I-95 CC 8-95-04

PROJECT # 8
Task 4- Traveler Information Services (TIS)

Evaluation of Available TIS Technology

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May 22,1995

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1. INTRODUCTION

This Working Paper, the fourth in a series of six, summarizes the results of Task 4 – Evaluation of Available TIS **Technology** – of the Traveler Information Services (TIS) Project. This Working Paper is submitted to the Project's Technical Review Committee (TRC) for review and consensus. The TRC's comments, recommendations, and assigned action items with respect to this paper will be analyzed and included in the TIS Final Project Report.

1.1 PROJECT OBJECTIVES

The I-95 TIS Project is an Advanced Traveler Information System (ATIS) implementation tailored to the unique needs of the Northeast Corridor. The project is designed to acquire and disseminate information on roadway traffic conditions, and other pertinent transportation information throughout the Corridor. The TIS will use a variety of static and dynamic information ranging from transit schedules and call-in reports to real-time traffic monitoring data and transit status information. The TIS systems will ingest, aggregate, and fuse these data in a database architecture that supports dissemination through a variety of communications systems and services to help travelers in the I-95 Corridor choose the most efficient transportation modes and/or routes.

This TIS Project's objectives are:

+ To develop a conceptual design and systems requirements for Corridor-wide applications.

+ To identify opportunities and principles for private/public partnering in providing traveler information services.

1.2 TASK 4 OBJECTIVES

There is a wide range of TIS technology currently being used or under development, including Highway Advisory Radio (HAR), Variable Message Signs (VMS), 800 telephone services, information kiosks, in-vehicle information systems, and similar systems. The primary objective of this task is to identify and evaluate those technologies that may be suitable to the needs of the I-95 Corridor-wide TIS (CTIS). The technologies considered in this evaluation include those that are in the public domain as well as the private domain.

This evaluation examines key technologies required to implement the CTIS. To provide a framework for the evaluation, candidate CTIS technologies were grouped into two categories; data management and data distribution.

Since the identification of TIS technologies is closely related to the work accomplished in Task 1 (Inventory of TIS and Commercial Opportunities) and Task 2 (TIS Goals Definition) of this Project, and the evaluation of candidate technologies depends of the systems requirements (developed in Task 3), the approach to this Task 4 accounts for these relationships as described in the next section.

1.3 TASK 4 APPROACH

The primary purpose of TIS technology evaluation is to gain an in-depth understanding of the current state-of-the-art in traveler information gathering, processing, and dissemination. This understanding forms a basis for developing the system's conceptual design. To properly guide the identification and evaluation of TIS technologies, a set of criteria is necessary. These criteria were established based on the understanding of the existing and potential TIS in the Corridor (results of Task 1), the TIS goals of the Corridor (results of Task 2), and the requirements for achieving the system goals (results of Task 3). Thus, the Study Team's approach to this Task 4 was first to develop criteria for technology identification and evaluation, and then evaluate all candidate technologies using the developed criteria (refer to Figure l-l).

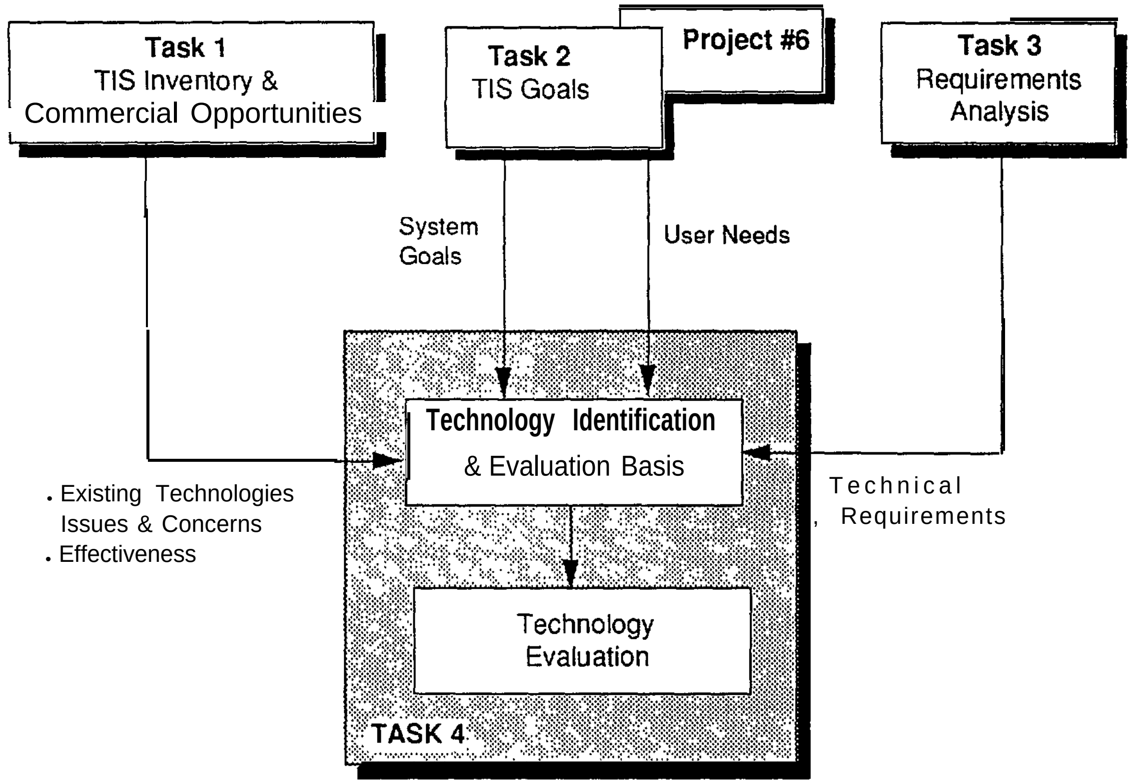

Figure 1-1. CTIS Technology Evaluation Approach

An evaluation of available TIS technologies is analogous to shooting at a moving target. As Intelligent Transportation Systems (ITS) evolve, new methods of collecting, fusing, and disseminating data are proliferating, and the future promises much more of the same. With these uncertainties, our approach focuses on both currently available technologies and emerging technologies. For consistency with earlier tasks, this evaluation separately identified and assessed technologies for data management and data dissemination. As shown in Figure 1-2, both of these categories were further subdivided. Data management was broken down into data collection and data fusion. Data dissemination was subdivided into delivery mechanisms and end-user devices.

1.4 ORGANIZATION OF WORKING PAPER

In addition to this Introduction, the Working Paper contains 4 other sections as follows. Section 2 provides an overview of CTIS. This overview will set the context for the evaluation of data dissemination and data management technologies presented in Sections 3 and 4, respectively. Section 5 concludes the Working Paper. Finally, Appendix A identifies a comprehensive list of TIS product ands service providers. This Appendix provides insight into the full gamut of relevant TIS technologies and vendors.

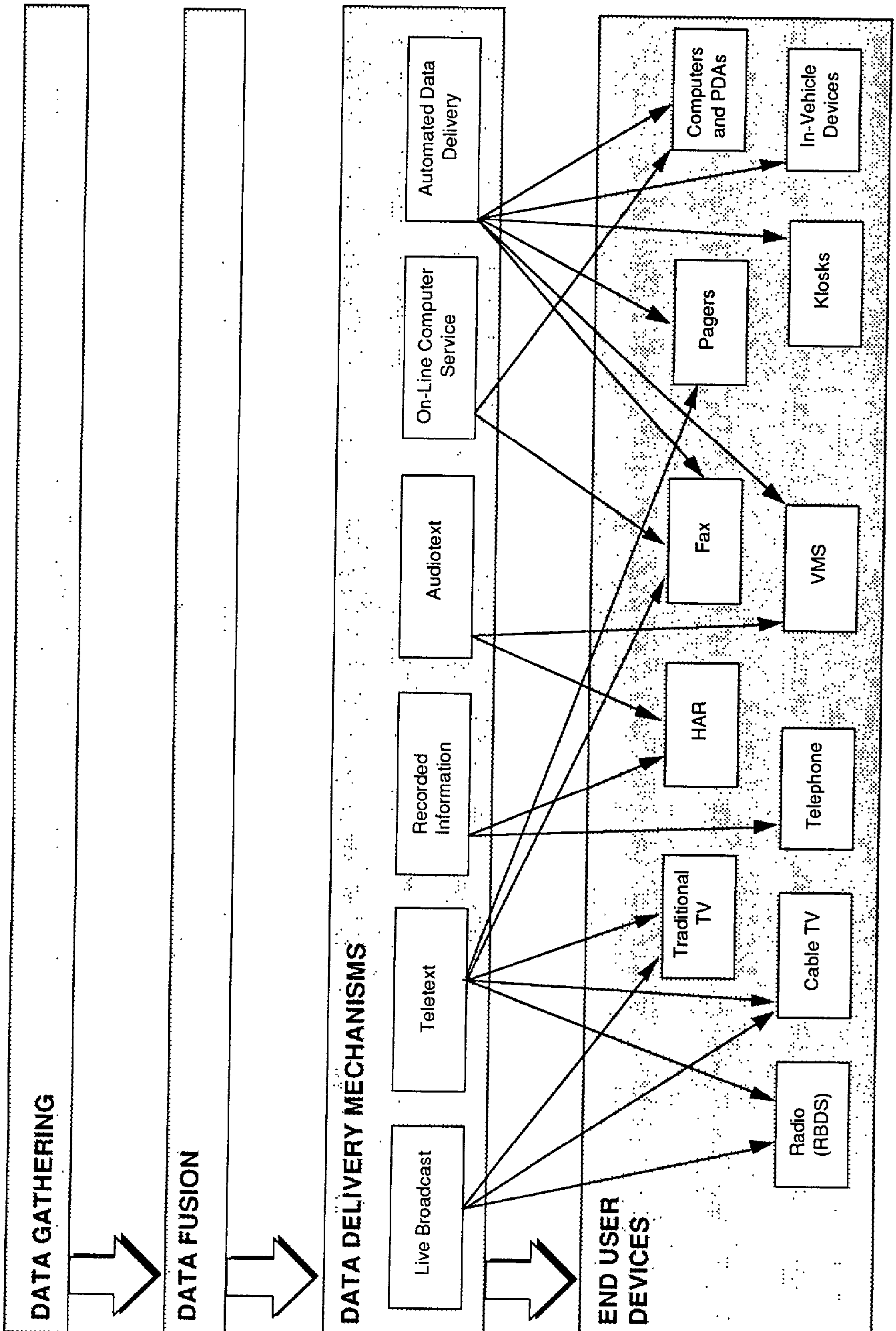

Figure 1-2. TIS Technologies Were Evaluated According to Functional Groups

2. OVERVIEW OF CTIS

This section provides an overview of the proposed CTIS, including the types of services offered, available dissemination technologies, and the functionality of Regional Traveler Information Centers (RTIC). This section is intended to set the context for the technology evaluations presented in later sections.

2.1 THE CTIS VISION

CTIS is an implementation of ATIS tailored to the unique, interregional needs of the Northeast I-95 Corridor, which includes the states from Virginia to Maine. The overall goal of CTIS is to assist travelers in efficiently utilizing the transportation system.

CTIS, in conjunction with state-of-the-art surveillance techniques provided through Advanced Traffic Management Systems (ATMS), will provide real-time, pretrip, and en route multimodal information to assist travelers in arriving at their destinations. Actionable, real-time traffic and travel information will be disseminated on all modes, including private vehicles, public, and commercial transportation. In addition, specialized CTIS functions will assist law enforcement, Commercial Vehicle Operators (CVO)/dispatchers, Public Transportation Operators/dispatchers, and various government agencies with their operations.

To effectively disseminate traveler information and to provide ubiquitous access to all types of users, a public/private partnership consisting of Coalition member agencies and various private sector sponsors is required. This will result in a publicly funded or subsidized Traveler Information Center (TIC) as well as commercial endeavors by Information Service Providers (ISP), Value-Added Resellers (VAR), Communication Service Providers (CSP), and various other types of repackagers, distributors, or TIS product/service providers. These private sector entities are expected to add information, package traveler information with other types of information, and disseminate information directly to end-users to enhance the effectiveness of the TIC. In addition, these partners will provide the research and development, market analysis, infrastructure deployment capital, and support for day-to-day operations of CTIS. Thus, the ultimate success of CTIS will be dependent on participation from both public agencies and private sector companies.

Since the I-95 Northeast Corridor consists of multiple consolidated metropolitan regions, and hosts over 20% of the total U.S. population, a distributed CTIS architecture is anticipated. Aggressive public/private partnerships are required to reach the vast traveling public. To support various users, the CTIS architecture must support intracity, intercity, and interregional, traveler information needs. The architecture, although distributed, will appear seamless to the user and will provide information about the entire Corridor from any point within the Corridor. CTIS will disseminate accurate and up-to-the-minute traveler information, including:

- Real-Time Traffic Information including, link speeds, link volumes, link surface condition (dry, wet, icy), congestion levels, travel advisories, alternate routes, and incident locations.
- Real-Time Transit Information including, incidents, vehicle locations, loading and arrival estimates.
- Planned Event Information including, construction and special events.
- Modal Travel Time Comparisons for given origin-destination pairs.
- Weather and Environmental Information including, current and forecasted temperature, precipitation, visibility, and air-quality.
- Traffic Forecasts, Demands, Trends for specific routes.
- Trip Itineraries for a given origin-destination, time of travel, mode(s), and user preferences (cost, walking distance, number of transfers, etc.).
- Static Traffic Information including, road geometries, road restrictions, historical traffic data, network topologies.
- Static Transit Information including, schedules, routes, fares, and usage information.
- Emergency Services Information including, hospital, emergency telephone, repair shop and police locations and hours of operation,
- Traveler Services Information including, yellow pages (lodging, food/dining locations and hours of operation), attractions, historical sites, festivals, parks and recreation facilities, cultural and arts activities, educational institutions, and resorts.

- Parking Information including, location, capacities, and real-time occupancy.

- Ride Matching/Paratransit Services for a given origin-destination, time, and date of travel.

2.2 REGIONAL TRAVELER INFORMATION CENTERS

Before traveler information can be effectively disseminated, it has to be acquired, fused, validated, and organized in a format suitable for further processing. In the context of CTIS, this will happen at several regions throughout the I-95 Northeast Corridor. The I-95 Business Plan has identified four regions for the I-95 Corridor:

- New York/New Jersey/Connecticut (TRANSCOM) area.

- Washington/Baltimore/Northern Virginia area.

- Philadelphia/Camden/Wilmington area.

- Boston/Providence/Maine/Vermont/New Hampshire area.

Each region will house a RTIC which will act as a clearinghouse for transportation information within its region. The clearinghouse function will utilize data servers within each region to manage RTIC data. These data servers will communicate by means of a regional Wide Area Network (WAN) backbone, provided by the Information Exchange Network (IEN); this is Project #1. Each of these regional data servers will collect and maintain data within its region. The regional data servers will also disseminate information to other regional data servers and to the other nodes on the WAN.

The primary goal of a Regional TIC is to compile, integrate, format, and manage data to be disseminated to travelers. To meet this goal, four major functions are required (see Figure 2-l):

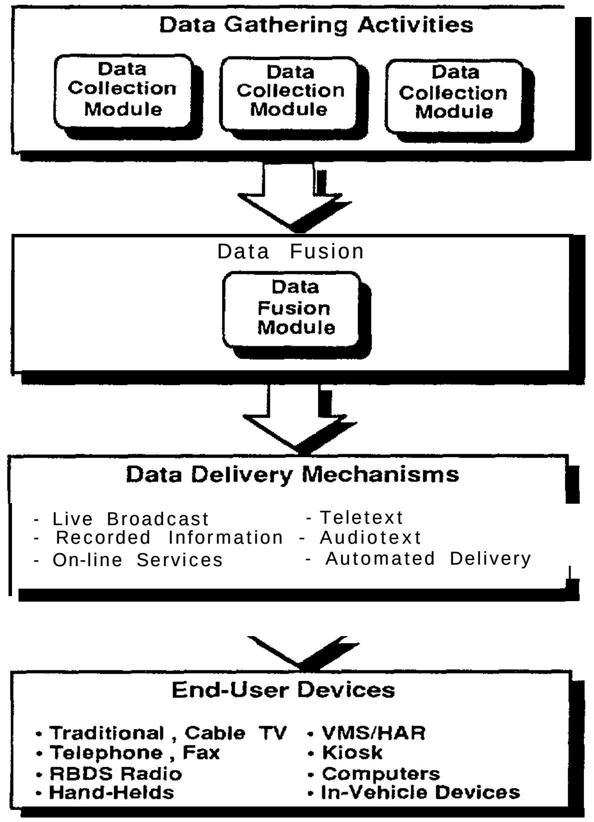

Figure 2- 1. RTIC Components

+ Data Gathering.

+ Data Fusion and Processing.

+ Data Delivery.

+ End-User Device Processing.

To support these RTIC functions, subsystems will be required in communications, data management, and data distribution. In addition, to support various user and system needs, subsystem components are required for trip planning, system security, data fusion, ad-hoc user-query, user-interface, data broadcast, map/Geographic Information System (GIS), and inter-RTIC data exchange.

2.2.1 Data Gathering

Providing seamless access to regional traveler information begins with the task of data gathering. To appear seamless to the user, traveler information must be collected locally and integrated regionally, since travelers do not recognize imaginary boundaries such as state, county, or city borders. Seldomly do end-users require information only for a given city or county jurisdiction. This is partly due to the pervasiveness of suburb-to-suburb travel in the transportation network, and the fact that employees no longer reside close to their place of employment. The implication of appearing seamless is that traffic/transit surveillance and condition information must be collected and integrated from multiple public and private agencies. Figure 2-2 identifies the various CTIS sources of information and illustrates the relationship between RTICs, Traffic Operation Centers (TOC), and IEN interfaces. Note that the figure is for illustration purposes and does not preclude the scenario of a joint RTIC/TOC operation.

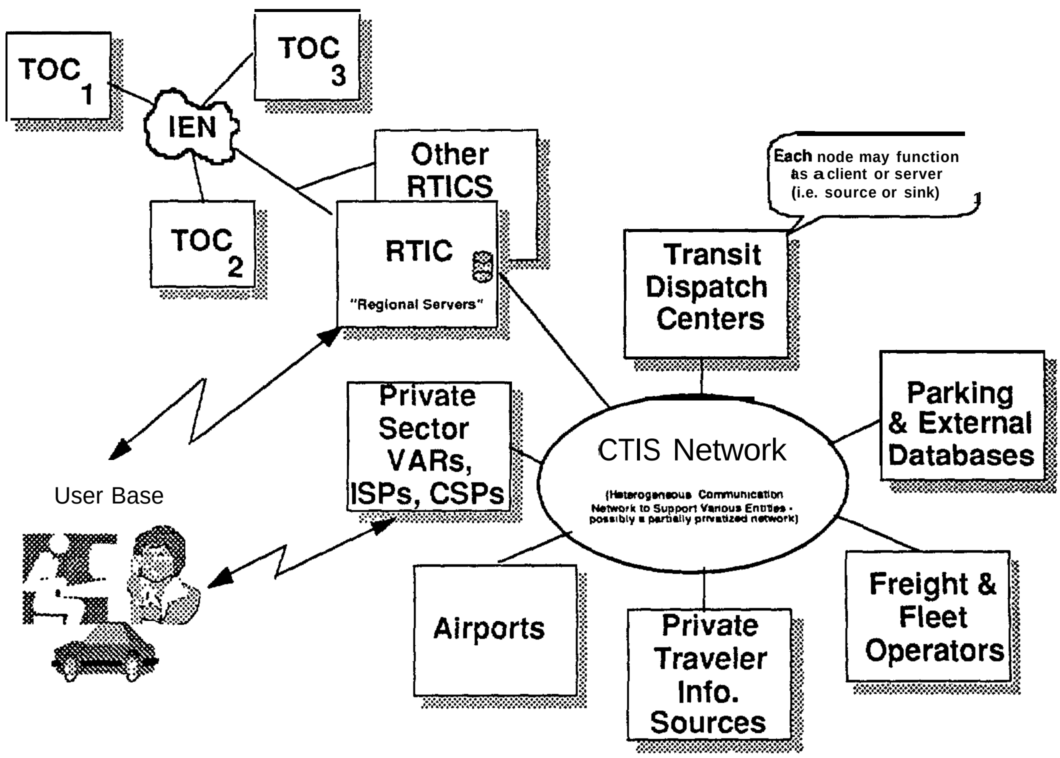

Figure 2-2. CTIS Integrates Multimodal Data at RTIC Nodes

Since most traffic surveillance data is collected locally, regional data gathering activities require many system interfaces to information sources. RTIC system interfaces supporting center-to-center (i.e., TOC to RTIC, Transit Dispatch to RTIC, etc.) information exchange of voice and digital data are required. Digital data will include video and data to support each of the TIS services identified in Section 2.1.

Unfortunately, not many existing jurisdictions have systems in place that electronically share/exchange data. Project #1, the IEN, is tasked with resolving this problem through the deployment of a uniform network backbone throughout the I-95 Corridor. The IEN backbone will host over 67 IEN nodes strategically deployed at various coalition member agencies. The IEN nodes will obtain local traffic data from each TOC. Acquired data will be in a unique format native to the host system. Data will be acquired and translated into a predefined IEN format that will be made available to other IEN nodes and RTIC data servers. Initially, the TOC to IEN interface will be manual. In the future, automated interfaces will be provided to reduce human intervention and duplication of effort.

2.2.2 Data Fusion and Processing

Once information is acquired, and prior to it being delivered to end-users, data must be fused, formatted, and further processed. Fusion includes consolidating and correlating data about the same point or area in the transportation network, from multiple sources. For example, consolidating incident reports from commercial traffic reporting firms (acquired via aerial surveillance or motorist call-in) and public agencies (acquired via instrumented links and detection algorithms) is typically required. It is important to note that not all data coming into the system is fused. For example, transit schedules are simply acquired and stored. Once data is acquired, it must be validated and put together into formats to be used by other CTIS applications -- for example, trip planning. This may involve calculations combining one type of data with another, or aggregating the same kind of data together. In order to support route or modal travel time comparisons, for instance, data must typically be aggregated. For example, to determine travel times between cities (e.g., Baltimore-Washington) low-level link data, typically obtained at .5-mile intervals, must be combined together to form a route travel time estimate. Finally, acquired, fused and formatted data must be spatially attached using georeferencing to a base map or spatial model.

2.2.3 Data Delivery

As depicted in Figure 2-3, CTIS will acquire information from many sources and will use various communication media to disseminate traveler information. Dissemination of traveler information will likely occur in phases (see Figure 2-4), progressively adding more services and incorporating sophisticated technology over time. In the short-term baseline phase (years 0-2), TIS will disseminate primarily via proven communication media: Commercial Radio Stations, VMS/HAR, Faxes, Pagers and Telephone. During the mid-term phase (years 2-5), more sophisticated private-sector information dissemination proliferates. Information will contain more multimedia components, and from the user's point of view will be more interactive and personalized. Dissemination technologies/devices will include regular, cable, and interactive TV; dial-up online services; public kiosks; Internet-accessed services; and various types of hand-held devices including, two-way pagers, Personal Digital Assistants (PDA), and Personal Communication Systems (PCS). In the final phase (years 5-10), heavy emphasis will be placed on widespread deployment of in-vehicle navigational devices displaying real-time, location-specific, multimodal navigational information. In addition, the use of intelligent agent processing will begin to be used. This technology will be employed to automate the information retrieval and delivery processes (i.e., from the user's point of view), and to increase the amount of personalized information, thereby facilitating more passive users who receive information only on an as needed basis.

2.2.4 End-User Device Processing

End-user device processing is potentially the most important component of the CTIS system, in that it is responsible for directly interfacing to end-users. While most end-user device processing is likely to be a private-sector function, several end-user devices are likely to provided by public agencies. These include, VMS/HAR, kiosks, and telephone.

Regardless of the device and the provider, all end-user device processing begins with acquiring traveler information. Then, depending on the device and vendor, device-specific processing occurs. These functions include, formatting, user-specific filtering, data presentation and display. In addition, for devices supporting two-way communications (Computers, PDAs, next-generation pagers, kiosks, etc.), support for the construction, retrieval, and display of ad-hoc and fixed queries is required.

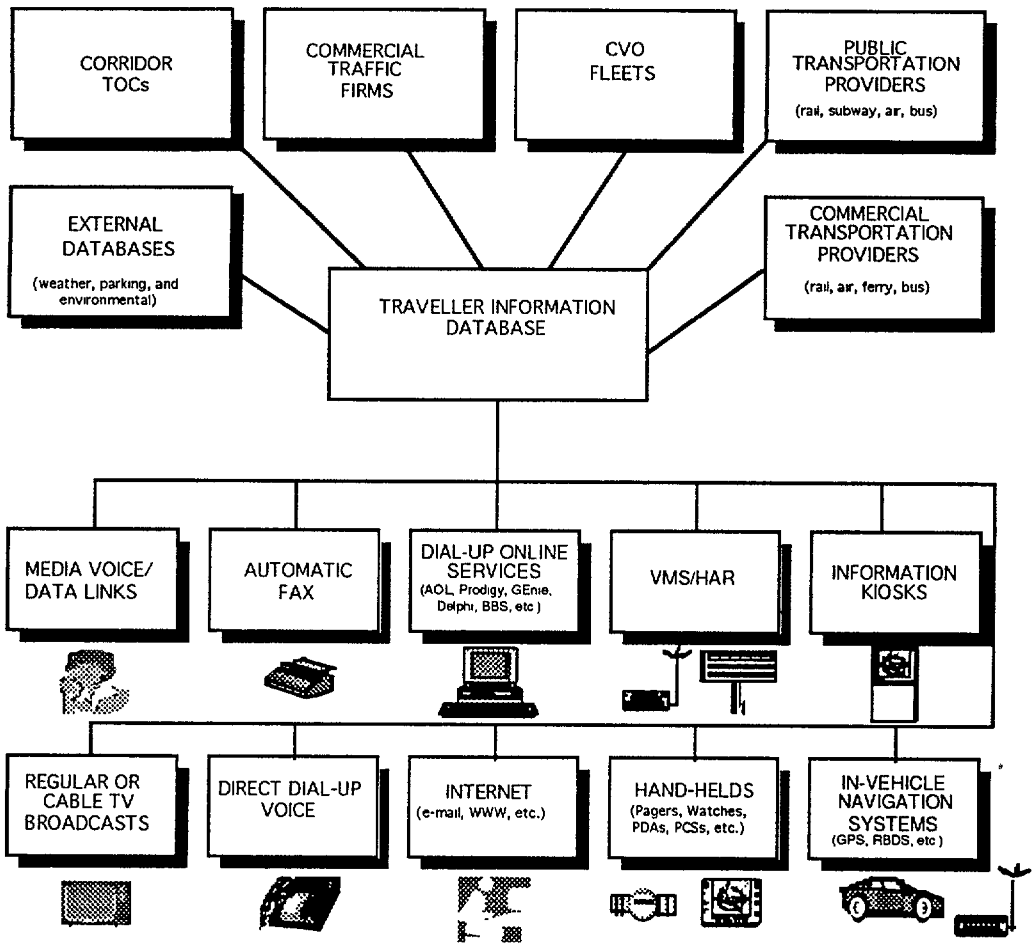

Figure 2-3. Candidate CTIS Data Sources and Sinks

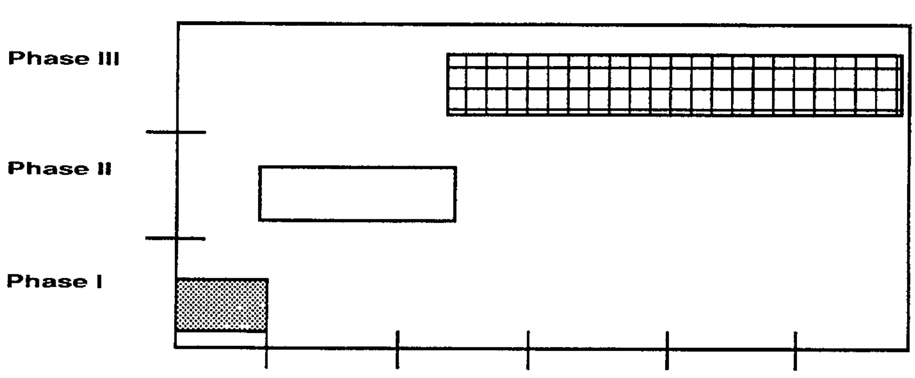

Figure 2-4. Phasing of TIS Deployment

3. DATA DISSEMINATION TECHNOLOGIES

This section addresses data dissemination technology. Both data delivery mechanisms and end-user devices will be discussed. Each technology evaluation will incorporate two different evaluation timeliness, current and emerging technologies.

3.1 EVALUATION CRITERIA

Each technology is evaluated according to its performance against these criteria:

+ **Ability to meet user needs:** How well does the technology meet its end-users' needs for traveler information? The Task 2 findings of this project identified the two highest priority items for traveler information user needs as the provisions for real-time incident/congestion summaries and the provision of traveler advisories including variable speed limits and road conditions. In addition, other industry research -- as summarized in A Market Analysis of the Commercial Traffic Information Business -- states that, " Based upon current market developments...the trend is toward route specific traffic information." From these findings, we have defined the ability to meet user needs as the provision of real-time, route-specific traffic and transit information in a timely, accurate, reliable manner.

+ **Accessibility:** How readily available is the technology? In order to be commercially viable and to meet public policy objectives, end-user devices need to be widely accessible to the traveling public. Since accessibility changes over time, system interfaces to some currently less prevalent devices may be required initially. Over time, these devices may gain wider acceptance.

+ **Interactivity:** What capabilities does the device have that support users requesting specific information? For example, an audiotext system is capable of interacting with users to support route-specific information, while a commercial radio broadcast is not.

+ **Cost of implementation:** How expensive is it for the disseminator to implement the technology?

+ **Cost to user:** How expensive is it for the user to obtain the technology. Can end-users afford the technology or do they already have access to it? Does the technology require them to acquire special equipment?

+ **Ease of use:** Once the users acquire the technology, how easily can they use it? Does it require specialized knowledge?

3.2 DELIVERY MECHANISMS

3.2.1 Live Broadcast Systems

Live broadcast systems serve the following end-user devices: broadcast radio, broadcast television, and cable television.

3.2.1.1 Current Technologies and Implementations

Up through the present, most information about traffic and transit conditions has been delivered through commercial radio and television broadcasting. Companies such as Metro Traffic Networks and Shadow Broadcast Services provide traffic information for many of the cities in the Corridor. Other companies, such as SmartRoute Systems and Traffic Net, serve regional areas within the Corridor using live broadcast systems.

Typically, this information is delivered live in a studio at the company's location, and broadcast out over radio and television stations in 30-second "traffic reports". These reports are on the air in 10- to 30-minute intervals, depending upon the station and the time of day. Television reports may include live video from Closed Circuit Television (CCTV) cameras and graphical map displays to alert travelers to potential problems and alternate routes.

3.2.1.2 Emerging Technologies

The use of dedicated cable TV stations for displaying traveler information is beginning to gain acceptance. These stations typically provide continuous video tours of CCTV within a region. Live video is supplemented with scrolling audiotext.

The deployment of interactive television is just around the corner. interacting with your TV and cable provider via telephones and computers will revolutionize the information-age, providing in-home services, such as on-demand video, billing, shopping, and traveler information services.

3.2.1.3 Evaluation

Live broadcast systems, as structured today, have certain limitations that hinder their ability to meet user needs. These systems deliver 30-second reports to describe an entire region’s traffic conditions. The two top priorities for user services identified in Task Z-real-time incident/congestion summaries and traveler advisories-typically require more information than can be imparted in 30 seconds.

Additionally, other user-needs surveys have found that travelers want route-specific information that is accurate, timely, and reliable. Systems that rely on 30 seconds at up to half-hour intervals may not fulfill these needs. In the future, interactive TV may overcome this deficiency.

Live broadcast of traffic and transit information provides a very high degree of accessibility to the consumer. This information is accessible in every home or office with a television and in every car with a radio, making it ubiquitous.

3.2.2 Recorded Broadcast Systems

Recorded broadcast systems serve the following end-user devices: telephone and highway advisory radio.

3.2.2.1 Current Technologies and Implementations

Recorded broadcast systems are typically run by government agencies, and are primarily used to provide information through radio or telephone. They are different from audiotext systems in that they are not interactive, and provide a single message per call or broadcast. HAR, for example, contains periodically updated traveler information in a prerecorded format. Similarly, transit agencies often provide prerecorded schedule, fare, and other static information through a telephone information number.

3.2.2.2 Emerging Technologies

The only emerging technology on the horizon in this category is voice synthesizers that will automate the recording process by converting text incident reports to audio formats.

3.2.2.3 Evaluation

These types of systems meet the user's needs in a very limited way. Highway advisory radio, having a limited transmission range, can only advise the traveler when they are in the vicinity of the facility to be served. Additionally, these services have less than ideal reception within the vehicles, often delivering weak and static ridden messages. Prerecorded telephone messages can better meet user needs for pretrip planning, but often contain static data only and require frequent rerecording to stay useful. Both methods of delivering information are accessible to the public, and have little or no cost of implementation for the user.

3.2.3 Audiotext Systems

Audiotext systems serve the following end-user devices: telephone and highway advisory radio.

3.2.3.1 Current Technologies and Implementations

Audiotext systems for traffic and transit information cover the entire spectrum, from rudimentary static transportation system information to real-time, on-demand, route-specific information on traffic and transit conditions customized to the caller's planned or ongoing trip. Several examples of the former type of system are audiotext services developed by state Departments of Transportation (DOT) to advise travelers of construction activity on their highway networks.

One example of the latter, a comprehensive audiotext delivery mechanism, is the SmarTraveler Service operated for the Massachusetts Department of Transportation by SmartRoute Systems. ***SmarTraveler's*** audiotext system provides real-time traffic and transit reports to anyone with a Touch-Tone telephone. Access to the information is menu-driven, and the information is conveyed through a recorded human voice digitally stored on a computer disc. A software program constantly updates the information without interrupting the service or the customers, thus increasing the effectiveness of this system.

Another example of existing audiotext systems are transit information systems providing route, schedule, fare, and sometimes trip-planning information for transit users. In addition, the Philadelphia International Airport provides, via an 800 number, access to real-time arrivals.

3.2.3.2 Emerging Technologies

Future generations of audiotext systems will incorporate call-back technology. This technology allows the user to register a request for specific updates and have the system call him or her back when an update occurs. It is a specific form of intelligent-agent technology described later in this document.

3.2.3.3 Evaluation

These systems are well-suited to meet user needs. The two most identified user needs in our Task 2 survey-the provision of real-time incident/congestion summaries and traveler advisories-can be fully met through this delivery mechanism. Typically, this would be accomplished through a menu-driven process that leads the consumer to the specific real-time or static information for a specific route. Previous user-needs surveys have found that up-to-date, location-specific traffic and transit information is the most sought after pretrip and en route data.

Audiotext services, generally accessed through a Touch-Tone telephone, are among the most accessible means of delivering traveler information. With virtually all homes and offices and 10-20% of the nation's automobiles equipped with Touch-Tone telephones, the accessibility of an audiotext system is nearly universal.

These systems are easy to use and somewhat familiar to most Americans. Most systems begin with instructions that can be bypassed by experienced users who know how and where to access the system for the specific information they seek.

Since the end-user is already equipped with the device to access this system, there is no cost of implementation involved-unless installation of a cellular phone is considered to access enroute information.

3.2.4 Teletext or Videotext Delivery Systems

Teletext or videotext delivery systems serve the following end-user devices: facsimile, pagers, Radio Broadcast Data Systems (RBDS) radio, and television.

3.2.4.1 Current Technologies and Implementations

These types of systems display a text message for the traveler. Currently, teletext systems are used to deliver information to pagers equipped with alphanumeric receiving capabilities. With these systems, text messages are received automatically by the pager owner for a predescribed set of circumstances. One such system, operated by SmartRoute Systems and the MobileMedia Paging Company in Boston, provides up to 30 reports a day for MobileMedia's customers for a predesignated portion of the Boston area.

In Seattle, Seiko Telecommunications Systems is testing a wristwatch pager that receives and displays brief traffic incident reports on an alphanumeric display.

3.2.4.2 Emerging Technologies

Emerging technologies for teletext and videotext systems include the transmission of text information to radio receivers using RBDS, and to televisions using the closed-captioning technology similar to that now used for hearing-impaired viewers. RBDS, Cellular Digital Packetized Data (CDPD), and Frequency Modulation (FM) subcarrier technology will also likely be used for in-vehicle technologies.

3.2.4.3 Evaluation

Teletext and videotext delivery systems have the ability to meet high priority user needs through the provision of specific information of use to the consumer. Messages need be sent only when of interest, based upon a predetermined set of criteria --the user is normally passive.

With the proliferation of pagers in circulation today, accessibility to this delivery mechanism is widespread and growing.

3.2.5 Bulletin Board Services

Bulletin Board Services (BBS) primarily serve computer users only.

3.2.5.1 Current Technologies and Implementations

BBSs were an early implementation, by independent service providers, of online services (e.g. news groups, software downloads) to subscribing users. The communication medium was largely modems and public switch telephone access. With the proliferation of personal computers in the workplace and home, these bulletin board services became specialized in providing specific information to users for a fee. They were typically localized to cities and specific topics of interest.

Some of these bulletin board services became quite extensive and began to offer a wide range of information content-rich services. Commercial bulletin board services still exist for product and service-specific information. Typically, existing bulletin board services have limited access with respect to capacity as well as speed. They provide the service for a niche market with very specialized information.

With respect to ATIS, it is feasible to design various dial-in bulletin board services that would provide specific travel information for a given region. This approach may not be a viable cost-effective method to disseminate information in a real-time environment. The limitations of regional as well as other physical constraints might prove to be unsuitable for extensive traveler information systems.

3.2.5.2 Emerging Technologies

For traveler information, BBSs are being replaced by online services, discussed in the next section.

3.2.6 Online Services

Online services serve the following end-user devices: computers, PDAs, and facsimile.

3.2.6.1 Current Technologies and Implementations

Online services form one of the fastest-growing industries of the “information superhighway”. This technology is changing dramatically with big commercial dial-up, online vendors reaching over 5 to 10 million users in the North American market, and the Internet providing access to another 20-30 million users world wide.

Commercial online services, the biggest segment in this area, are growing at an astonishing rate, while attempting to provide similar services. They are all getting easier to use, relying heavily on graphical user interfaces. They are all targeting the same users by cultivating similar content. The basic market segments that these commercial online services support are:

+ Business and commercial use.
+ Home and personal use.

Most online services provide basic services that cover many areas, including, investing and finance, computer and software support, travel, online reference materials, business and career, news and weather, online shopping, health, sports, hobbies and leisure, games, and others.

Online services available to North American users include:

+ CompuServe International.
+ America Online.
+ Delphi Internet.
+ Prodigy.
+ Dow Jones with MCI Mail.
+ GEnie.

All of these services are accessible via standard land-line public switch networks and modems. The basic features which could be used to evaluate these commercial online services would include:

- Installation and Orientation.
- Content.
- Interface.
- E-mail Capability.
- Discussion Groups and Forums.
- Internet Connectivity.
- Cost.
- Downloading Files.
- Working Offline.

Ease of installation and orientation identifies what it takes to make the first connection. Some services let you try it before joining. There are toll-free access phone numbers and easy installation procedures.

The breadth and depth of available content areas are central. The quality, accuracy, and the timeliness of this information allows for assessment of different online services.

A clear interface into a variety of information areas can be as important as information itself. Whether the interface is graphical or text based, ease of navigation and effectiveness of search mechanisms are all critical features.

The E-mail packages available with these services are also becoming extremely important for average users. Abilities to attach multitext and binary files, as well as multimedia elements to messages; return receipts; and designate urgent notices are some of the features in this category.

Discussion groups and forums provide users with an interface to various topics. Users can exchange ideas, get questions answered, provide support, or simply read and learn. Discussion groups are available for a wide range of topics ranging from sports to computer programming.

User transparency is the key for good Internet connectivity. Methods for accessing Internet services such as File Transfer Protocol (FTP), Gopher, Usenet, Telnet, and the World Wide Web (WWW) are becoming standard features. The depth of connectivity and determining whether the service provides only a few FTP sites or access to the entire Internet and the related costs involved are typical evaluation features.

Monthly cost is typically not a discriminator among the top three providers. Hidden costs, however, may be substantial. For example, some vendors add usage surcharges during peak hours. Others charge extra for accessing Internet services (e.g., Internet E-mail gateways).

Downloading data files and graphics are an important activity when working online. Providers offer varying support in these areas. The best providers offer search tools and high-speed connections to allow users to quickly find and download items of interest.

Working offline provides substantial cost savings, if offered. This allows users to perform such activities as constructing E-mail messages offline, thereby saving connection charges.

Each of these services also provide traveler information with a current emphasis on airline, hotel and car reservation systems, and tourism-related information -- usually from private-sector providers.

3.2.6.2 Emerging Technologies

In the area of online services, the emerging trends include providing seamless connectivity to Internet and wireless-specific, online services. They also allow for universal access with unlimited time constraints. Faster access and ease of connections to other WWW Internet sites are features that will allow users to travel across the world electronically. Wireless connectivity, as well as advanced multimedia systems, will soon be available through these online services.

Delivery of traveler information through the WWW is an emerging technology. Probably the most advanced such technology in this country is a service providing real-time traffic conditions in Southern California (San Diego and Los Angeles). This service, a collaboration between CalTrans and Maxwell Laboratories, provides a graphic display mapping the region's main highways with color-coded vehicle speed and congestion information. In addition to Southern California, other areas of the country have or are planning WWW/Mosaic interfaces. Seattle and Houston have recently added home pages. In addition, several cities in the I-95 Corridor (NY, Boston, Washington) have plans to provide access.

Another example of a WWW-based, online delivery mechanism is a service provided by the North Carolina Department of Transportation which displays construction information on the highway network in a "point and click" format. Each project is described graphically and contains text information of potential traffic impacts and possible detours. Both of these applications have potential for an I-95 Corridor TIS.

Online services provide a mechanism for enhanced information resource accessibility for traveler information within the I-95 Corridor. These services offer a cost-effective approach for providing traveler information to not only corridor residents but also to anyone planning a trip within the corridor. The existing infrastructure allows for this information mechanism to be set up quite quickly and accurately. There is very little learning curve associated with providing users with the capability for obtaining this information. Specific online services for traveler information purposes, as well as the commercial online services and Internet, could be used effectively to satisfy traveler information requirements in a positive manner.

There are efforts underway to provide WWW pages for traffic operations centers for more cities in the United States and Canada.

3.2.6.3 Evaluation

Online computer services have significant potential for meeting the highest-priority user needs as described in Task 2 of this project. Online services are capable of delivering the large amounts of information necessary for satisfying user service needs such as real-time, route-specific traveler information and traveler advisories. Since standards have been set with respect to user interfaces and access methods for commercial online services, the possibility of providing traveler information-related data to the existing commercial services, or an I-95 Corridor-specific online service, would be a practical, demonstrable technology.

One drawback of online services is the lack of accessibility to the general public. Unlike audiotext or broadcast systems, online services-while growing in popularity-are far from the universally available services that use telephone, radio, and television as delivery mechanisms.

It is likely that online services would deploy user interfaces similar to those used for other information types. Therefore, high rating for ease of use could be assigned to online services.

Online services require some implementation investment on the user's pan for both equipment and online access. The cost of implementation under this technology would range from setting up specific services with existing commercial online providers; interfacing with pertinent real-time traveler information data collectors; and developing specific worldwide server environments to provide I-95 traveler information services. From an overall perspective, the cost of implementation of such a system to provide traveler information is not prohibitive.

The online service technology used to provide traveler information systems would exhibit flexible and expandable network characteristics. It is relatively easy to expand the geographical coverage as well as feature content of online services with minimum overhead. Since these technologies are not infrastructure-intensive, it is feasible to provide flexibility and expandability in a cost-effective manner.

3.2.7 Automated Data Delivery Systems

Automated data delivery systems serve the following end-user devices: in-vehicle information and navigation systems, kiosks, computers, pagers, facsimile, and VMSs.

3.2.7.1 Current Technologies and Implementations

This delivery mechanism is applicable to end-user devices that demand large amounts of data for their processes. In-vehicle navigation systems, for instance, require constant monitoring of network data to incorporate real-time conditions into their system condition reports and navigation algorithms.

Automated data delivery systems feed this information directly to the device from the traveler information database. This delivery mechanism is being tested in several locations around the country and the world, and involves many varied approaches to its implementation.

For the purpose of the I-95 Corridor project, the design of the Regional Traveler Information Database needs to take such delivery mechanisms into account.

3.2.7.2 Emerging Technologies

Widespread use of public kiosks and in-vehicle, location-specific, mobile navigational systems are not yet prolific, but are on the horizon. As ITS evolves and as standards are developed, traveler information broadcasts over FM subcarrier or CDPD will be more widely utilized.

The use of public kiosks at rest stops, shopping malls, intermodal transfer points, and employment centers will also make advances in deployment.

3.2.7.3 Evaluation

Most of the end-user devices (kiosk, computer, VMS) used to support this technology are widely accessible to the traveling public, while others are not (in-vehicle devices). In addition, while the cost of using a public kiosk may be free, many of the end-user devices that support automatic delivery of personalized information will charge on a per message basis. On the other hand, most of the technologies in this category will provide a high-level of user satisfaction, since they can deliver personalized or route-specific information.

3.3 END-USER DEVICES

As mentioned above, each end-user technology described in the following paragraphs will be evaluated to determine its conformance with the criteria established in the Introduction to this report. At the conclusion of this section, Table 3-l summarizes the evaluation of each end-user device technology.

3.3.1 Radio

3.3.1.1 Current Technologies and Implementations

Currently available technology for radios to act as end-user devices for traffic information rely primarily on home, office, and vehicle radios receiving Amplitude Modulation (AM) and FM signals. As described in the previous section, these devices are serviced primarily by live broadcast of information from either the radio station's staff or a commercial traffic reporting firm under contract to the station.

3.3.1.2 Emerging Technologies

Emerging technologies in radio broadcast have the potential to significantly alter the dissemination of traffic and transit information through this device by using FM subcarrier radio transmissions. This technology--known as RBDS-allows the continuous broadcast of text signals to properly equipped FM radio receivers. Like broadcast radio, this is one-way communication and there are limitations on the level of detail that can be provided through this device (each message limited to 20 characters). Continuing development of International Traveler information Standards (ITIS) for messages transmitted through RBDS will improve its functionality.

3.3.1.3 Evaluation

Radio is currently the most widely used device for receiving en route traveler information. Given the widespread usage of this device for current purposes, there is no doubt that it will continue to be a significant disseminator of traveler information for the foreseeable future.

This technology scores well on several of the evaluation criteria listed above including accessibility, ease of use, and cost of implementation for the user. The one area where this device is limited is in meeting user needs of personalized traveler information.

As mentioned previously, the consumers and agencies surveyed put a high value on receiving specific, real-time information for pretrip and en route planning purposes. Radio traffic reports (even with RBDS technology) do not at this time possess the interactive component necessary to fully meet this criteria.

3.3.2 Television

3.3.2.1 Current Technologies and Implementations

Like commercial radio for en route services, television is currently the prominent disseminator of pretrip traveler information of all currently available technologies.

Most television traffic reporting is contracted through commercial traffic reporting firms who collect and manage transportation information, and then broadcast it through the commercial television station.

3.3.2.2 Emerging Technologies

Emerging technologies in television are plentiful. Some that may have some application to Traveler Information Services include:

+ Delivery of Information Through Teletext on Cable Television. This technology is similar in concept to RBDS for messaging in radios. It **uses** the Vertical Blanking Interval (VBI) portion of the channel's bandwidth to transmit text information. Used in conjunction with a local access channel dedicated to traffic information, images and text could be combined to provide a detailed local service.

+ Interactive Television. Many companies are now striving to be among the first to launch interactive television services. This technology provides significant opportunities for better dissemination of traveler information over **the** television by removing the one impediment to its improvement: the 30-second traffic report. Interactive TV traveler information services would allow the consumer to choose the information most useful to their purpose at the time that they most need it.

3.3.2.3 Evaluation

Currently available television technology profiles the same as radio technology against the evaluation criteria. It meets the criteria for accessibility, ease of use, and implementation cost.

In the area of user needs, current television technology is limited by the depth of reporting possible in short, infrequent segments. Television, however, may soon remove this limitation through the introduction of interactive information services.

3.3.3 Telephone

3.3.3.1 Current Technologies and Implementations

According to the Task 1 Inventory of Traveler Information Services for the I-95 Corridor, the telephone is the most widely used dissemination device in the Corridor. Currently available technology includes landline and cellular telephones. Telephones can be used to access audiotext, recorded or live information sources, and can be interactive in use.

3.3.3.2 Emerging Technologies

Emerging technologies in telephone communications include CDPD technology, which transmits data over a cellular telephone infrastructure during downtime for network.

3.3.3.3 Evaluation

Landline and cellular telephones perform well on all evaluation criteria for end-user devices, Because of interactive capabilities, they can meet user needs for pretrip and en route information for specific, real-time traffic and transit information. Telephones are universally accessible in the home and off ice, and growing in number as in-vehicle devices.

3.3.4 Pagers

3.3.4.1 Current Technologies and Implementations

This form of wireless technology has been in existence for more than 30 years and has been extremely effective in providing information under a variety of environments. This is a technology that has matured considerably and is a very practical, viable, and cost-effective method of transmitting real-time traffic and other traveler information in a timely manner.

Paging technology is used to broadcast messages to low-cost receivers. Alphanumeric paging allows those messages to carry text as well as numbers. Pagers are increasing in usage as a device for dissemination of traveler information services.

Paging is a wireless technology that facilitates transmitting information to specific individuals or a select group of individuals. Each message is coded so that it can be received only by the person for whom it is intended.

A typical paging system consists of a page being issued from a manually controlled paging encoder, or by using a voice phone connected to automatic paging terminals via the Public Switch Telephone (PST) network, or a Private Automatic Branch Exchange (PABX). The encoder or terminal accepts the input, validates it, converts the input to paging tones, and controls the system which will transmit the page to the user. In multiple transmitters, simulcast paging systems where all-call, sector call, and individual transmitter control are required, specific Simulcast System Controllers (SSC) are used. The SSC expands the capabilities of a paging terminal to control the large multiple transmitters simulcast system. The page must be distributed to simulcast paging transmitters. This is typically done using distributed Radio Frequency (RF) links or microwave. Typically, RF links, transmitters, or receivers operate at 72 MHz and 450 MHz.

There are two basic coding techniques used for paging. These are:

+ Tone coding format.

+ Binary recording format.

In additional to the signaling techniques used to select the particular receiver, there are several ways in which to convey the message. These are:

+ Tone only alert message.

+ Tone and voice message.

+ Display message.

Depending upon the radio paging system, one, two, or all three types of messages can be handled. In a system that is capable of receiving the information, the display pager (once selected) will respond with an audible tone followed by a data display message (such as phone number and/or person to call). There are, however, some pagers where the audible tone may be silenced and replaced with vibration or visual indication [Light-Emitting Diode (LED)/display message].

A typical paging system consists of a bay station, a terminal or encoder, and a number of pagers sharing a common RF frequency. Each alphanumeric pager has one or usually more “addresses”, called CAP codes. It is important to realize that pager service is a broadcast medium: all messages to all pagers that use a given frequency are broadcast together. It is up to the pager to collect messages meant for it out of the broadcast stream, and display them. It does this by comparing the header of each broadcast pager message to its set of CAP codes. When it receives a message whose CAP code matches one of the pager’s, that message is displayed.

Multiple CAP codes are a simple but very powerful way to individualize pagers. In a typical traveler information application, a pager may be addressed directly - that is, messages can be sent to it and it alone - or the pager can be addressed as part of a group. In the Toronto traffic pager application, which is quite typical, the metropolitan area is divided into four geographic zones. A subscriber can choose individual or a combination of zones. Pagers with more than four CAP codes are coming onto the market, and even subtler combinations will be possible in the near future.

As mentioned earlier, paging of traffic information is already taking place in Boston and Seattle. In Minnesota, Loral and Motorola are conducting an operational test for the Minnesota Department of Transportation that provides personalized traveler information to alphanumeric pagers.

Current pager technology is based on alphanumeric data transmission in one direction from a central server. It is primarily used for telephone/voice communication access and has succeeded in providing timely information to individual mobile environments.

A variation of the existing technology is satellite-based mobile paging that allows people using various modes of transportation, such as airlines and ocean going vessels, to receive paging information. The current systems are also capable of targeting specific areas by telephone **access** codes, i.e., a specific area code could be designated to receive certain sets of messages.

Extremely simple receiver requirements have lead to a proliferation of pagers in a multitude of application environments. Current technology also permits some receivers to be capable of sending limited information, such as an acknowledgment message, back to the receiving **stations.** These systems are typically connected to public switch telephone networks that provide access to landline telephone/voice system users.

3.3.4.2 Emerging Technologies

The emerging technology in the paging industry revolves around two-way paging capability, and the capability of pagers for communicating with PDAs and computers. These technologies would make the pager more interactive, and therefore more useful for traveler information service dissemination.

With the advent of low cost, high frequency transmitter receivers, tests demonstrating two-way paging are being conducted. The results of these tests indicate that this technology will be available to consumers in the very near future. This type of low cost two-way communication would be ideal for traveler information systems in a real-time environment. These systems would allow the transmission of basic American Standard Code for Information Interchange (ASCII) text as well as binary data. This technology allows for the deployment of traveler information to a wide spectrum of users without extensive infrastructure costs. These “two-way” pagers are not, in truth, “pagers” at all, but rather specialized receivers and transmitters of packetized data.

Standard pager technology, much miniaturized, is being used to provide wireless links to PDAs or portable computers. What is nothing less than an ordinary alphanumeric pager is built onto a PCMCIA card, where it can be inserted into a small computer and acts like an ordinary modem-but communicating (one way) with the base station. Various demonstrations are under way showing the power and effectiveness of this simple and inexpensive technology.

3.3.4.3 Evaluation

As far as meeting user needs, pagers perform fairly well because they can be programmed to receive personalized information. However, paging is not-at present-interactive, therefore denying the user the opportunity to follow up and further query the information provider.

Paging technology is very mature and provides for a reliable, capable medium of transmitting traveler information to specific users. In addition, the paging infrastructure is already in place and is both cost-effective and practical.

Paging technology is very accessible to average users for potential CTIS applications. The cost of these receivers is extremely moderate, and the service is provided by a variety of independent service providers. Most of the major service providers have plans or are currently involved in the ITS arena. Paging technology, therefore, is one of the easiest technologies to use for disseminating and receiving traveler information in a real-time environment. The current paging receivers are extremely simple and provide logical, legible text and/or graphic information to users.

The paging technology is a low-cost deployment technology that can be implemented **quickly and** effectively. Because of the existing infrastructure for disseminating other types of information by paging technology, there is a minimum investment cost associated with deploying this technology.

3.3.5 In-Vehicle Devices

In-vehicle navigation and information systems are gaining wider market penetration with each passing year. There are various products on the market providing some combination of the following services: geolocation, routing, tourist advisory information, and integrated traffic information.

3.3.5.1 Current Technologies and Implementations

For the purposes of this analysis, several in-vehicle devices have been identified that are capable of receiving real-time traffic information. Since this information is critical to a Traveler Information System, devices that provide routing advice without real-time traffic, although available, are not described or evaluated.

Volvo Dynaguide

Volvo has developed a product with a 4-inch, high quality, color screen, and Etak maps. Geolocation is determined through differentially corrected Global Positioning System (GPS) as well as the map matching capability built into the Etak software. The current model does provide an RBDS-standard link for traffic information which can be displayed as icons on the map. **The** icons can be clicked to call up text information on the traffic condition. Their next revision will allow integration of the information into the routing algorithm. Routing advice is provided graphically, not turn by turn. At this point, their emphasis appears to be accurate geolocation, traffic information, and routing as opposed to tourist-type information.

Traffic Master

Traffic Master has developed a simple, fairly inexpensive device called Y_Q to provide motorists with traffic information on 400 miles of motorways in Great Britain. This device, which receives data from infrared sensors placed at two mile intervals, provides a warning to the operations center when speeds on any segment dip below 30 miles per hour.

Data is then transmitted to all Y_Qs, using a radio signal, and the device provides details about congestion, traffic speeds, and accidents. The system can also transmit weather and news information and receive personal messages.

This system does not provide geolocation or routing algorithms, but is a straightforward, inexpensive way to transmit traffic information to the driver on a real-time basis.

Motorola's Mobile Navigation Assistant (MNA)

Motorola, as a partner in the Advance Project-an Intelligent Vehicle Highway Systems (ITS) operational test in Chicago-has developed an in-vehicle device capable of integrating traffic information into route guidance functions. The MNA serves as a two-way communication device. Speed information is transmitted to the operations center and real-time traffic condition information is received in real-time. Real-time traffic condition information is then used to calculate the best route for the given user's destination.

Two additional systems which do not currently have the capability to integrate traffic information but may soon are:

Zexel Navmate

The Zexel Navmate uses NavTech maps as its database displayed on a 4-inch color monitor. The system uses noncorrected GPS, dead reckoning, and map matching for geolocation. A modest level of tourist/yellow pages-type information is available. There is no external communication link currently available, so it does not have the ability to communicate or integrate real-time traffic information.

A route can be selected between two street addresses, points of interest, intersections, or freeway entrances or exits; and a route can be selected based on the shortest time, using freeways to the maximum, or avoiding freeways all together. After the route is calculated, the display begins with a graphical representation of the route and then walks the user through turn by turn with text, pointing arrows, a filling horizontal thermometer (which shows the remaining distance to the next maneuver), and concatenated speech voice prompts.

Delco Telepath 10Q

Delco has introduced a relatively inexpensive in-vehicle device that uses a simple arrow to display the direction the car should be traveling. There is also a simple two-line display similar in size to the display of a two-line pager. The display and controls are part of an integrated car entertainment system containing the navigational system, AM/FM radio, and a cassette player. Delco also has a heads-up display option to the Telepath 100 which allows the arrow and text information to appear to be floating out in front of the windshield - roughly above the car's grille.

In terms of geolocation, the Telepath 100 uses Etak maps, which are compressed into one PCMCIA card per city and one additional PCMCIA card for the interstate highway system. The system uses uncorrected GPS, a compass, and a link to the odometer for dead reckoning. To utilize the system, the user simply inserts a card for the appropriate city or highway system in a slot alongside the edge of the unit, and then enters origin and destination information. Currently, there is no communication link for real-time traffic.

3.3.5.2 Evaluation

Due to the volatility of the in-vehicle device market, the evaluation of these devices is difficult to quantify. However, based upon the evaluation criteria, the following conclusions can be drawn about in-vehicle devices:

- These devices, or at least some of them, clearly have the ability to meet the user' s needs for specific, real-time incident and congestion information.
- On the criteria of accessibility, these end-user devices do not meet the criteria as there is no currently available device capable of transmitting this information to a wide segment of the traveling public.
- Ease of use is almost wholly dependent upon which system is evaluated, but generally these devices are harder to use than cellular phones, pagers, and other potential dissemination devices.
- Implementation costs for these devices is also the highest among the devices evaluated, ranging from $300 to $2,000 to purchase, plus an additional monthly fee for service.

3.3.6 Kiosks

Several kiosk systems have been deployed to disseminate traveler information at sites where motorists and/or transit users gather.

3.3.6.1 Current Technologies and Implementations

Kiosks typically resemble automated teller machines, with video monitors mounted in stand-alone cabinets, or counter tops. Most kiosk systems employ touch screen technology to increase ease in use.

Some examples of recent kiosk projects involving traveler information systems include:

+ American Automobile Association (AAA) Travel Match Express. AAA deployed its prototype travel kiosk in 1992 to assess public reaction to self-service travel information. Twenty-five kiosks were located in hotels, airports, office buildings and retail establishments, and were offered free of charge to the public. Demand for use of the service far exceeded predictions, and user satisfaction was very high.

+ Los Angeles Smart Traveler Project. This project involved the installation of over 70 information kiosks in shopping malls and public buildings. The kiosks provide information on transit and traffic conditions, as well as online ridesharing opportunities. The information is provided by audiotext and videotext and is intended to increase transit usage.

+ Discover America. The Discover America InfoCenter Program was launched by the State and Territorial Tourism Offices in cooperation with the USA Marketing Council. Kiosks were placed in rest areas, welcome centers, restaurants, airports, malls, and other public areas around the country. Users can access information regarding weather and road reports (for areas where it is available), buy tickets to sporting events and concerts, or send post cards to relatives.

3.3.6.2 Emerging Technologies

In addition to interactive kiosks, large “read-only” travel boards displaying color-code segments with icons for incidents and construction will be utilized.

3.3.6.3 Evaluation

Kiosks have the capability to meet priority user needs by providing up-to-date, route-specific transit and traffic information for pretrip and enroute planning. The availability of kiosks is not as wide as telephone, radio, and television, and current designs tend to allow only one person access at a time. Kiosks are generally easy to use, and are well accepted by those that use them. Kiosks have a fairly high implementation cost to the information provider, but no cost to the user.

3.3.7 Computers and PDAs

PDAs, notebook and laptop computers, and home and office-based computers offer a wide variety of end-user device possibilities for traveler information services. PDAs and notebook computers can serve as both pretrip and en route end-user devices, while home and office computers allow pretrip planning to occur.

3.3.7.1 Current Technologies and Implementations

PDAs such as the Apple Newton being used in Minnesota DOT’s project Guidestar, and the former Way To Go Corporation’s PDA, used in San Francisco for transmitting real-time traffic information, provide wireless communications without the limitations of a pager. In Seattle, International Business Machines’ (IBM) Simon PDA receives real-time traffic and transit information in text format and on map displays.

Computers in the home and office provide yet another way to access traveler information for pre-trip planning. Some examples of such access were mentioned previously in the online systems description, including Internet Access to Southern California Freeway conditions, and North Carolina DOT construction information.

3.3.7.2 Emerging Technologies

One emerging technology created by SEI Information Systems called SEI EnRoute, is intended to provide a national dial-up directional information service from a host computer containing all of NavTech's map databases. SEI is currently seeking interest from national online services to mass market this product.

Another possibility for the dissemination of traveler information through computers is the downloading of specific personalized information through electronic mail -- on an as needed basis. This type of service could, for instance, alert a commuter in his/her off ice of traffic and transit conditions 10 minutes prior to a predesignated departure time on a daily basis. In addition to E-mail, more sophisticated technologies, such as intelligent agent processing, will emerge. Intelligent agent processing (e.g., telescript technology) enables users to specify their information needs, and then to have them fulfilled by personalized electronic agents that traverse various computer networks, performing local queries on remote systems.

3.3.7.3 Evaluation

PDAs and computers are relatively complicated to use from the end-user's perspective. Computers and PDAs certainly have the capability to meet the user's needs identified as part of our evaluation criteria. Specific real-time traffic and transit information and traveler advisories can easily be communicated through computer channels. Accessibility to PDAs and computers is growing, but is still far from the levels of accessibility of other dissemination media. Implementation cost of PDAs can be significant, although prices are expected to drop as PDAs become more prevalent.

3.3.8 Automated Facsimiles

3.3.8.1 Current Technologies and Implementations

Facsimiles generated by computer have quickly gained a prominent place in the dissemination of traveler information. Well documented services have been in operation in Toronto, Boston, and elsewhere for almost five years.

Facsimile machines provide an already widely used device as a means of disseminating traveler information. Computer-to-computer and computer-to-fax machine software programs, such as WinFax Pro and ProComm Plus, provide for increased capabilities for traveler information dissemination through this media. Services such as broadcast faxing and fax-on-demand allow personalized access to traveler information.

The facsimile technology used in traveler information dissemination resembles, **but is not identical** to, the technology used, for example, in an office's desktop computer. In this latter technology, a consumer software product, such as WinFax Pro, simulates a printer to a desktop computer's other applications. The software packages the "printout" into a faxable document, and manages the computer's fax/modem to emulate a fax machine.

This software is adaptable to the dissemination of traveler information, but, has a number of serious drawbacks with respect to the dissemination of traveler information that include:

+ Only a single fax can be transmitted to a single recipient at a time.

+ Typically, the entire computer is dedicated to the process of faxing - most fax/modems need computer management to operate, which prevents other programs from running at the same time.

However, there are methods for addressing these shortcomings. One potential method is to designate a fax “server”. The server will contain several fax cards and each of these cards, in turn, is attached to its own outgoing telephone line.

The application software on the computer (as distinct from the software on the fax cards) typically maintains subscription lists, archived copies of bulletins, copies of bulletins to be transmitted in the future, together with the traveler information system’s unique management tables. For example, the Toronto system mentioned above keeps a different subscription list and manages bulletins differently, depending on where the events described in the bulletin take place and on whether the event is marked as an “emergency”. In the latter case, for example, all other faxes are preempted, and a larger distribution list is used.

In this type of automated fax system, the fax cards themselves do all of the management of the faxing process, once they have received the text to be faxed and names and fax numbers (a multiple is possible) to receive a given bulletin.

3.3.8.2 Emerging Technologies

The direction of technological change in facsimile technology is for faxes to be faster, more robust, and for the application software driving it to be richer in features. Radical change in fax technology is not likely, the technology for text conversion and the protocol for transmitting facsimile data are mature technologies. Most fax machines today operate in the range of 9600 to 14,400 baud. Fax machines operating at 19,200, or possibly faster, will become common toward the end of this decade. This significantly speeds up the process of sending out information to multiple recipients.

The other key constraint of any fax software - the exclusive use of a circuit-switched public switched telephone number - is also not likely to change. However, fax “mailbox” services may come into use. To date, use of this technology has been limited, although it is not technologically very difficult. In such mailbox services, a single fax can be sent to a single mailbox, and multiple recipients can pick up the faxed item at their convenience.

3.3.8.3 Evaluation

This end-user device has the capability to meet user needs for pretrip planning real-time information on traffic and transit.

Computer-based facsimile technology is popular for disseminating traveler information because of its ability to transmit precise information in a well defined and coherent manner to a large number of recipients, more or less simultaneously.

Fax machines now have an extremely high penetration in the work place, and are penetrating into North American homes. Consequently, faxed text is highly accessible. The downside is that faxed text is difficult to manipulate once it is received. It can be translated to digital text, but this is an unreliable and computer intensive process.

Automated fax technology is extremely easy to use. The explosion of faxes in the 1980s testifies that the ease-of-use feature was critical in its widespread acceptance over E-mail technology, which is about the same age. Anyone with a fax machine needs no technical knowledge to receive a faxed traveler information bulletin. Similarly, on the transmitting side, automated technology puts everything out of sight of the operator, except time-to-time revisions of the subscriber list.

Implementing automatic fax technology is extremely inexpensive. Fax cards typically sell for under $1,000, and operate on any Personal Computer (PC). There are fax add-on cards for other platforms as well, in the same price range. Software to operate the technology is also less than $1,000. A modest investment will typically yield a powerful dissemination tool. Costs are not likely to drop significantly further, in part because they are so low and in part because these off-the-shelf prices can be dwarfed by the administration and customization effort.

Cost of implementation-while not a factor in most office locations-would be high at home for most people. However, as mentioned above, more and more computers are becoming capable of sending and receiving fax transmissions.

The number of fax cards can be increased to meet demand. However, unlike BBS technology for example, fax technology creates a pipeline through which all data must go, sometimes creating a queue. Nonetheless, a traveler information disseminator can balance their own costs with the length of queue they are willing to tolerate and expand appropriately. For example, a single wide-chassis PC accommodates eight fax boards. If the disseminator requires more than eight, this can be done through the use of more computers.

3.3.9 End-User Device Evaluation Summary

Table 3-1 provides a summary of the end-user device evaluation.

Table 3-1. End-User Device Technology Evaluation

Device	Priority 1 Accessibility	Priority 2 Ability to Meet User Needs	Priority 3 Interactivity	Priority 4 Cost of Implementation	Priority 5 Cost to User	Priority 6 Ease of Use
Radio	High	Medium	Low	High	High	High
Television	High	Medium	Low (unless interactive)	Medium	High	High
Telephone	High	High	High	Medium	High	High
Pagers	Medium	Medium	Low	Medium	High	High
In-Vehicle Devices	Low	High	High	Low	Low	Medium
Kiosks	Medium	High	High	High	Medium	High
Computers and PDAs	Medium	High	High	High	Medium	Medium
Faxing	Medium	High	Low	High	Medium	High
VMS	Medium	Medium	Low	High	High	High

High = meets all criteria Medium - partially meets criteria Low = does not meet criteria

4. DATA MANAGEMENT TECHNOLOGIES

4.1 DATABASE TECHNOLOGIES

The I-95 Corridor-wide Traveler Information System will be supported by a collection of regional (multiple cities and in some cases states) and subregional (normally metropolitan areas) WANs. As depicted in Figure 4-1, regional WANs provide support for moving data between regions, while subregional WANs provide support for collecting local data on a regional basis. A client-sewer architecture which provides regional data servers is envisioned. Client applications will collect and disseminate information across both the regional and subregional WANs.

As mentioned in Section 2 of this report, it is envisioned that each region will house a RTIC which will act as a clearinghouse for transportation information within its region. The I-95 Business Plan has identified four regions for the I-95 Corridor:

- New York/New Jersey/Connecticut (TRANSCOM) area.
- Washington/Baltimore/Northern Virginia area.
- Philadelphia/Camden/Wilmington area.
- Boston/Providence/Maine/Vermont/New Hampshire area.

Data servers will exist in each RTIC and will communicate by means of a regional WAN, provided by the IEN -- Project #1. Each of these regional data servers will collect and maintain data within its region. Note that each region may have multiple subregional WANs (e.g., the Baltimore/Washington/Northern Virginia region has three subregions). It is envisioned that the subregional WANs will be only partly supported by the IEN, since various private-sector initiatives will provide the remaining infrastructure. In addition to collecting regional data, the regional data servers will also disseminate information to other regional data servers and to the other nodes on the regional or subregional WAN.

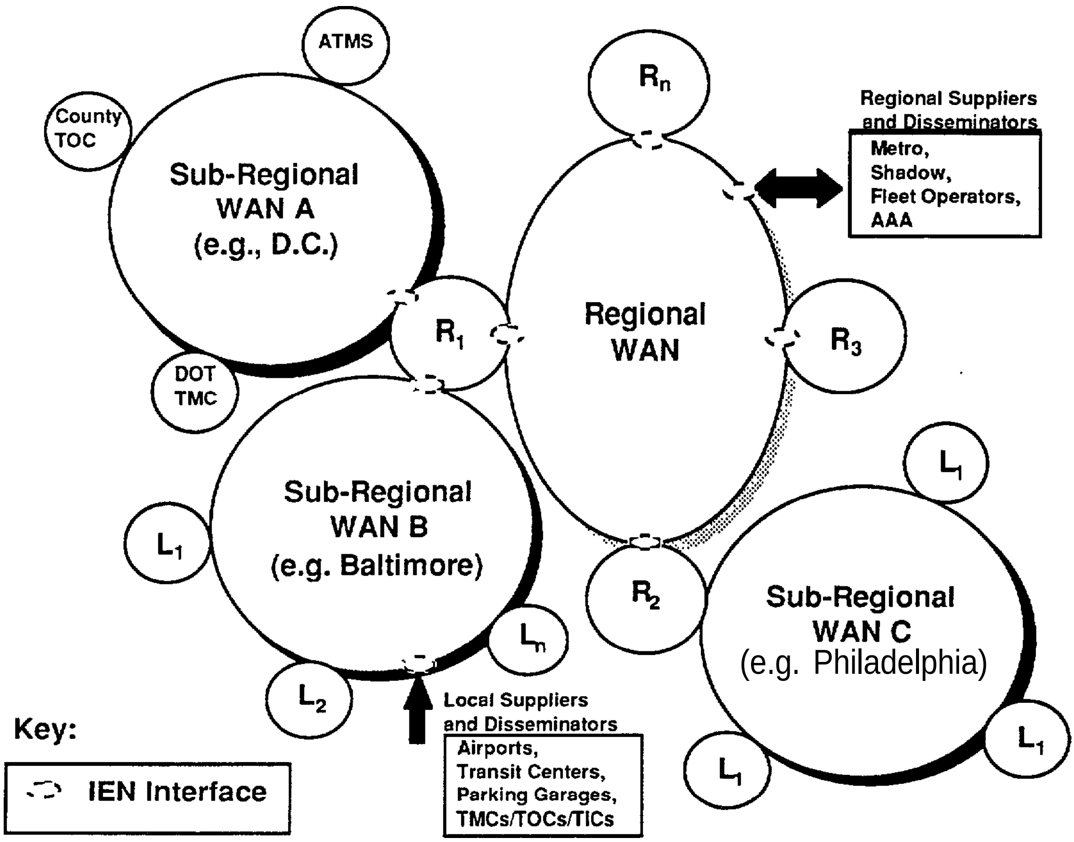

Figure 4- 1. Candidate CTIS Network Illustration

Local ITS systems within each subregion (metropolitan area) will have the capability to communicate and share data with other local ITS systems and the RTIC by way of a subregional WAN, provided by the IEN. These local ITS systems include Traffic Management Centers (TMC), TOCs, and TICs which exist at the state, county, and city level. In addition, the RTIC will receive information from local data suppliers and disseminators by means of the subregional WAN. Examples of local data suppliers and disseminators include airports, transit centers, emergency services agencies, freight/fleet operators, commercial traffic reporting firms, and parking garages.

4.1.1 Database Architecture

The database for the CTIS will be implemented as a distributed database throughout the I-95 Corridor. Although the database will be physically distributed among the RTIC (regional data servers) nodes, the database will appear logically as one database to the user. Each RTIC will maintain the data that is specific to its region.

Client applications will provide user services by connecting to a regional data server, available at each RTIC, in order to perform database searches. The actual location of the data, whether it be locally available on the Regional Data Server or whether it requires querying multiple regional data servers, will be transparent to the application.

4.1.2 Database Selection Process

In order to preserve current investments in technologies throughout the I-95 corridor and ensure system scalability and portability, Commercial-Off-The-Shelf (COTS) database management systems will form the foundation of the CTIS. COTS products facilitate lower development costs through the reduction in the amount of custom software. As a result, development time is minimized. Selecting COTS products which may operate on a variety of hardware platforms will ensure system scalability and portability.

There are two modern models of database management systems (DBMS), Relational Database Management Systems (RDBMS) and Object-Oriented Database Management Systems (OODBMS). Each of these DBMS derives its name from the method that data in the system is represented.

The data representation model in a RDBMS relies on data being stored in two-dimensional tables, each of these tables is known as a relation. The columns of an individual table are the attributes of the relations and the rows represent the elements that are related. If two tables (relations) contain a common column (attribute) then it is capable of relating a piece of information stored in a table to information contained in another table.

There are three important elements in an Object-oriented system, classes, messages, and objects. A class is a representation of real-world entities. It represents the entities compostion, behavior, and interfaces with other entities. An object is an instance of a class and objects communicate through messages. One of the major advantages of object-oriented systems is the notion of inheritance, new classes can be created by extending, modifying, and mixing classes.

The decision as to which type of database management system (relational or object oriented) should be selected will depend on the products ability to fulfill the CTIS database requirements identified in Task 3. An important consideration to ensure the system's ability to interoperate with a diverse set of applications and systems is the utilization of a standard Data Definition Language (DDL) and Data Manipulation Language (DML). Currently, a standard for OODBMS has not been established. Structured Query Language (SQL) is the standard language used by RDBMS. Since RDBMSs have been in existence longer than OODBMSs, RDBMS technology is more mature. This provides two distinct advantage:

+ Relational database systems outperform OODBMS. However, as time goes by the performance gap should diminish.

+ There is a larger population of people experienced in the use of relational database technology.

In addition, more COTS products have been developed to interface with RDBMSs than with OODBMSs. OODBMS technology is expected to continue to mature, and may eventually have the same type of widespread acceptance and utilization as RDBMS technology.

Since RDBMS technology is currently a more mature technology with established standards, the sample database technology survey listed in Tables 4-l and 4-2 evaluates the leading RDBMSs. The following information is presented:

- Table 4-1 includes requirements extracted from the CTIS Database Requirements identified in the Requirements Analysis Repot-l (Task 3). Only requirements that pertain to the COTS RDBMS products are listed. CTIS requirement numbers are included with each of these selection criteria.

+ Table 4-2 includes criteria not specifically listed in the CTIS Database Requirements which must be understood in order to select a robust database management system.

Each item is required unless listed as “BONUS”. “BONUS” items are features that can be reasonably supplied by hardware or application software. The existence of the “BONUS” functionality may reduce the need for custom code development. For example, a product that has the ability to exchange data between two or more RTICs (“replication server” technology) will reduce the amount of application development needed to implement the system.

Table 4-1. RDBMS Requirements

Number	Requirement	Informix	Ingres	Oracle	Sybase
1.	Must have direct access and application program interface to all data (DB 1, DB l.l,DB 1.1.1, DB 1.1.2)	Yes Informix ISQL, pre-compilers	Yes ISQL, Terminal Monitor, C pre-compiler, Report by Forms	Yes SQL*Plus Oracle Precomp-ilers	Yes Open Client, Apt-Forms, Momentum tools, ISQL
2.	Must be multiple user/application system (DB 1.3, DB 1.3.1)	Yes	Yes	Yes	Yes
3.	Comply with industry standard DML and storage formats. (DB 1.4)	At SQL FIPS 127-I Level 2	At SQL Level 2 FIPS 127-1 almost 2	At SQL FIPS 127-2 Level 2 includes flagger for non-FIPS SQL	At SQL FIPS 127-2 Level 2 includes flagger for non-FIPS SQL
4.	Must comply with structured data: (DB 1.4.1)	At SQL FIPS 127-1 Level 2	At SQL Level 2	At SQL FIPS 127-2 Level 2	At SQL FIPS 127-2 Level 2

Table 4-1. RDBMS Requirements (Con t'd)

Number	Requirement	Informix	Igres	Oracle	Sybase
5.	Must be able to prioritize transactions and estimate query response time (DB3)	Yes. DB-Monitor, prioritize, and estimate	Yes. Inter-active Performance Monitor (IPM) can estimate, but not before data	Utility monitor will not estimate	SQL Monitor limit rows returned, shows CPU and queries, etc.
6. Bonus	Must have a user friendly front end for *ad* hoc queries and DBA functions (DB 2, DB 2.3). The front-end tool must support: - Building and storing custom reports (DB 2, DB 2.3) - Online help (DB 2.4)	Informix online administra-tion, DBA, 4GL, Forms (Motif), Menu	ASK Windows 4GL-GUI (Motif)	SQL*DBA, Browser, Data Query, Forms (Motif)	Momentum (GUI - Motif) Build, Gain, Enterprise
7.	Must have access control to the database and functions (DB 3)	Yes	Yes	Yes	Yes

Table 4-1. RDBMS Requirements (Cont'd)

Number	Requirement	Informix	Ingres	Oracle	Sybase
8	Privileges must be established on the database, table, view, and procedure levels. Maybe even at the row and column levels (DB 3.1)	DB, table, view select, and update at column	DB system login, DBA grant access, table, view, to the column level on updates	DB login, table, view, stored procedures, use view for column privileges	DB login, table, view, stored procedures, use view for column privleges, secure server provides row and column privelege
9.	Provide privilege authorization based on identified groups of users (DB 3.2)	Yes	Yes	Yes	Yes
10.	Provide access control procedures (login, password, etc.) (DB 3.4)	Yes	Yes	Yes	Yes
11.	Provide user-friendly dictionary facilities for defining, maintaining, and updating RTIC database structures, map attribute/feature data and other geographic data structures (DB 4, DB 4.1)	Informix View Point, DBA, SQL	ING Menu -Forms -Menu -Report -1SQL for DBA	Yes SQL*Plus Browser	Yes ISQL DWB
12.	Support creation and modification of primary and secondary search indices of attributes (Bonus if supports different index structures including BTREE/HASH and ASCENDING/DESCENDING orders). (DB 4.2)	Parellel index builds	Yes Optimizer knows which to use, HASH, BTREE, ISAM. May be able to trick optimizer	Yes Override the optimizer by using a HINT-BTREE, HASH, Cluster data	Yes Optimizer uses BTREE. May be able to trick optimizer

Table 4-1 RDBMS Requirements (Cont'd)

Number	Requirement	Informix	Ingres	Oracle	Sybase
13.	Support addition of tables, GIS layers, and attributes to existing structures without bringing down the database (D 4.3))	Yes	Yes	Yes	Yes
14.	Provide capability to store database files and tables across multiple disk volumes (DB 4.4)	Yes	Yes	Yes	Yes
15.	Support referential integrity, data element format checks, and valid value constraints (i.e., triggers and rules) (DB 4.6, DB 4.6.1, DB 4.6.2, DB 4.6.3)	Triggers, rules, stored procedures	Triggers, rules, stored procedures	Yes	Yes
16. Bonus	Support an integrated view of all data (DB 4.7)	IRDS	Use a third party vendor	Case Designer	Yes DEFT - on Macintosh for ERDs
17.	Provide automated and procedural loading capabilities (DB 5, DB 5.1)	Yes Import/ Export	Yes Copy command in and out reads ASCII files	SQL* Loader, Export /Import	BCP
18.	Support online backup, including manual and automatic (DB 6)	Yes Manually	Yes Manually	Yes Manually by file, table, space, or DB	Yes Manual, Auto via scripts
19. Bonus	Support data mirroring (DB 6.1)	Yes	Yes	Yes	Yes
20.	Provide automated capability for checkpoints, dump files, journals, and transaction logs (DB 6.2)	Journaling, rollback, transaction logs	Yes Journaling, rollback, transaction logs	Journaling, rollback, transaction logs	Check-points, dumpfiles, and transaction logs
21. Bonus	Provide procedures for creating, storing, and managing archives of the database (DB 6.3)		Third party vendor	Third party vendor or manual backup DB and logs	Third party vendor or manual backup DB and logs

Table 4-1. RDBMS Requirements (Cont'd)

Number	Requirement	Informix	Ingres	Oracle	Sybase
22.	Support automatic and procedural database recovery (DB 7)	Yes	Yes	Yes	Yes
23, Bonus	Provide 2-way exchange of structured data between two or more remote RTICs (replication) (DB 1.2)	Yes Master slave - master writes to slave - slave is read only	Yes Peer-to-peer read and write both ways, out this summer	Yes Distributed databases - read only for replicated data - out this summer - will be able to update data	Yes True Replication Server- read and write both ways

Table 4-2. Additional RDBMS Evaluation Criteria

Number	Requirement	Informix	Ingres	Oracle	Sybase
24.	Hardware and operating systems supported (for portability and scalability, if necessary)	HP, Sun, IBM, etc. UNIX, Macintosh, DOS, Windows, etc.	PC and UNIX workstations, UNIX, Windows, VMS, etc.	UNIX, VMS, etc. Most hardware platforms	UNIX, VMS, etc. Most hardware platforms
25.	Language supported (e.g., C, C++, etc.)	C, Fortran, Cobol, SQL, Ada	C, Fortran, Cobol, SQL Ada, Basic	C, Cobol, Ada, Fortran, Pascal, PL/l, can use C complier for C++ code	C, Fortran, C++, Ada
26.	Locking - Table level - Page level - Row level Page level locking is the highest granularity accepted. However, due to the "real-time" sensor activity, row level is probably preferable	Row page, or table	Table, page to row by forcing the row to a page level	Row level	Page level (System 11: Row level)
27.	Maximum number of tables per database	Unlimited	Unlimited	Unlimited	Unlimited
28.	Maximum number of columns per table	33,767	300	254	255
29.	Maximum size of character column	32,511 bytes	2GB BLOB 2,000K varchar field	2Gbyte	2G byte
30.	Support of large text/binary/image columns (BLOB) Rasterized Closed-Circuit Television (CCTV) data storage required also	BLOBs and 2Gbyte text field	BLOBs	Maximum character field 2Gbyte	BLOB Field

Table 4-2. Additional RDBMS Evaluation Criteria (Cont'd)

Number	Requirement	Informix	Ingres	Oracle	Sybase
31.	Maximum database size	Unlimited	Unlimited	Unlimited	8 terabyte
32.	Type of optimizer (cost-based or syntax-based) Cost-based optimizer with the capability to override the query plan selection is preferred	Cost-based Yes With explain option	Cost-based Yes By use of SQL	Cost-based Yes By use of SQL	Cost-based Yes By use of SQL
33.	Support user-defined datatypes	No	Yes	Yes	Yes
34.	Provide stored procedures	Yes	Yes	Yes	Yes
35.	Provide ability to automatically update remote databases (i.e., replication server)	Gateway product, but not a specific server	Yes	Yes	Yes
36.	Interfaces to other DB or GIS products	DB2, Sybase, Oracle, OBDC, EDS, SQL, etc.	IMS, DB2, RDB, remote calls to Sybase, Oracle	Yes Sybase, RDB, RMS, DB2, GDS, ARC/INFO	Yes Oracle, Ingres, Inforniix, RDB, RMS, DB2, GDS, ARC/INFO

Table 4-2. Additional RDBMS Evaluation Criteria (Cont'd)

Number	Requirement	Informix	Ingres	Oracle	Sybase
37.	Scalable architecture allowing a variety of configurations, including multi-threaded, symmetrical multi-processing, and client/server	Client/ Server, multi-processing, multi-threaded	Yes multi-processing, multi-thread, client/ server	Multi-processing, multi-thread, client/ server	Multi-processing, multi-thread, client/ server
38.	Minimum memory/disk space requirements	770 Kbyte server, 65 Kbyte user process virtual address requirements, 3 Mbyte disk space	8-12 Mbyte RAM (preferably 32) 120 Mbyte disk space	Platform dependent	12 Mbyte RAM, 16 Mbyte hard disk

4.1.3 Product Summary

The COTS database management system products are continually evolving as each vendor tries to surpass the other vendors with “bigger and better” features. New product versions are released nearly every quarter. As a result of this competitive market, the major RDBMSs have few distinct functionalities. For example, all four RDBMSs evaluated operate on a variety of hardware platforms, support multiple simultaneous users, provide user-friendly *ad-hoc* query capabilities, provide privilege control, support online schema modifications, support online backups, provide bulk data load capabilities, interface with Third Generation Languages (3GL) such as “C”, and provide trigger and rule support at the database level. The distinct functionalities change as each vendor releases a new version of the product.

The OODBMS products are expected to continue to mature and the establishment of standards is expected to eventually occur. Therefore, the selection of the specific database management system that should be utilized should be determined closer to the time at which system development will occur. At that time, the database technology survey should be updated. OODBMS technology should be reviewed if standards are being established, robust tools are available for use, and a variety of hardware platforms are supported.

4.2 GIS TECHNOLOGIES

Based on the requirements of the CTIS, Geographic Information Systems (GIS) are an important technology for this system. Nearly all CTIS subsystems have very strong spatial components that would be facilitated by tools and capabilities available in a GIS. For instance, vehicle probe-data and weather contours are easily associated and visualized in a geographic context. Several GIS products include network analyses and routing algorithms, complete with user-defined impedances and single/multiple nodes, to address vehicle routing and scheduling. Data integration, query, and analysis are major strengths of geographic systems. These capabilities allow numerous diverse data types to be superimposed and visually related, and provide tools to spatially query data in ways that are more intuitive and useful than traditional RDBMS query techniques.

For evaluation purposes, four UNIX GIS product suites were selected. Each product line is comprised of several subsystems and modules that contribute to functional completeness. These four products were selected based on the requirement for UNIX support:

+ ARC/INFO 6.1 .1; Environmental Systems Research Institute (ESRI), Inc.
+ Maplnfo 2.0; Maplnfo Corporation,
+ GenaMap 5.2; Genasys II, Inc.
+ MGE 5.0; Intergraph Corporation.

The Genasys and Intergraph tools were demonstrated by their respective vendors. As a result of other efforts, knowledge of ARC/INFO and Maplnfo was available. Input was also obtained from the 1994 *International GIS Sourcebook,* product manuals, and marketing literature. In addition to these four, many other candidates exist, such as Geographic Data Systems (GDS), and Sherrill-Lubinski's Graphic Modeling System (SL-GMS).

4.2.1 Product Descriptions

The ARC/INFO product suite comprises a very full-featured GIS. The product does not have the user-friendly Graphical User Interface (GUI) and tools to allow the beginning user to start work immediately with the product. The power, flexibility, and complexity arise from the extensive number of commands and parameters in each module. However, the ARC Macro Language allows interface development and extendibility to other programming tools to facilitate development and integration of ARC/INFO into a myriad of applications. The ARC/Software Development Language (SDL) provides a low-level interface for C programmers to enhance and add functionality. Several general-purpose graphical interfaces are available from the vendor, as well as from third party developers. The ability to develop RTIC applications with GIS Application Programming Interfaces (API), is limited with ARC/INFO. The ARC Macro Language hinders embedded application development by requiring application control. In addition, ARC/INFO (as well as ARCVIEW) are lacking with respect to real-time updates of map objects. These functions are, however, continually readdressed by ESRI as they attempt to penetrate the ITS ATMS and ATIS markets.

Intergraph's MGE suite of tools provides exhaustive GIS, image processing, and Computer-Aided Design (CAD) functionality. The complete set of tools is driven by a graphics engine provided by MicroStation (Bentley Systems Inc., an affiliate of Intergraph). The MGE modules and tools are completely MGE-integrated through a flexible graphical interface, allowing point-and-click access to GIS functions. Several levels of customization are available including simple user interface forms generation and Microstation Development Language.

Display speed is addressed via internal memory-based graphics management. The major detriment, and perhaps eliminating factor, is the requirement for Intergraph proprietary hardware. Intergraph's MGE tools run on the Intergraph flavor of UNIX, which is POSIX compliant, but only available for proprietary Intergraph hardware. MGE is also available on the non-UNIX POSIX-compliant Windows NT operating system.

GenaMap and associated modules also provide complete functionality. The system is command driven, in a similar manner to ARC/INFO, though there is a greater level of integration **and** consistency of command structure throughout the Genasys product suite. Genasys promotes a 'seamless' data model, allowing access and reference to very large volumes of data without concern for the underlying data storage structure. Tools for application development and customization are provided at several levels. The GENIUS interface builder uses object-based forms development with attached macro commands. Genasys provides a complete application programming interface for integrating GIS functionality for specific application needs.

Asynchronous communication, from sources such as vehicle probes, commercial traffic reporting firms, and user input is supported and is an important feature for real-time data manipulation and analysis. Note that ARC/INFO is planning a new communications protocol for the next product revision; no details were available. GenaMap will build topology and redisplay data on the fly, two considerable time saving features.

In an attempt to differentiate themselves in the GIS market, MapInfo targets their product as a desktop mapping solution instead of a full featured - and hence, complex - GIS. As a result, MapInfo has the least comprehensive functionality, and the lowest cost. MapInfo promotes a very strong third-party development and vendor community which provides value-added products and applications to augment the product capabilities.

MapInfo has several critical limitations: raster data is not supported but will be supported in the next version; vector data has no topology; there are no tools for network analysis, surface modeling and visualization, or image processing/manipulation; performance is suitable for smaller local data sets but would be inadequate for querying and feeding data from large, SQL-based databases: and data conversion and import is very limited.

4.2.2 Analvsis Results

The ARC/INFO, GenaMap, and MGE product suites contain the comprehensive functionality to provide adequate support for CTIS. There are several factors that must be considered before recommending a final solution.

None of the products were tested or demonstrated against the SQL RDBMS; therefore, the complexity of setup and expected performance are unknowns. Based on our experience, we believe neither the current versions of ESRl's ARC/INFO and Genasys's GenaMap have sufficient performance capabilities for real-time data display from a SQL RDBMS, *without* an underlying enhancement to the technology. Enhancing the performance of either product would not be a great issue. Intergraph's MGE product may provide the best performance in this environment due to the in-memory graphics management. However, if hardware purchase, or the use of proprietary hardware, are not feasible or desirable options, then MGE cannot be considered a viable candidate.

The planned timing for application prototyping and deployment must be considered since ESRI, Genasys, and MapInfo are planning summer 1995 revisions to their products that will add significant new functionality. We strongly recommend that any decision should immediately be validated by a trial development license for prototyping and verification purposes.

Table 4-3 is a product matrix for the major components of each product suite. A summary of the analysis of the individual products capabilities is provided in Table 4-4.

Table 4-3. GIS Product Matrix

Product Suite	Module Function
ARC/INFO 6.1 .1	Vector mapping/editing; ARC Macro Language; spatial analysis; data conversions
GRID	Raster and cell-based data manipulation/processing
TIN	Surface modeling
NETWORK	Network analysis/dynamic segmentation
COG0	Coordinate geometry
SDL	Software development library
ARCVIEW	Viewing tool to support real-time display.
MapInfo 2.0	Vector mapping/editing; spatial analysis
MapBasic	Development language
Runtime Licenses	Runtime applications distribution
ARCLink	ARC/INFO data conversion
CADLink	CAD data conversion
SenaMap 5.2	Vector mapping/editing; COGO; network analysis; spatial analysis; GENIUS user interface builder
GenaCell	Raster and cell-based data manipulation/processing
GenaRave	Raster-vector data conversion: one license per site
API	Programming interface for C
Runtime License	Runtime application distribution
Reformatters	Data reformatting/conversion
GenaCivil (4 modules)	CAD; TIN; road design; hydrological analysis
MGE SX	
Nucleus	Foundation for all products; project management; mapping
Mapper	Capture, manipulation, validating data
Administrator	System and database tools; one seat needed per LAN
Analyst	Spatial analysis/query/display
Network Analyst	Network analysis
Grid Analyst	Raster manipulation/analysis; raster-vector conversion
Imager	MSI enhancement/analysis
Terrain Modeler	Surface modeling
Projection Manager	Map projection and coordinate system transformations
Map Finisher	Map composition: plot symbolization
Microstation	CAD software: underlying graphics engine
GIS Translators	Data conversion
DTM Translators	Convert DEM/DTED to terrain format
CogoWorks	Coordinate geometry

Table 4-4. GIS Analysis

Requirement	ESRI	MapInfo	Genasys	Intergraph
High Priority				
Availability on platforms running POSIX-compliant UNIX	X	X	X	X Requires IG hardware
Multi-user, distributed networking support	X	X	X	X
Links to SQL databases (e.g., Oracle, Sybase)	X	X	X	X
Provide macro capability to build graphical interface tools that may be called from the operating system or through a 3GL such as C, C++, FORTRAN	X	X	X	X
Performance to support real-time data display, dynamic graphics	X Display speed and dynamic features enhance-ments	Highly unlikely	More likely in next release or with techno-logy enhance-**ment**	X Must be fully **tested**
Support for asynchronous communications	Next release	No	X	?
Perform coordinate transform among: State Plane, Lat/Long, UTM	XXX	XXX	XXX	XXX
Overlay display of topological data over raster data	X	No raster	X	X
Convert topological data to raster data	X	X (non topo)	X	X
Convert raster data to topological Datatypes	X	No raster	X	X

Table 4-4. GIS Analysis (Cont'd)

Requirement	ESRI	MapInfo	Genasys	Intergraph
Generate buffers around points, arcs, and polygons	XXX	XXX	XXX	XXX
Measure straight-line distance Measure distance along arcs Measure area within polygon	X X X	X No X	X X X	X X X
Provide address matching	X	X	X	X
Import and export the following: ASCII ARC DIME TIGER ETAK ERDAS LAN DSAT SPOT DEM Digital Ortho DCW (VPF)	 i/e i/e i/e i/e i/e i/e i/e i/e i/e i i/e	 i/e i/e w/ARCLink -- -- 	 i/e i i i i i/e i I i/e i i	 i/e -- i/e i/e i i/e i/e i/e i/e I i/e
Provide following network analyses: Shortest path, lowest cost/resistance, Point-to-point/multiple point route allocation, Accumulative network attributes	 XX XX X	 No no X No	 XX XNo X	 XX XX X
Dynamic segmentation	X	No	No	X
User interface capabilities including: Zoom and pan-by-pointing device Display of map coordinates by pointing device Features selectively displayed by attribute Image displayed on multiple screens	 X X X X	 X X X X	 X X X ?	 X X X X

Table 4-4. GIS Analysis (Cont'd)

Requirement	ESRI	MapInfo	Genasys	Intergraph
Selection of features based on attributes, features types, Boolean criteria	X	X	X	X
Annotate maps with symbols (including transportation symbolization) from vendor provided library. Size selectable. Tie symbol and size to attribute values	X X X	X X X	X X X	X X X
Text annotation: font size color angle wrapping to objects	 X X X X X	 X X X X X	 X X X X X	 X X X X X
Support output to film recorder, electrostatic plotters, inkjet plotters, and pen plotters	XXXX	XXXX	XXXX	XXXX
Perform datum transformation between a spheroid, NAD27, and NAD83	X	X	X	X
Transform data among various projections, which must include orthographic	X	X	X	X
Support storage and analysis of the topological spatial datatypes in FIPS 173	X	No	X	X
Support storage and analysis on the raster spatial datatypes defined in FIPS 173	X	No	X	X
Support spatial metadata as specified in the proposed amendment to the FIPS 173	X	No	X	X

Table 4-4. GIS Analysis (Cont'd)

Requirement	ESRI	MapInfo	Genasys	Intergraph
Moderate Priority				
Detect point in/on polygon, arc intersection or inclusion within polygon, arc-with-arc intersections	X X X	X X	X X X	X X X
Unify or intersect polygons and their attributes	X	X	X	X
Merge or subsegment arcs based on location or attribute	X attr		X	X attr
Support coordinate entry from: digitizers scanners mouse GPS receivers keyboard	 X X X X X	 X No X X X	 X X X X X	 X X X X X
Support output to bit-mapped video display and to laser printers	X	X	X	X
Ability to reclassify or record features/attributes	X	X	X	X
Overlay, add, or subtract maps. Merge maps according to Boolean expressions	XX X	XX X	XX X	XX X
Create or import customized symbols for map annotation	X	No	X	X
Links to CAD	i/e DXF + ARC/ CAD	i/e DXF thru CADLink	i/e DXF + GenaCivil module	i/e DXF + Micro station
Links to mathematical and statistical analysis packages	X SDL + third party packages	X MAPBasic third party products	X GEN API	X
Seamless spatial data model	New release	No	X (claims to be)	?

Table 4-4. GIS Analysis (cont.)

Requirement	ESRI	MapInfo	Genasys	Intergraph
Low Priority				
Generate a viewshed for point or arc	X	No	X	X
Proximity analysis such as spatial autocorrelation	X	No	X	X
Provide surface analysis capabilities such as: interpolation of elevation data generation of cross sections cut and fill	 X X X	 No No No	 X X X	 X X X
Links to expert systems	X	No	Pattern recog	X
Links to image processing software	X + many capabilities included	No	X + some built In capabilities	X +many capabilities included
Extended display capabilities including: multiple maps on a single plot, thematic layer draping, animation, 3D	 XX xx	 X no No no	 X no NoX	 xx xx
Store screen snapshots for replay	X	X	X	X
Determine number of occurrences along arc or within polygon	X X	No	X	X

5. CONCLUSION

This report has identified and evaluated CTIS technologies in the areas of data management and data dissemination. Data management evaluations addressed Database Management Systems (and Geographical information Systems. Data dissemination evaluations addressed various data delivery mechanisms and associated end-user devices.It is recommended that these evaluations be re-addressed (i.e., updated) when the implementation phases (Phase II and on) of CTIS begin.

In addition to these technologies, various other CTIS-relevant technologies were investigated. These include trip planning, data fusion, map databases, wireless communication systems, and navigation and route planning systems. These technologies and vendors are documented in Appendix G. This Appendix provides insight into the full gamut of relevant TIS technologies and vendors.