMS, HAR and ATIS equipment control.
- Color CRTs for textual and graphical information displays.

The ATMS/ATIS operator consoles should have priority over the CCTV monitors and the large-scale wall or screen display. Final console layouts and components will be determined during the detailed TOC design effort.

CSP/CDOT Integrated Dispatch Consoles

Integrated dispatching functions will be administered from the TOC using appropriate consoles. These will be defmed in cooperation with CSP as the detailed TOC design proceeds. It is anticipated that the dispatch console would be capable of accessing ATMS and ATIS system status data but not controlling these functions when an ATMS/ATIS operator is present. Each dispatch console could include the following:

- Radio transmitter and receiver control panel.
- Telephone panel and dedicated hotlines.
- Mobile radio scanner and receiver panel.
- Interactive keyboard communication
- CRTs for textual and graphical information displays.

These may be located in a room separate from, but electronically linked to, the ATMS/ATIS consoles.

Call Taking Console

This operation console could be designed for use with both emergency phone call boxes and cellular phone (911, *DUI, and *77) services. This would provide a single point for all telephone communications with the motoring public. Some operating systems that this console could provide include:

- Telephone switchboard with dedicated hotlines.
- TOC and control room intercom system.
- TOC and control room security monitoring.
- Interactive keyboard communication
- CRTs for textual and graphical information displays.

These may be located in a room separate from, but electronically linked to, the CDOT consoles.

Traffic Engineer Console

The possibility exists that some cities or counties in the Denver Metro Area may want to support their operations through placement of a traffic engineer within the TOC. Suitable consoles should be provided for this purpose if required. These would support all traffic system monitoring, status review and control operations within appropriate jurisdictional areas. Each console could include:

- Interactive keyboard communication with the traffic system network.
- CRTs for textual and graphical information displays.
- General use multi-function telephone.

Systems Integrator Console

The responsibilities of the systems engineer require an elaborate network of system and communication interface capabilities. Therefore, the console provided for this purpose should provide access to all operations of the TOC. However, control of any ATMS or ATIS functions would be possible only at the ATMS/ATIS operator's discretion. This would generally occur during off-peak periods to test or implement any new systems or recent system enhancements. The systems engineer console should be similar to the ATMS/ATIS operator's console, with the control functions disabled unless specifically activated. This precaution should prevent interference or disruptions within the control center should any new systems develop problems during trial runs.

Media Work Station

This console would display information on Denver Metro Area travel conditions to a public information coordinator. The console would also serve as a back-up to an automatic traffic information dissemination system should this service go off-line. It should be capable of accessing all ATMS, ATIS and incident information. Control functions at this console should be limited to those which relay data to the media. The console could include:

- CCTV control and video switching.
- Interactive keyboard communication
- CRTs for textual and graphical information displays.
- Telephone panel and dedicated hotline.
- Radio transmitter and receiver control panel.
- Radio and television monitors (to allow verification of disseminated information).

The public information coordinator would have CCTV camera selection control for the console TV screens, but not for the main CCTV display area. This control panel should be designed so that it can be easily upgraded to an additional ATMS/ATIS operator's console if needed at a later time.

RTD Work Station

It is possible that RTD will want to support its transit operations in the Denver area through placement of a representative within the TOC. Suitable consoles should be provided for this purpose if required. This position will act as a liaison between the TOC

and RTD. Duties may include coordinating transit scheduling information, the RTD audiotex system, and other transit project information. Each console could include:

- Interactive keyboard communication with the RTD system network.
- CRTs for textual and graphical information displays.
- Audiotex information generation capabilities.
- Data and communication links with GPS and AVL components of transit fleet.
- General use multi-function telephone.

CDOT Workstations

Representatives from CDOT Region 1 and Region 6 will most likely be provided separate operations consoles for their activities. Each CDOT representative will be responsible for managing ramp metering and traffic control strategies including VMS, and monitoring the status of all field equipment within their jurisdiction. These consoles will be capable of accessing ATMS and ATIS system status and management of the appropriate activities with the their jurisdictions. Each console could include:

- Interactive keyboard communication with ramp metering system.
- Radio transmitter and receiver control panel.
- Telephone panel and dedicated hotlines.
- Mobile radio scanner and receiver panel.
- CRTs for textual and graphics information displays.
- CCTV control and video switching.

CCTV Camera Displays

CCTV displays should be incorporated into the design of the TOC control center to take advantage of cameras installed on the I-25 HOV facility and other subsequent locations. However, due to the relatively low number of cameras and the labor-intensive effort associated with reviewing video screens, a large number of displays is not considered necessary.

CCTV control would be available at any of the ATMS/ATIS consoles. The ATMS/ATIS operators should have the ability to select and control any camera and switch its output to any monitor. It may further be desirable to use an automatic scanning process to assist the operators in some of these control functions. CCTV displays should be viewable on any monitor screen which is manually or automatically selected, as well as having the capability to be relayed to the large projection screen display and any console CRT. Video taping capabilities should also be available when needed.

Large-Scale Projection Display

Many current TOCs or similar facilities in the U.S. use static wall maps to display network conditions and highlight congestion. While these are useful, they are limited in their ability to show different scales or data. Therefore, more advanced techniques can be considered for use in the Denver Metro Area TOC. One option is the use of a large-scale projection display capable of performing a variety of functions.

Projection screen television has the potential to offer many advantages in providing visual displays to the TOC staff. These displays could show traffic information on a range of scales, from a single intersection to system-wide. In the longer-term, the equipment could display computer simulations of traffic conditions under different management strategies. Inevitably, the utility of these displays would depend on the software packages that develop the graphics.

The projection screen would be located within the control center for easy viewing by the TOC staff and any visitors. Both system software graphics and CCTV displays could be viewed from this screen. The ATMS/ATIS operators would control the display according to current traffic conditions.

Support Facilities

Other areas within the control center should provide space for all support facilities. These facilities may include printers, fax machines, photocopying machines and any other desired equipment.

6.2.3 Computer and Equipment Room

All TOC computers and related support equipment should be housed in a confined area near to the control center. This should contain the central computer plus all other individual functional computers (e.g., VMS, HAR, ramp metering, operator consoles, etc.). All interface equipment, data storage and other related support equipment should also be located within this area.

6.2.4 Conference Roomsl' War" Room

Conference rooms should be considered for the final layout design to accommodate various TOC functions. These could include internal TOC staff meetings, training sessions, multi-jurisdictional and interagency meetings, public observation activities and emergency operations coordination. A "war" room with communication and operations interfaces should also be provided to coordinate traffic agency and jurisdictional information during major incidents. CSP's EIS facilities should be among those electronically linked to consoles in the war room. An interactive operator's console located in one of the conference rooms could be installed to provide convenient direct operator interface during emergency situations as well as for training exercises and visitor viewing.

6.2.5 CDOT and CSP General office Space

The TOC layout should provide sufficient office space for the control room staff as well as for other necessary administrative and support staff. More detailed office space requirements will be determined through coordination with CDOT and CSP as the TOC design process continues.

6.2.6 Other Space Requirements

Other space requirements for the TOC may include the following:

- Electronics and maintenance area.
- Reception and clerical area.
- Kitchen and lounge area.
- Restroom and shower facilities.
- Storage area.
- Visitor viewing area.

6.2.7 TOC Overall Space Requirements

The previous sections within this chapter have highlighted the Denver TOC' s functional and spatial requirements based upon the initially desired operations and characteristics. A primary objective in considering the Denver TOC's layout is to provide a location of sufficient size and utility to allow participating agencies to coordinate and manage all aspects of the TOC's, ATMS, incident management, and ATIS functions. Table 6.1 provides a preliminary overview of the Denver TOC's spatial requirements as they apply to the facility's overall, day-to-day operations. This has been included for purposes of illustration and discussion, and will be subject to refinement to more precisely meet the needs of the TOC users, while allowing for further expansion. The final floor layout and its associated spatial requirements will be determined during detailed design work as the effort progresses.

The total usable building floor area for this facility is approximately 32,600 square feet. It will be noted from Table 6.1 that, of the usable building area, about 15% is for CDOT use, 23% of this area is for CSP use, 4% is for other jurisdiction use, while the remaining 58% is for the joint use of CDOT and CSP staff. Much of this joint use area would be duplicated if CDOT and CSP facilities were not combined (e.g., computer room, electronics maintenance shops, communications room, kitchen, lunch room, building/ground maintenance area would be required for each facility).

In conjunction with relocation to the TOC, the CSP will begin providing additional services for various agencies, including the Department of Wildlife, Department of Public Safety, State Corrections, and, of course, CDOT. These additional services will allow for greater overall efficiency for several State divisions. For example, if CSP did not provide dispatching services for these agencies, additional FTE's, as well as building space, would be required.

Existing TOC's throughout the world vary greatly in scope of operation and, thus, building size. The closest TOC in function to the proposed Denver facility is the San Antonio TOC. This facility has a total usable floor area of approximately 26,600 square feet. It should be noted that the San Antonio facility does not contain State Patrol functions as in the proposed Denver TOC. In the Denver TOC, the CSP will occupy about 7,500 square feet. If a similar function were contained in San Antonio's TOC, the total useable floor area would increase to approximately 34,100 square feet. This floor area would be slightly larger than the proposed Denver TOC.

Table 6.1 - Denver Area Traffice Operations Center Space Requirements

Space/Function		
CONTROL CENTER		
Communications Supervision	10 offices	1,250
Call Taking	12 workstations	780
ATMS/ATIS Operation	6 workstations	450
Dispatching	22 workstations	2.200
Weather Information	1 workstation	75
Emergency Information	2 workstations	150
Systems Integrator	2 workstations	600
Projection/Viewing		4,000
Printer, FAX, Photocopy		75
Halls and Aisles	(20% of subtotal)	1,916
Expansion Area	(15% of subtotal)	1,437
	Control Center Subtotal:	12,933
"WAR ROOM"		600
STAFF OFFICES		
CSP Officer in Charge	1 office	200
TOC Supervisor	1 office	200
Public Information Coordinator	2 offices w/ workstations	300
Incident Management Planning	4 offices	500
Telecommunications Engineer	1 office	125
General Offices		
CSP	3 offices	375
CDOT Operations/Maintenance	3 offices	375
Lane closure Coordinator	3 offices/general area	1,200
CDOT Research	1 office	125
CSP Clerical Area		300
TOC Clerical Area		225
Halls and Aisles	(20% of subtotal)	785
Expansion Area	(15% of subtotal)	589
	Staff Offices Subtotal:	5,299

Table 6.1 - Denver Area Traffic Operations Center Space Requirements

OTHER PARTICIPANT OFFICES		
Other Representatives as Necessary	6 offices	875
Halls and Aisles	(20% of subtotal)	175
Expansion Area	(15% of subtotal)	131
Other Participant Offices Subtotal:		1,181
SPECIAL SPACE REQUIREMENTS		
Computer Room		1,250
Electronics Maintenance Shop		1,250
Communications Room		500
Electrical Room		250
Conference/Media/Visitor Rooms	3 rooms	1,500
Halls and Aisles	(20% of subtotal)	950
Expansion Area	(15% of subtotal)	713
Special Space Requirements Subtotal:		6,413
MISCELLANEOUS SPACE REQUIREMENTS		
TOC Reception Area		600
Locker Room/Check-In Room		400
Kitchen		240
Lunch Room		1,000
Supply/File Needs		400
Building/Grounds Maintenance Area		200
Response Vehicle Storage		1,000
Halls and Aisles	(20% of subtotal)	768
Miscellaneous Space Requirements Subtotal		4,608
TOC BUILDING SUBTOTAL		31,034
Auxiliary [storage, restrooms, etc.]	6% of subtotal)	1,552
TOTAL BUILDING USABLE FLOOR AREA		32,586
Control Center "Airspace"	(2/3 control center area)	8,622
TOTAL BUILDING FOOTPRINT		
l/2 Usable Floor Space + Airspace	(two story building)	20,604

7.0 TOC LOCATION

7.1 Introduction

The TOC is intended to provide a focal point for the collection, management and dissemination of all traffic-related data, and subsequent initiation and coordination of control actions. These functions are the primary responsibility of the TOC and will be performed by the appropriate staff with the most comprehensive traffic management and communication tools at their disposal. It is important, therefore, that sufficient attention is given to selecting a location for this facility, recognizing the impacts that this choice may have on its functions and efficiency.

This section establishes the rationale for general TOC location, describes general site requirements, proposes a site evaluation process, identifies vacant land and a sample of for-sale buildings within the siting corridor, and presents a preliminary evaluation of the suitability of potential sites identified to date.

7.2 Location Area Boundaries and Basic Site Requirements

The universe of potential sites for the TOC is broad. To focus the process of sire selection on those factors most important to the success of the TOC, a review of several general location criteria is necessary.

Most of the proposed IVHS functions planned for the TOC rely very heavily on electronic communications. A TOC location which is near the corridors with high communications requirements can decrease the cost of communications substantially. While the TOC will ultimately serve many and varied IVHS technologies on both the freeway and arterial systems throughout the Denver region, the technologies initially tied to the TOC are focused within the I-25 corridor. The North I-25 HOV lane project currently under construction will require a great amount of communications to function. Underground conduits located adjacent to the I-25 roadway are planned to serve these requirements. The further the TOC is located away from the North I-25 HOV lane project, the more costly the initial communications connection to the TOC will become.

Specific IVHS technologies have not yet been identified for future installation in specific corridors. However, it is likely that the high volume freeway corridors will be the first to implement IVHS technologies. Therefore I-25 and I-70, in the central portion of Denver, two of the City's most traveled freeways, are likely to be among the first to implement additional IVHS projects. A location close to the intersection of these facilities is thus likely to minimize communication connection costs associated with the initial installations.

The multijurisdictional nature of the TOC functions, user accessibility, and media access would be well served by a central location. For these reasons, it is recommended that the list of potential TOC sites include I-25 from Speer north to U.S. 36 and I-70 from Pecos to Washington. This will assure a site which meets many of the criteria associated with a central location. The primary study area for the location of the TOC is shown in Figure 7-l.

TOC Primary Location Study Area

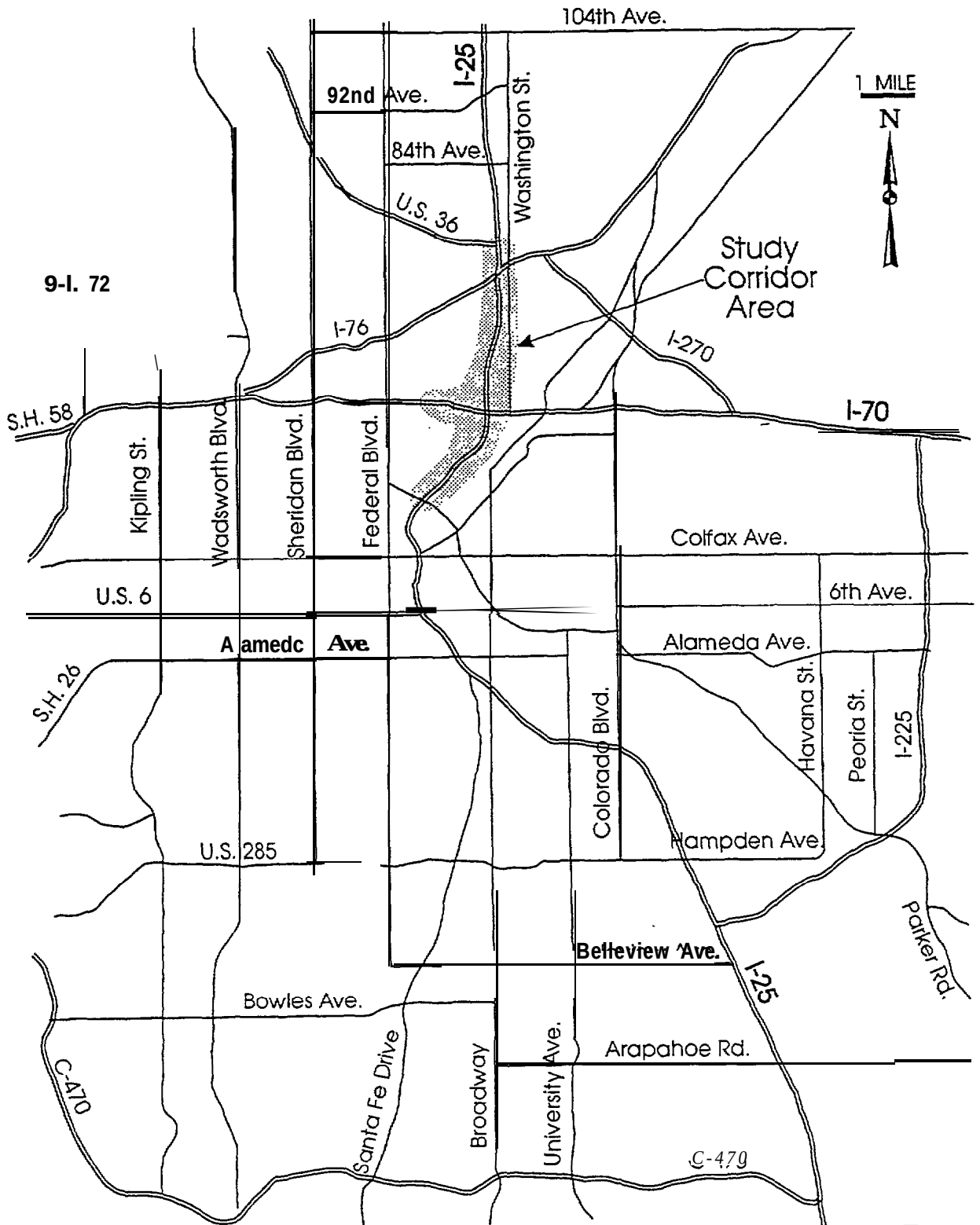

Figure 7.1

This preliminary site identification effort focuses on vacant land and for-sale buildings. Because the TOC will house so much specialized computer, electronic, and communications equipment, it is recommended that the TOC building and site be owned by the state. Leased space in a multi-tenant building is not considered feasible due to the on-site infrastructure installation requirements which would disrupt tenant and visitor access during construction. Future expansion would be more complicated in a multi-tenant building and could require TOC functions to be housed in separate portions of the building or could require extensive intra-building moves and costly reconnections of communications systems. Leased space in a single tenant building is also considered undesirable as life cycle costs would be higher than under an ownership scenario.

The TOC will house approximately 45 CDOT and CSP staff members as well as offices for local government and media. Special space requirements include computer, communications and electronics facilities, conference rooms and a command center. Total initial space requirements are estimated at about 32,600 square feet (see Table 6.1). A minimum of 70 parking spaces (24,500 square feet of land area) will be required initially for staff, visitor, media and motor pool parking. Total site area required, including landscaping and building setback, is estimated at approximately 1.2 acres. Tables 7.1 and 7.2 provide a breakdown of parking requirements and site space requirements.

7.3 General Site Requirements

The factors listed below were identified by CDOT and CSP staff as being important siting considerations. Several of the site requirements initially identified by CDOT or CSP staff are reflected in the delineation of study area boundaries and are thus not considered on a site by site basis. These include central location, media accessibility and multijurisdictional user accessibility.

7.3.1 Location Considerations

- Freeway accessibility - Freeway proximity lowers initial communications connection costs, ensures media and user accessibility and may improve accessibility during inclement weather.

- Arterial accessibility - Access from or proximity to a major arterial improves media and user accessibility and may improve accessibility during inclement weather.

- Proximity to communications network - Proximity to the communications network will lower overall initial communications connection costs.

- Radio transmitting/receiving qualities - Towers of adequate height must be allowed on site. The site should not be located near facilities which would interfere with transmitting/receiving (high voltage power lines for example).

- Flooding potential - The site should be out of the floodplain or in a location where floodplain location can be mitigated.

Table 7.1
Summary of TOC
Off Street Parking Requirements

General Types of Off-Street Parking	# of Spaces
Staff or Employee	51*
Media	2
Local Agencies	5
Visitor	5
Loading and Unloading	2
"Motor Pool" Vehicles	5
TOTAL	70

* Includes additional spaces required to accommodate-a double staff for some positions during shift change.

Table 7.2
Summary of TOC
Site Size Requirements

	Square Feet
Building (Footprint)	20,604
Parking (All Surface)	24,500
Site Landscaping (10% of Parking)	2,450
Setback Requirements	4,000
TOTAL	51,554 (1.2 acres)

- Accessibility during inclement weather - This relates to proximity to freeways/arterials as well as to the incline of the approach to the site and the relative priority ranking for snow removal.

- Proximity to Hazardous Materials Spill - The CSP has expressed concern with the potential need to evaculate the TOC during a hazardous material incident, a time when CSP dispatch functions are particularly critical. The 23rd Street rail yard is one area which is believed to have a higher than average potential for incident occurences, due to the heavy traffic in the area. Sites within a one mile radius of this location may have a higher potential for incidents requiting evacuation than do those sites located farther away.

- Land use compatibility - Although state sites do not have to meet City zoning requirements, the state may wish to avoid sites where a land use conflict between the TOC and adjacent residential uses is likely.

7.3.2 Physical Requirements

- Security of personnel - The facility will be staffed 24 hours a day. Shift changes will occur late at night and early in the morning. For staff security reasons, it is important that the site be large enough to accommodate on-site parking. Facility security is considered to be a design issue rather than a site selection issue.

- Site size - The site must be large enough to accommodate current staffing and parking requirements and to accommodate future expansion needs, both building and parking area (inadequate size is considered a fatal flaw)

- Hazardous material potential - A site assessment should be conducted prior to acquisition; however, all things being equal, a site which has obvious potential for contamination would likely be less desirable than one without such potential.

7.3.3 Cost Considerations

- Site cost - Per square foot land acquisition costs can vary according to location, zoning, infrastructure availability, parcel size and other factors; sites already owned by CDOT would not involve acquisition cost.

- Building Cost - CDOT can choose to construct a new building or retrofit an existing building to meet its needs. Costs of either option will vary based on site location, availability of utilities and other characteristics of available sites/buildings.

7.4 Proposed Site Evaluation Process

A three-phased site evaluation process is proposed. The first phase includes identifying vacant land and for-sale buildings larger than about 25,000 square feet on sites of 1.2 acres or larger within the proposed siting area. A preliminary evaluation related to

considerations outlined above is then conducted to screen out sites/buildings which are obviously deficient.

The second phase of the evaluation includes a more detailed evaluation of the remaining sites/buildings. Results of this analysis will be presented to CDOT and CSP decision makers who will rank sites according to the criteria weighting scale outlined below.

Finally, a cost evaluation will be prepared for the two vacant sites and renovation of two existing buildings with the highest cumulative scores. The preferred siting option would be chosen by CDOT and CSP decision makers based on relative ranking and cost considerations.

7.5 Proposed Criteria Weighting Scheme

The site selection considerations discussed above were weighted to reflect their relative importance in the site selection process. Relatively higher weights were assigned to those characteristics which cannot be mitigated. For example, a site's distance from the freeway cannot be mitigated; proximity to infrastructure, however, can be changed by infrastructure extensions.

Negative weights were assigned to flooding potential, hazardous material potential and presence of other environmental sensitivities, as these are undesirable characteristics. These negative characteristics, however, can generally be mitigated, through building up the site in the case of flood potential or remediation in the case of hazardous materials. The impact of these site characteristics in terms of project feasibility is thus related to the cost of mitigation. Inadequate site size is considered a fatal flaw. A "perfect" score would equal 82.

Criteria	Weight
Location Considerations	
Freeway accessibility	15
Arterial accessibility	10
Proximity to communications network	15
Radio transmitting and receiving qualities	15
Proximity to required infrastructure	10
Flooding potential	-8
Accessibility during inclement weather	4
Land use compatibility	5
Physical Requirements	
Hazardous material potential	-8
Presence of other environmental sensitivities	-8
Topography	8
Site size (inadequate size is considered a fatal flaw)	

After CDOT and CSP decision makers have ranked each site as to physical and locational suitability, a cost analysis will be conducted to analyze relative building construction and operating costs of the two highest ranked vacant sites and existing building sites. The following factors will be considered in the cost analysis.

Cost

Site acquisition
Site preparation
Building construction/renovation
Hazardous material clean-up
Other environmental mitigation required
On-site infrastructure costs (including communications)
Off-site infrastructure costs (including communications)
Relative building operation costs*

- Relative building operation costs will be presented in a qualitative fashion only for those building elements expected to differ substantially among alternatives.

Cost factors will be balanced against general site suitability in the selection of the preferred site.

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