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PROJECT # 8 (95008)
Task 5 - Traveler Information Services (TIS)

TIS Conceptual Design

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1.0 INTRODUCTION

This Working Paper, the fifth in a series of six, summarizes the results of Task 5 – System Conceptual Design – of the Traveler Information Services (TIS) Project. This Working Paper is submitted to the Projects 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 included in the Final Report for this Project.

1.1 PROJECT OBJECTIVES

The I-95 Traveler Information Services 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 Traveler Information Services (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 Projects objectives are:

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

+ To identify opportunities and principles for private/public partnering in providing TIS.

1.2 TASK 5 OBJECTIVES

The primary focus of this Task 5 is to develop a conceptual design for the Corridor-wide Traveler Information Services (CTIS). The conceptual design should account for the key requirements defined in Task 2 (TIS Coals Definition) and Task 3 (Requirements Analysis): for the TIS opportunities identified in Task 1 (Inventory of TIS and Commercial Opportunities); and the institutional framework recommended in Task 6 (Scenarios for Private Sector/Partnership TIS Opportunities). Notice that Task 6 was completed before this Task 5.

To fulfill this purpose of Task 5, the following task objectives were achieved:

+ Development of the CTIS logical and physical architectures.
+ Decomposition of the CTIS system into appropriate subsystems, components, and elements.
+ Specification of design requirements at the component levels, including communications, hardware, and software.
+ Estimation of system cost.

1.3 TASK 5 APPROACH

The approach was to use the relevant results of all the other tasks of the project to create a design concept that meets the Corridor TIS requirements. The overall process, as shown in Figure l-1, consists of several primary activities, including architecture development and design concept development for system components that support the architecture.

The design process followed a functional decomposition technique (using a Computer-Aided Software Engineering, CASE, tool) to ensure system consistency from one level to the next. In the decomposition of the system, input and output data requirements for all system elements were defined. In addition, key features of the design concept were described by various design requirements.

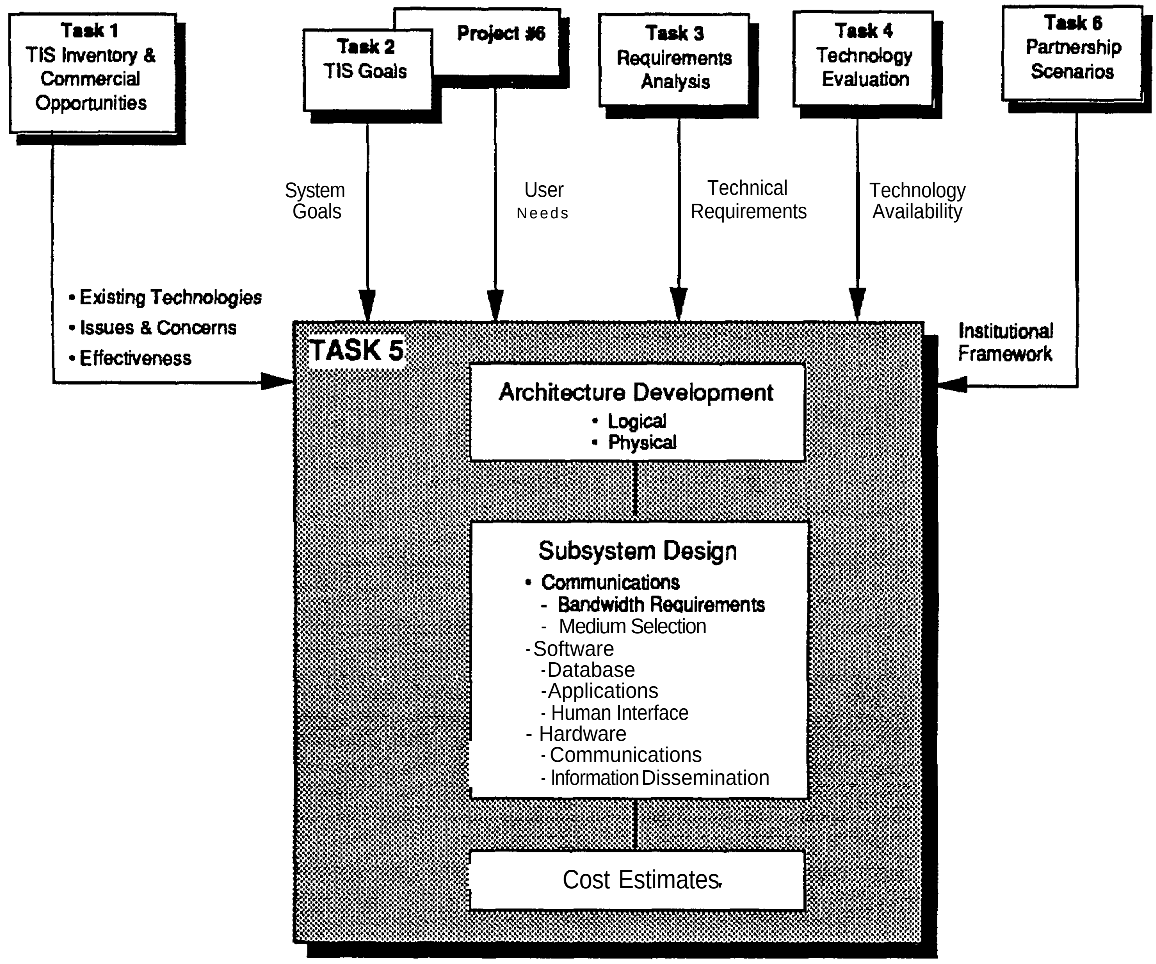


Figure 1-1 Task 5 Approach

Because the systems architecture and the conceptual design follow the vision of the CTIS system described in the Working Paper for Task 3, it is important to briefly summarize this vision to more easily understand the product of this task. This summary is provided below.

1.4 CTIS VISION

A "vision" of the CTIS was described in Task 3 – Requirements Analysis. This vision, as summarized in Table 1-1, has three phases and is seen from the perspectives of an end user and a CTIS operator. These phases provide a basis for the proposed evolutionary deployment of the CTIS architecture as discussed in Section 2 of this Working Paper.

Table 1-1 Summary of a Three-Phase Vision of CTIS

PHASE	END-USER'S VIEW	CTIS OPERATOR'S VIEW
Phase I: Baseline Information Dissemination Little or free of charge Designed for near-term public policy objectives Designed to build momentum for CTIS Broadcast and dial-in services: telephone, electronic bulletin board, faxes, and pagers	• Multimodal information for pre-trip planning • Real-time incident and congestion information • Infrastructure-based en route information • Substantially subsidized by the public sector • Enhanced information for commercial vehicle operators, perhaps for a fee. • Enhanced information for commercial radio and TV broadcasters • Enhanced information for public sector's traffic incident management	• Coordination with transportation operating agencies to gather data • Reliance on commercial traffic reporting firms to supplement database • Enhanced incident management support to traffic operations agencies • Data gathering and dissemination is manually intensive
Phase II: Multimedia, Interactive Information Dissemination Proliferation of private sector information disseminators Availability of interactive media More extensive real-time transportation condition information	• Wide-spread dissemination and use of traveler information • On-demand and personalized travel information • Easy access to information through telephone, TV, on-line services, and personal communication devices • Value-added travel information: dynamic trip planning, routing and pre-trip guidance, traffic prediction, etc. • Users' willingness to pay for information, thus reducing public subsidy needs • Expansion of public agencies deployment of en route information dissemination systems	• Availability of more traffic information sources through additional TOCs/TMCs • Reduced reliance on commercial traffic reporting firms for supplemental data • Increased level of automation in data gathering, fusion, and dissemination • increased level of sophistication of information dissemination methods • New services to be provided such as traffic and travel modeling and prediction
Phase III: Real-time, In-vehicle Information Dissemination Wide-spread deployment of in-vehicle navigation and information devices Availability of two-way communication between vehicles and infrastructure Corridor-wide real-time transportation and travel information Sophisticated home/office communications devices suitable for comprehensive pre-trip planning	• Easy access, real-time travel information at home, at work, and during trips • Well informed travel choices • Competitive and affordable traveler information services	• Richer traffic information contributed by vehicle probe data • High level of information gathering and dissemination automation, though more complex because of a larger customer base • Shift towards private, for profit operations

1.5 ORGANIZATION OF PAPER

The remainder of the Working Paper is organized around the task objectives and the major subsystems of the CTIS. It includes 9 Sections as follows:

- Section 2: CTIS Architecture
- Section 3: Communications Subsystem
- Section 4: Data Management Subsystem
- Section 5: Data Distribution Subsystem
- Section 6: Trip Planning Subsystem
- Section 7: Trip Guidance Subsystem
- Section 8: Dissemination Subsystem
- Section 9: Common Services Subsystem
- Section 10: System Cost Estimates

2.0 CTIS ARCHITECTURE

This section will present the logical and physical architectures for the Corridor-wide Traveler Information System. In addition, major CTIS standards to be used in the detailed design and implementation phases will be described.

A structured, systems engineering methodology was followed for the development of this architecture. In performing this analysis, a functional decomposition technique, based on the Yourdon/DeMarco and Gane/Sarson methodologies, and a computer-aided software engineering (CASE) environment was utilized. Table 2-l summarizes the notation used in the diagrams for this project.

Finally, supporting documents that provide details to the conceptual design were generated during the systems engineering process and have been included in this report. These include the following:

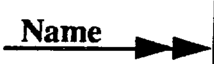
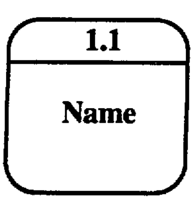
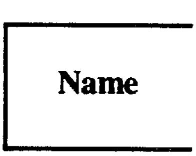
+ CTIS Data Dictionary (reference Appendix H)
+ CTIS Database Schema (reference Appendix I)
+ Requirements to Design Traceability Matrix (Appendix J)

2.1 HIGH-LEVEL LOGICAL ARCHITECTURE

A well designed CTIS architecture is one that fully complies with all agencies and end users needs, and which provides interfaces for existing and planned systems. To understand the various types of external interfaces with CTIS, a context diagram was developed. This section discusses the context for the I-95 Corridor-wide Traveler Information Services and provides an overview of the major CTIS subsystems. This logical architecture provides a foundation for deriving and instantiating a physical architecture. The physical architecture will be presented in section 2.2.

It should be noted that this section only presents the high-level logical architecture. The details of each subsystem are presented in sections 3 through 9.

Table 2-1. Design Methodology Notation

Notation	Description
	Square boxes are external entities to the system. They are normally found on the context diagram. These are entities that transmit information to and receive information from the system.
	The arrow depicts a dataflow. Dataflows on the context diagram are normally composite dataflows. That is, they consist of sets of logically grouped data. In lower-level diagrams, composite dataflows are split into individual pieces. Dataflows and their composition are defined in a data dictionary.
	Same as above, except this dataflow depicts a continuous or synchronous flow of data between an external entity and the system. To adequately address communication requirements, it is important that the context diagram differentiate between synchronous and asynchronous interfaces. For composite data flows, if one or more element of the composite flow is synchronous, the whole flow has been tagged as synchronous.
	Square or rectangular boxes with numbers represent a process or functionality. In the context of this report the highest level is a subsystem, the intermediate level are components, and the lowest level elements. These boxes are functional areas of the system, they are not necessarily software processes. The number contained with the box maintains the tracking of parent and child relationships among the processes.
	Rectangular boxes without right hand borders indicate data stores for the system. These data stores may include databases, flat files, and computer memory.

2.1.1 Logical TIS Context

Figure 2-1 presents the context diagram of the I-95 Corridor Traveler Information Services. It shows the CTIS interfaces with external entities. Each external entity acts as a source and/or sink of the CTIS information. The CTIS receives information from the information sources for further processing and dissemination to the information sinks. The information sinks are mainly the CTIS users; but also include other entities with which CTIS shares data. A brief description of TIS context is provided below. The description contains discussions on each external entity and the related data elements. Explanation is also provided on some critical data elements.

2.1.1.1 Traffic Operations Centers (TOCs)

A primary source of CTIS data will be from traffic operations centers located throughout the I-95 Corridor, These centers will all exchange data with the CTIS over the Information Exchange Network (IEN).

The local and regional systems will gather local and regional information respectively, such as: real-time traffic and road information (e.g., post processed, validated link data), incident data and togs, event plans and status, and static network data. This mostly real-time information will be provided to CTIS, which will, in turn, supply the local and regional systems with traffic demand and trends information. It should be pointed out that each TOC may also be a user of the CTIS (reference the upper right corner of the context diagram).

The CTIS will receive the following data from the TOCs:

+ Real-Time Traffic and Road Information.
+ Event Plans/Status.
+ Incident Data/Logs.
+ Static Network Data.

The CTIS will send the following information to TOCs:

+ Traffic Demands/Trends. Based on the travelers' trip planning request data (O-D data, and intended travel schedule) and the information on subsequent planned routes, the CTIS can project the traffic demand on roadways.

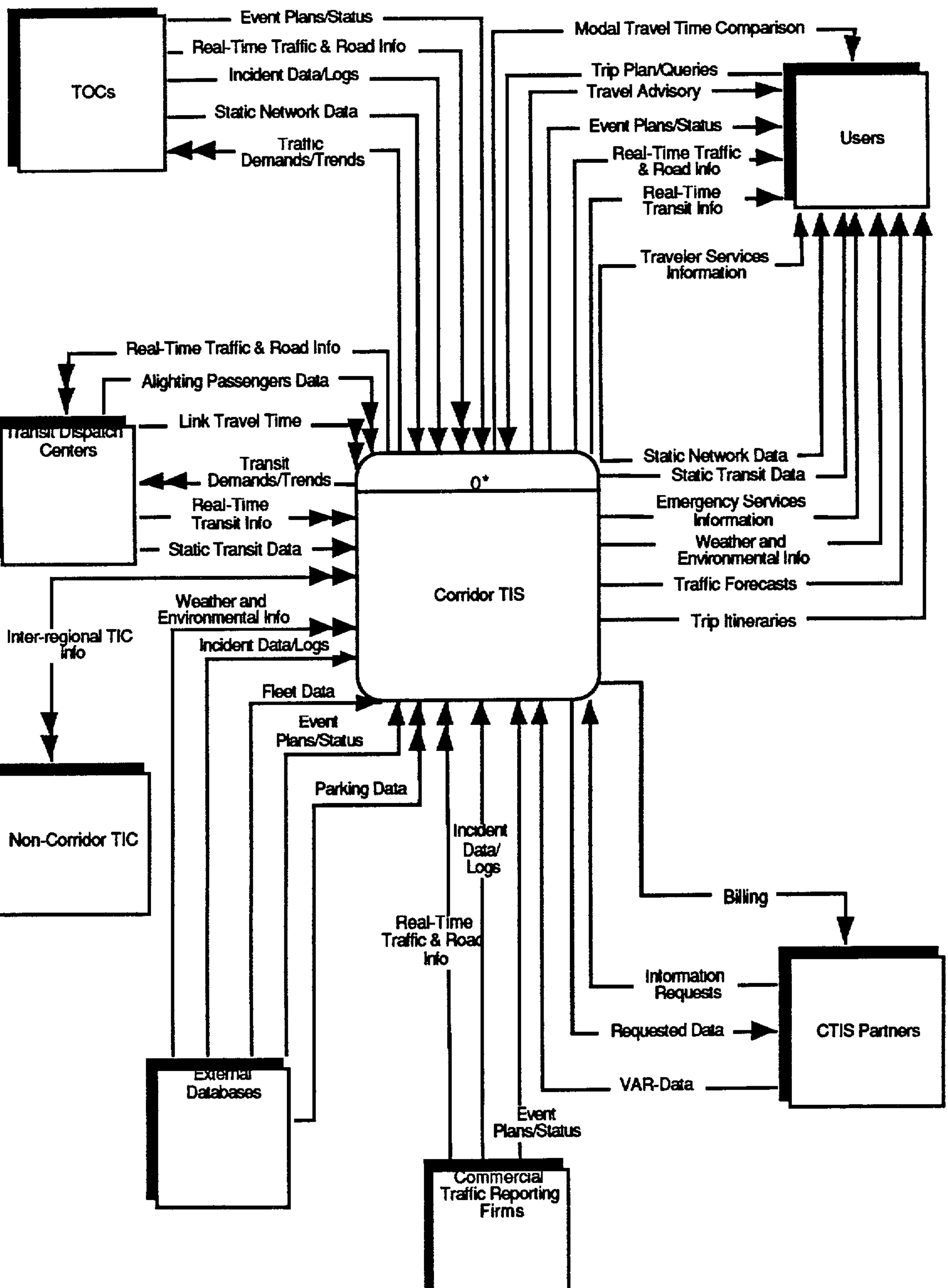


Figure 2-1. Context Diagram of the Corridor-wide Traveler Information Services

2.1.1.2 Transit Dispatch Centers

Public and private transit dispatch centers will be the primary provider of transit related information to CTIS. Transit dispatch centers will gather data and information for bus, rail, air, subway, and ferry. Typical information available at a transit dispatch center would include real-time transit information, static transit data, and traffic demands and trends. CTIS will then supply the transit dispatch centers with updates to the projected demands and trends, based on actual public user information and the real-time transit information. Therefore, CTIS and the transit dispatch centers will work in accord to achieve maximum efficiency when exchanging transit related information. When applicable, information exchanged between these two systems will use the IEN.

The Transit Dispatch centers will provide the CTIS with the following data:

- Real-time Transit Information (e.g., any modification in the schedule).
- Static Transit Information (e.g., transit route and schedule).
- Traffic Demands/Trends. Transit Dispatch Centers can estimate this data based on the anticipated transit arrivals and the passenger loading.
- Link Travel Time. This information will be collected from the AVL-equipped transit vehicles.

The CTIS output to Transit Dispatch Centers is as follows:

- Transit Demands/Trends. The CTIS will estimate this information by synthesizing the users' trip planning requests.
- Real-time Traffic and Road Information, particularly that along transit routes.

2.1.1.3 Commercial Traffic Reporting Firms

Commercial traffic reporting firms will be another source of relevant information for CTIS. Metro Traffic, Shadow Traffic, Traffic Net, SmarTraveler, and Traffax are all examples of the increasing presence of commercial traffic reporting firms in the Corridor. These external entities play an important role in both gathering data and disseminating information to the travelers through various broadcast media. Usually, Commercial Traffic Reporting Firms have their own surveillance assets, including air-borne surveillance. Although the actual operations of the firms vary substantially, the information required by CTIS is consistent; real-time traffic information, incident data and logs, and event plans and status. Interfaces with these commercial traffic reporting firms could potentially use the IEN.

The following are the data outputs to the CTIS:

+ Incident Data/Logs.
+ Event Plans/Status.
+ Real-Tme Traffic and Road Information.

Commercial Traffic Repotting Firms also receive relevant information from the CTIS. However, functionally these act as Users and hence are covered under the Users entity.

2.1.1.4 External Databases

There are several types of databases that will maintain information relevant to CTIS. Typical information expected to be available from external databases includes weather and environmental information, parking data, fleet probe data, and geographic data.

The data outputs to the CTIS are:

- Weather and Environmental Information. This information is provided by national and regional weather and environmental agencies, such as National Weather Services (NWS).

- Incident Data/Logs. These information sources are non-TOCs, such as FEMA.

- Fleet data. This data will be supplied by commercial fleet operators.

- Event Plans/Status. The special event information includes games, parades, etc. The appropriate agencies will notify the CTIS regarding the schedule of such plans.

- Parking Data. This data will be supplied by individual parking systems. It may include a static parking capacity information or real-time parking availability and location information.

2.1.1.5 Non-Corridor Traveler Information Centers

Non-Corridor traffic information centers (TICs) do not lie within the geographic boundaries of the I-95 Corridor. For example, if a trip begins within the Corridor and ends outside, the traveler would be interested about the information at the destination. Hence, the CTIS will exchange (both receive and send) with the Non- Corridor TICs Inter-regional TIC Information. This may include includes traffic, weather and environmental, and construction information. The IEN will not be the mechanism for exchanging data with non-Corridor systems.

2.1.1.6 CTIS Partners

Private-sector disseminators will exchange data with the CTIS on an as-needed basis or a synchronous basis. In general, the private-sector disseminators may have their own subscribers, and may wish to augment their own information with information available from the CTIS. The CTIS will have provisions to accept information requests from and send access grants and requested data to the private disseminators. In addition, the CTIS may receive value-added data from the private disseminators. For example, the CTIS may provide the link travel time information to the CTIS Partner entities which will further process the data to calculate the shortest path matrix for area-wide O-D pairs. This data then can be sent to the CTIS as Value Added Reseller (VAR) Data and used for subsequent route guidance requests.

Private sector disseminators encompass a wide range of information disseminators. Typical examples are information service providers, communication service providers, value-added resellers, hardware and software providers, media (TV, radio, newspaper), commercial traffic firms, and employers. These private disseminators would each have unique information needs and therefore would request relevant data as needed from CTIS.

2.1.1.7 Users

The users are the primary data sink, and of course, are the customers of the CTIS. The CTIS receives requests from the users and sends them the necessary information based on the travelers' needs. It is important to understand that the interface to users will be provided for the most pan by private sector ISPs.

The information flow from the CTIS to the Users entity includes basically all or a combination of the data residing in the CTIS database. The data includes:

+ Modal Travel Time Comparison.
+ Travel Advisory.
+ Event Plan/Status.
+ Real-Time Traffic and Road Information.
+ Real-Time Transit Information.
+ Traveler Services Information.
+ Static Network Data.
+ Static Transit Data.
+ Emergency Services Information.

+ Weather and Environmental Information.

+ Traffic Forecasts.

+ Trip Itineraries.

The request that the CTIS receives from the Users is Trip Plan Queries,

2.1.2 TIS Subsystems

The CTIS have a number of subsystems as shown in Figure 2-2. The subsystems are designed to be modular in nature. Therefore, the entire system does not need to be implemented at the same time, but different combination of the subsystems can be implemented depending on the desired functionalities. Also, the entire system will not be located in the TIC, and individual subsystems and combinations thereof, can reside in segments in both TIC and at the user's end, such as in-vehicle navigation device. The subsystems are as follows:

+ **Communication.** This subsystem provides the capability for receiving and sending data between the CTIS and the external entities.

+ **Data Management.** This is the core of the CTIS. This subsystem is responsible for validation, storage and retrieval of all CTIS data as necessary.

+ **Data Distribution.** This subsystem is responsible for handling all external requests and information dissemination. It receives the individual external requests (both scheduled and ad hoc) for information, and routes to the appropriate subsystem applications. Once the information is processed, this subsystem sends it to the appropriate external entity. Since, this subsystem acts as the channel for incoming users' requests and outgoing information, it will also monitor the user activities (type of requested information and system time) and determine the relevant fees.

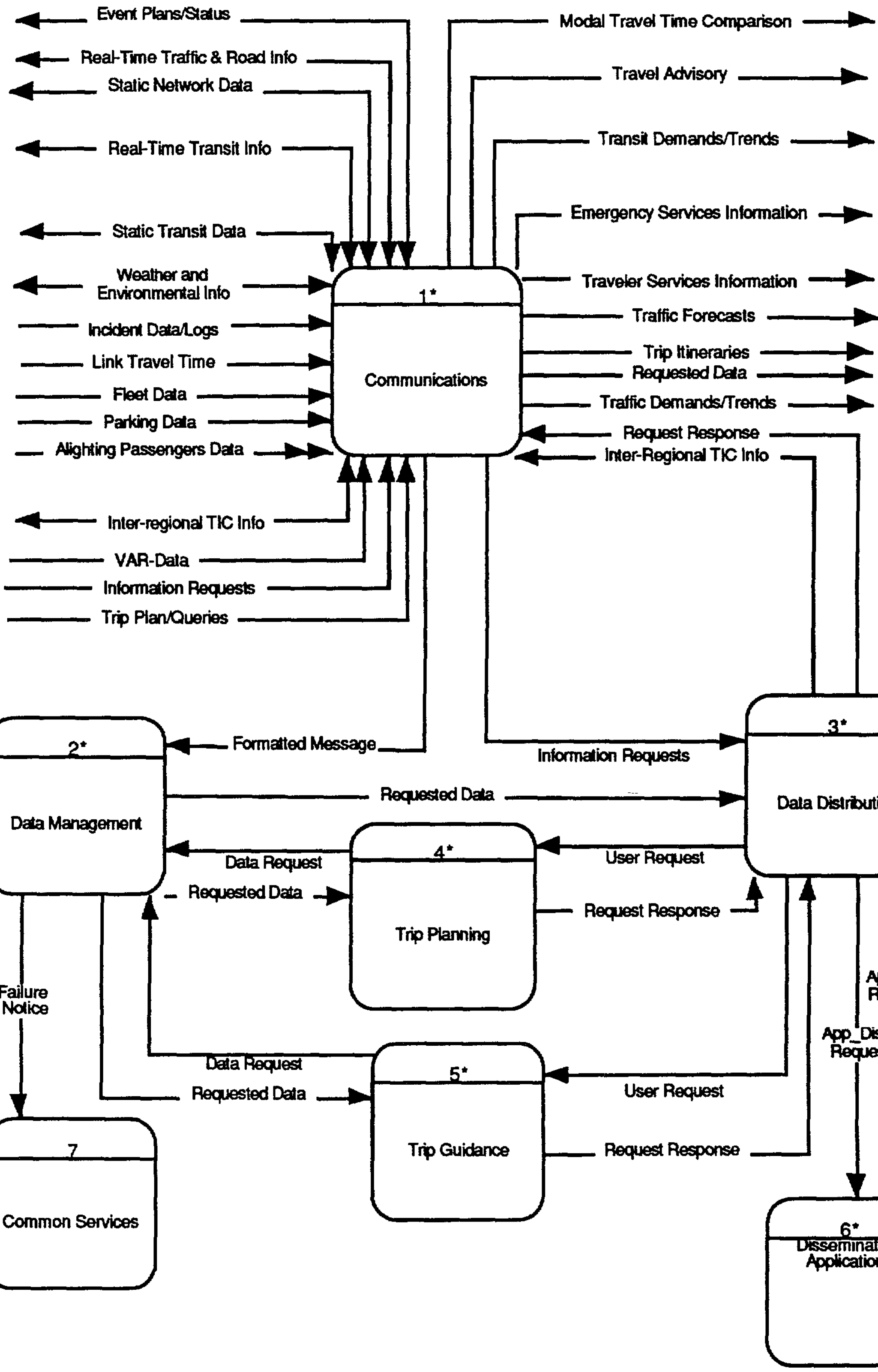


Figure 2-2. Level 1 Decomposition of CTIS

+ Trip Planning. This subsystem provides users with the capability to plan a trip using a single or multiple modes of transportation. The plan will be based on the user selected criteria. It also includes the ability to took up traveler services information of interest.

+ Trip. It provides explicit directions to the users on how to go to their destinations while they are in the vehicle. This includes vehicle maneuvering instructions.

+ Common Services. These is a combination of subsystems that support other applications and the overall system. These common services include:

  - Graphic User Interface (GUI).
  - Software/Hardware Monitoring.
  - Security.
  - Configuration Manager.
  - System Management.
  - Inter-Process Communication.

+ Dissemination Applications. This subsystem provides users with reports of traffic and transit status that affects their trips.

Detailed descriptions of the individual subsystems are provided in sections 3 through 9. Further decomposition of individual subsystems are also presented.

2.1.3 Modularitv of the TIS Subsystems

The modular design of the TIS subsystems allows a mix and match of the subsystems to provide the desirable architecture. For example, Figure 2-3 illustrates an architecture that shows grouping of the subsystems for the TIC, hand-held devices, and in-vehicle navigation. The intent of this figure is not to recommend an architecture, but to illustrate the modularity with which various combinations of the subsystems can be implemented to achieve desired functionalities.

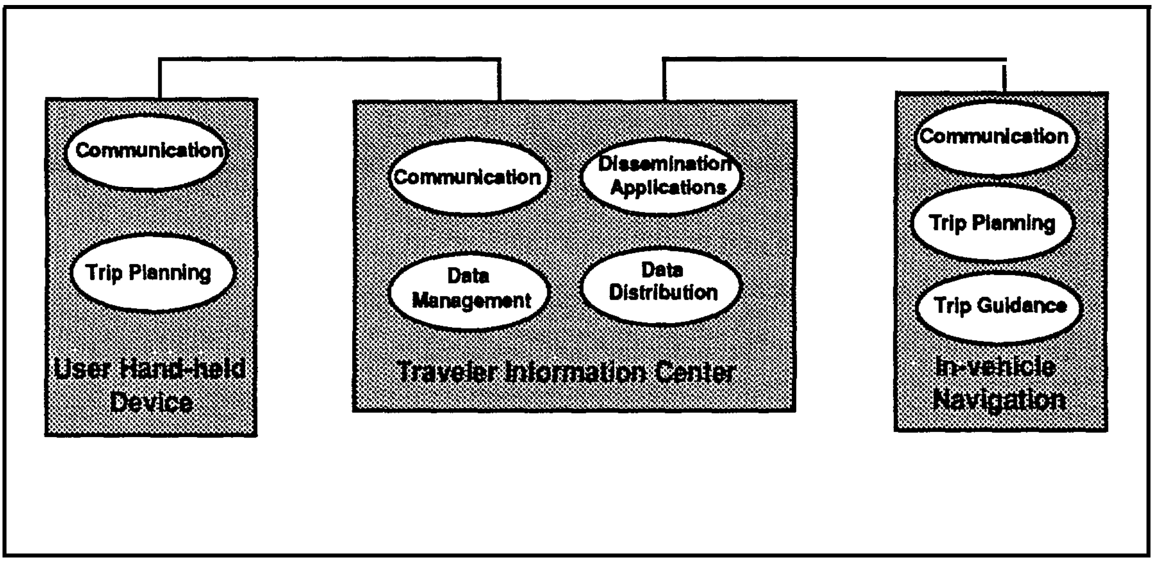


Figure 2-3. An Example of Flexible Grouping of TIS Subsystems

2.2 HIGH-LEVEL PHYSICAL ARCHITECTURE

In this section we will present a physical architecture, which represents one of many candidate instantiations of the logical architecture presented in section 2.1. The architecture was developed to map to the CTIS vision presented in section 1. This section, therefore, will be discussed and illustrated in an incremental fashion, providing a clear mapping between the CTIS architecture elements and phases in the CTIS deployment vision.

2.2.1 Theme: Travelsheds. Not Jurisdictions

Corridor traveler information services are best organized according to how the traveler sees his or her world, rather than how the operating agencies see it. Consequently, Corridor traveler information services must rise above jurisdictional boundaries. The end user does not know and does not care who owns a roadway or in which city, county, or state he or she is.

Instead, he or she thinks of himself or herself in a "travelshed". Just as a watershed marks where water flows in the same direction, a travelshed marks where (most) travel is concentrated. This includes not just travel in the same direction at a given time of day, that is, commuters inbound in the morning and outbound in the evening, but also business travelers arriving or departing to another "travelshed", and inter- and intra-travelshed commercial traffic.

The focus of Corridor traveler information services is best organized around the Corridor's five significant travelsheds:

- Boston (including Hartford, Providence, and northern New England).
- New York (including southern Connecticut, northern New Jersey, and northeastern Pennsylvania).
- Philadelphia (including Camden, Chester, Wilmington, and central and southern New Jersey).
- Battimore-Washington (including northern Virginia).
- Richmond-Norfolk (including Hampton Roads).

These travelsheds correspond to the three consolidated metropolitan statistical areas identified by the U.S. Bureau of the Census in the Corridor, plus aggregations of the Baltimore and Washington, and Richmond and Norfolk standard metropolitan statistical areas. In order to avoid the development of a centralized architecture (requiring an enormous communication infrastructure), the candidate architecture presented in this section will assumes Regional Traveler Information Centers (RTICs) that map to these travelsheds.

2.2.2 Regional Traveler Information Centers

Since the I-95 Corridor consists of several regions, and hosts over 20% of the total U.S. population, a distributed architecture, illustrated in Figure 2-4, was developed. A distributed architecture is envisioned not just for technical reasons (greater system redundancy, and a manageable set of communication interfaces), but also for geographical reasons. The spatial distribution of the population in the Corridor lends itself to the development of a distributed architecture. As illustrated, each of the regions (also identified as travelsheds) will house a regional traveler information center (RTIC), which will act as a clearinghouse for transportation information within its service area. To support Corridor-wide traveler information, each RTIC must be able to communicate with any other RTIC. Inter-RTIC compatibility is required to support the Coalition's goal of providing traveler information at any point in the Corridor about any other point in the Corridor. To facilitate this capability, the development of each RTIC must adhere to format and protocol standards that define information to be shared between RTICs In addition, to support maintainability and an open architecture providing easy access to data by the private sector it is recommended that each RTIC comply with various established and de facto standards as identified in Table 2-2.

Table *2-2 Architecture Complies with Existing and De facto Standards*

Requirement	***Recommended Standard-Approach***
Unix/NT	POSIX Compliant Unix & TCP/IP
C/C++	ANSI C/C++
X-Windows	OSF Motif
Object-Oriented	Rumbaugh's Object-Modeling Technique (OMT)
Relational Database	ANSI SQL, RDBMS
User-Friendliness	FHWA Human Factors Compliance Demonstrated through Simulation & Prototyping
GIS	SL-GMS, ArcView II or GDS
Expert Systems	Rule-Based and Case-Base Solutions
Scaleability	Client-Server/RISC Platforms

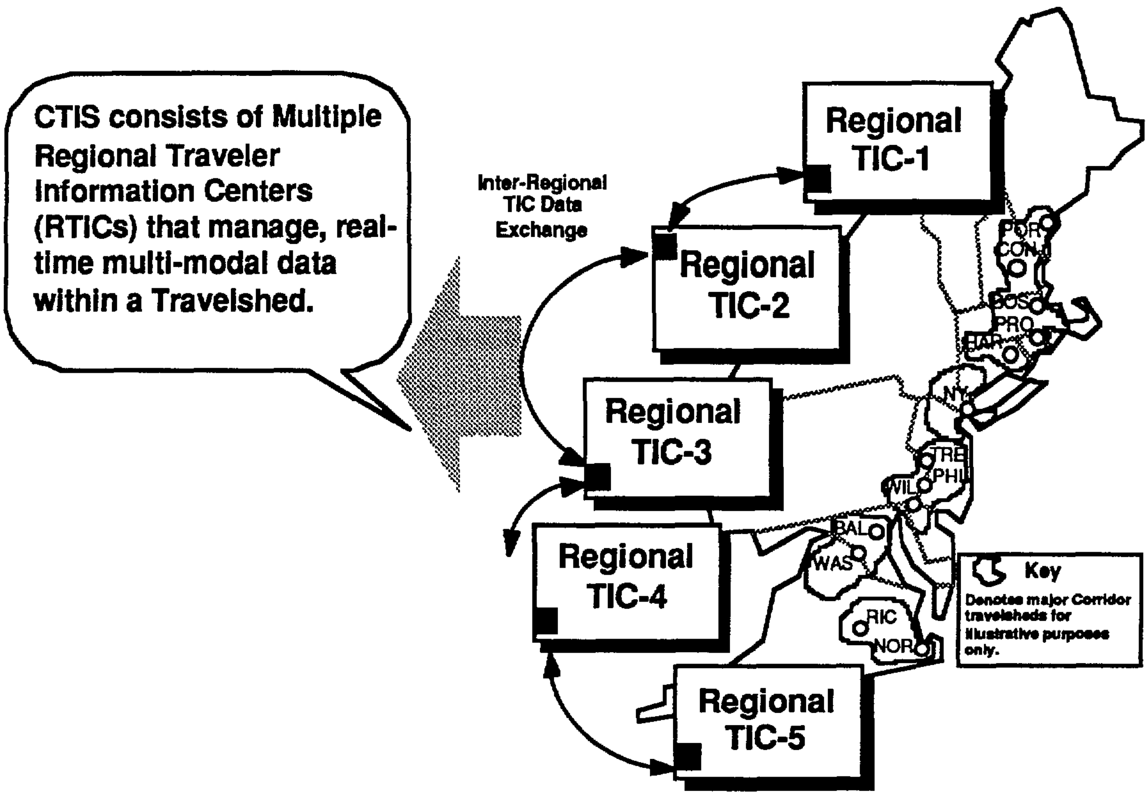


Figure 2-4. High-Level CTIS Block Diagram Illustrating Candidate CTIS Regions

To maximize the use of existing resources, it is envisioned that each RTIC will come on-line over time and be co-located with an existing TOC or private-sector ISP. For instance, SmartRoute Systems may serve as an RTIC in the New England area; TRANSCOM as the RTIC in the New York, New Jersey, Connecticut area, and the Maryland State Highway State-wide Operations Center (SOC) as the RTIC in the Baltimore, Washington, Northern Virginia area. Regardless of whether a private-sector ISP or a public agency hosts the function of the RTIC, it is anticipated that each RTIC will require a public/private partnership for the design, implementation and operations and receive initial public funding to help jump-start and "prime" the system. Over time, however, full privatization may occur as CTIS and traveler information markets mature.

The primary goal of each RTIC is to compile, integrate, format, and manage data to be distributed to end-users, ISPs and other RTICs; thus, the regional centers are the engines for the traveler information marketplace. To meet this goal, four major functions are required:

+ Data gathering.

+ Data fusion and processing.

+ Data delivery.

+ End-user device data processing.

The first three functions are the responsibility of the RTIC and in most cases the last function, end-user device data processing, is the responsibility of the ISP. The relationship between these functions and the logical subsystems presented in section 2.1 is identified in Table 2-3. Each of these four functions will be further explained below.

Table 2-3. ***Mapping Between Logical Subsystems and RTIC Functions***

RTIC Function	Logical *Subsystem*
Data Gathering	Communications, Data Management
Data Fusion and Processing	Data Management, Trip Planning, Trip Guidance, Dissemination Applications
Data Delivery	Data Distribution, Communications
End-User Device Processing	ISP/Product Vendor function

2.2.2.1 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. End-users seldomly require infonation 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 2-5 identifies the various CTIS sources of information and illustrates the relationship between RTICs, Traffic Operation Centers (TOCs) and IEN interfaces. The principal data to be collected will include traffic and transit data obtained from Traffic Operation Centers (TOCs) and Transit Dispatch Centers (TDCs), respectively. It is envisioned that the interfaces to the TOCs and TDCs will occur through an Information Exchange Network (IEN) interface.

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. Unfortunately, not many existing jurisdictions have systems in place that electronically share/exchange data. Because of this fact, the Coalition is sponsoring Project #1, the IEN. 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 canonical 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.

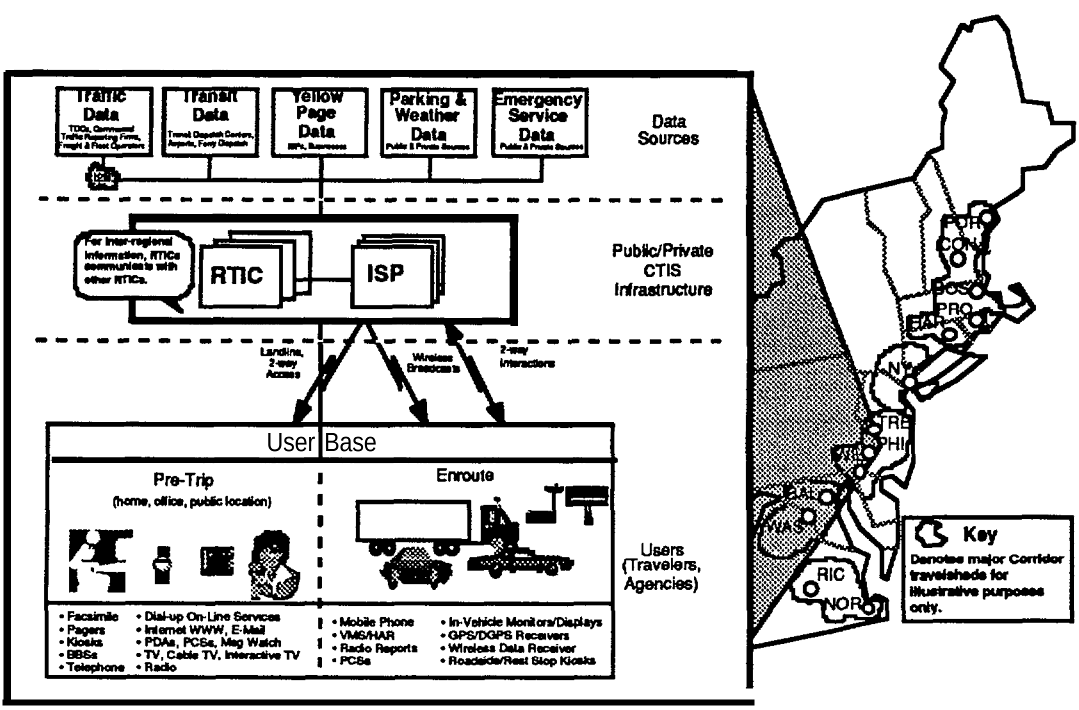


Figure 2-5. CTIS Block Diagram:Illustrating Coupling Between RTICs and Regions and Private-Sector Involvement Through ISPs

2.2.2.2 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 roadways 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 0.5 mile intervals, must be combined together to form a route travel time estimate. Finally, acquired, fused and formatted data must be spatially attached using geo-referencing to a base map or spatial model.

A key element inside each RTIC is a data management subsystem that will use relational database servers to manage traffic and transit data. Each of these regional data servers will collect and maintain data within its region in order to satisfy the needs of intraurban, interurban, and interregional travelers. In addition to acquiring data, the regional data servers will also disseminate information to other regional data servers and to the other nodes on the IEN. The kind of data exchanged between regions and the frequency of update is dependent on the proximity of regions, performance, available bandwidth, user needs and other factors. It may not be desirable or required to transmit synchronous link data between RTICs, until a well-defined need is identified. This would not precluded the ability for a given RTIC to on-demand, poll another RTIC for a link update. On the other hand, for system redundancy and possibly performance, it may be desirable to have all link data exchanged between adjacent RTICs.

2.2.2.3 Data Delivery

To disseminate traveler information effectively and to provide ubiquitous access to all types of users, public/private partnerships comprising Coalition member agencies and various private-sector sponsors are required. Commercial endeavors by ISPs, VARs, CSPs, and various other types of repackages, distributors, and other providers of traveler information products and services are envisioned. 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 regional traveler information center. As illustrated in Figure 2-6, actionable, real-time traffic and travel information will be collected and disseminated (by both the public and private sectors) on all modes, including private vehicles, and public and commercial transportation.

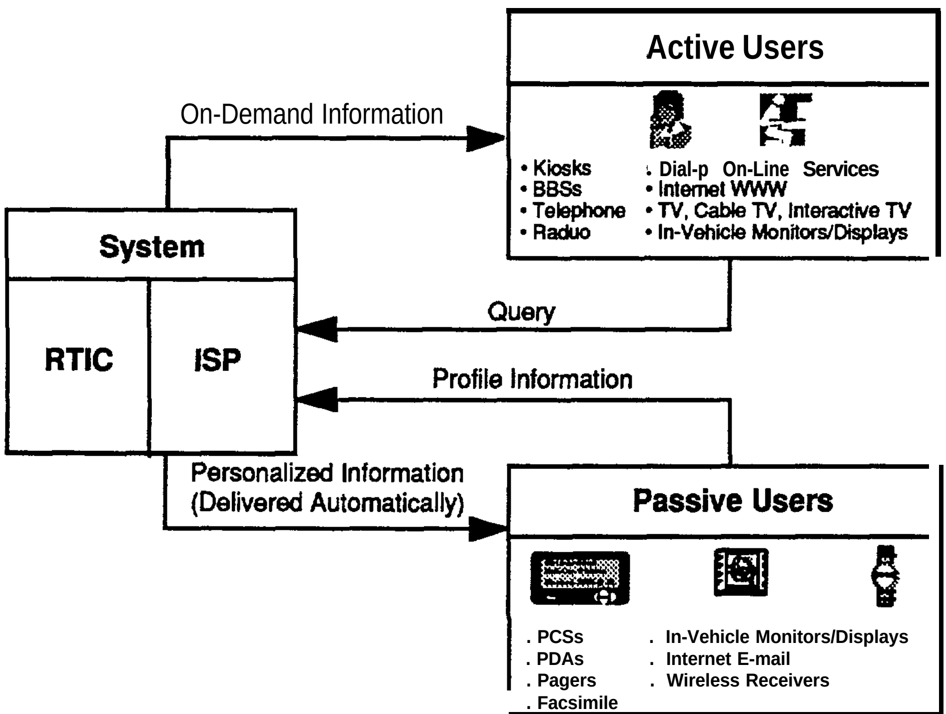


Figure 2-6. RTIC Architecture Supports Active and Passive Users

Dissemination of traveler information will likely occur in phases (as previously discussed), progressively adding more services and incorporating sophisticated technology over time. Figure 2-7 illustrates a concept of providing various levels of support for traveler information. 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 on-line services; public kiosks; Internet accessed services; and various types of hand-held devices including, two-way pagers, personal digital assistants (PDAs), and personal communication systems (PCSs) 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, multi-modal 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. As shown, various levels of costs will be incurred by the user varying from free for broadcast information, to premium costs for personalized, automatically delivered information.

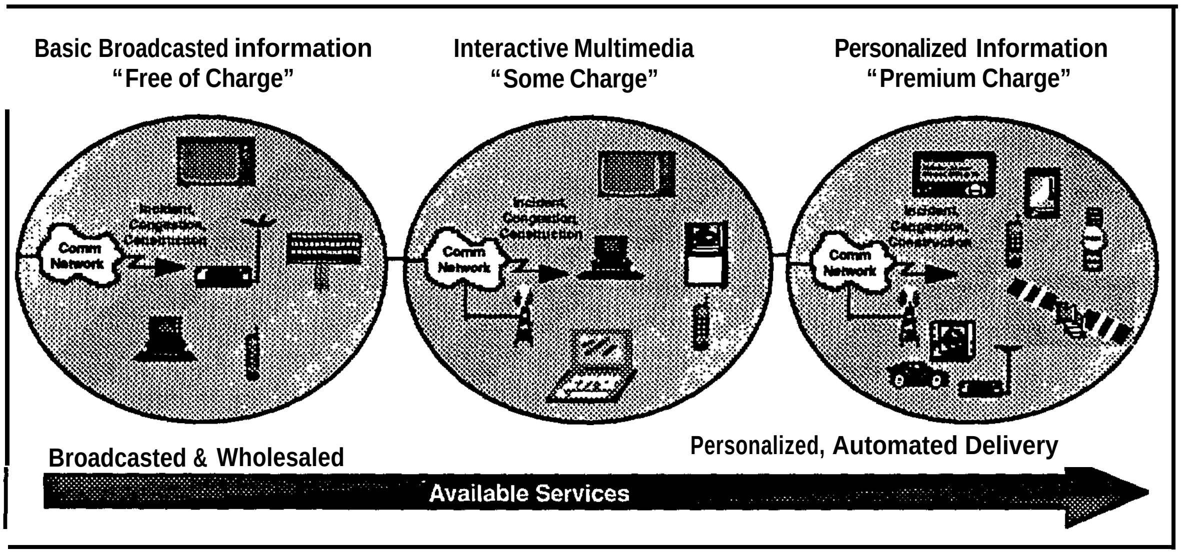


Figure 2-7. RTIC Architecture Supports Multiple Levels of Service

For a comprehensive illustration Figure 2-8 identifies the various information sources and sinks of a given RTIC. In addition, Appendix K provides a functional specification for each of the potential CTIS dissemination devices. This Appendix is intended to provide additional technical detail with respect to capabilities and design guidelines of the individual dissemination technologies.

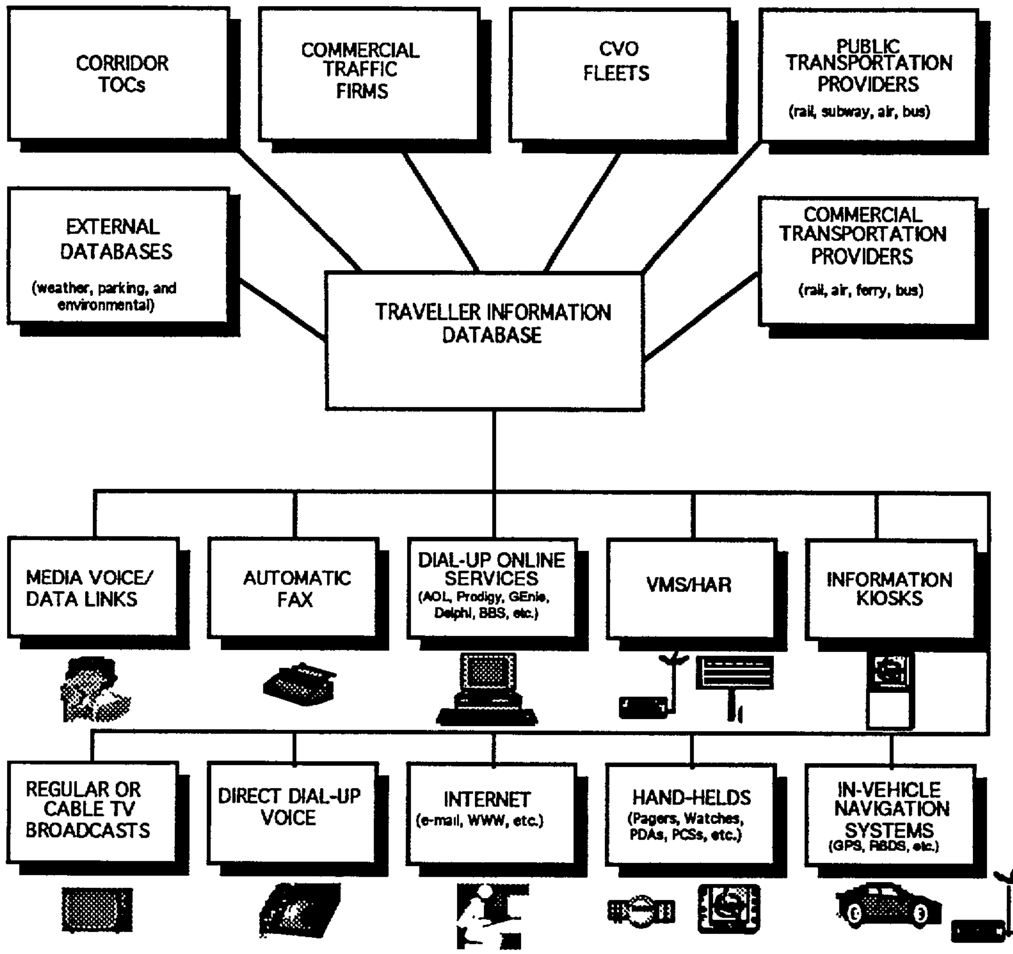


Figure 2-8. CTIS Architecture Identifying Data Sources and Sinks

2.2.2.4 End-User Device Data Processing

While most end-user device data 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 data processing begins with acquiring traveler information. Then, depending on the device and vendor, device specific data 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.

2.3 RTIC COMMUNICATION ARCHITECTURE

Each RTIC will provide a communication architecture capable of accommodating interfaces to other RTICs, agencies, users and the private sector. Each RTIC will support interfaces for local networks, Wide Area Networks, and switch elements which connect to public phone lines. Figure 2-9 shows how a typical RTIC will interact with the various communication elements. The RTIC exchanges data with TOCs/TMCs (even if the RTIC is co-located within the TOC/TMC building) via a local gateway. This network interface allows for the exchange of data between the RTIC data processing equipment and the TOC/TMC. The TOC/TMC. network(s) are isolated from the other CTIS elements since the data exchange is controlled by the local gateway. This interface can be a network, such as Ethernet, using compatible communications equipment connected to a subnetwork. This subnetwork allows for the distribution of RTIC network information among the various data processing equipment within the center.

Inter-regional data networks are configured using the same gateway approach to allow the exchange of data to be controlled by the RTIC. Again these networks can be Wide Area Networks (WAN) using a compatible protocol such as DS1 . The equipment used here may include the following:

+ Network modem(s) - Used to connect to the public switch or the landline network

+ Bridge(s) - Used to modify the WAN format to a local network protocol

The RTIC's data processing equipment will have the capability of monitoring the WAN for operational reliability.

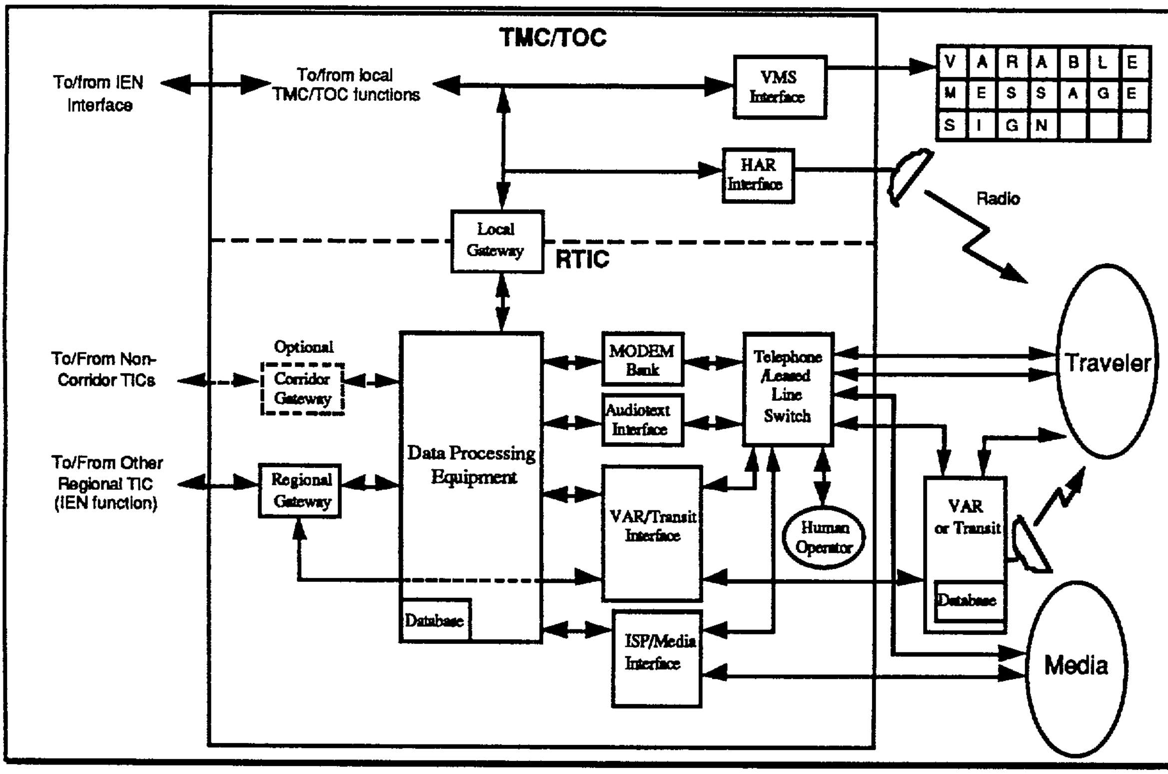


Figure 2-9. Typical RTIC Communication Architecture

At the local level an ISP or media entity enters through a dedicated interface or through a dial-up modem. This interface allows the service provider controlled access to the CTIS's data and satisfies the specialized data requirement of the ISP/partner. The typical equipment used here is analog and digital video/voice equipment, specialized modems, and network switch components. In addition, the traveler has access to the CTIS via the RTICs leased lines. Queries enter the CTIS via commercial modem, or audiotext equipment connected to the RTIC's data processing equipment.

To adequately assess the bandwidth requirements for the communication network, three major communication interfaces were analyzed: 1) RTIC to TOC, 2) RTIC to RTIC and 3) RTIC to ISP. The following are relevant facts and assumptions that have been made in our analysis:

2.3.1 RTIC to TOC Assumptions:

+ The RTIC to TOC interface will handle two types of data: synchronous and asynchronous data. Synchronous data includes link-based data from instrumented Corridor freeway and arterial roads, that is transmitted on a regular basis. Asynchronous data includes, incident and construction reports and static information, such as road geometries, turning restrictions, etc. Incorporating network overhead for error checking, framing, and packetizing, each link will require 610 bytes of information. Incorporating network overhead for error checking, framing, and packetizing, each incident record will require 500 bytes of information.

+ Project #3, Surveillance Requirements/Technology (SRT) has identified that the Corridor has approximately 5600 miles of Corridor designed roads (including freeways and arterials). Of the 5600 miles, approximately 1600 miles (or 30%) of the roads have existing or planned surveillance coverage. We assume that over the next 10 years, 3200 miles of roads would be instrumented with surveillance equipment. Dividing these 3200 miles by 5 RTICs yields an average of 640 miles of roads under surveillance by each RTIC.

+ We further assume that the average length of a roadway link is a total of 640 one-way links per RTIC. Thus, the highest synchronous communications scenario would be one where traffic condition updates from all 640 links are required during one-minute intervals. In reality, it is likely that only links exceeding , say, a 25% reduction in speed will be transmitted, representing a lower communication demand.

+ A recent survey conducted by Project #1 , has revealed that there are approximately 35 existing and planned centers, including TOCs, Police barracks, and Emergency Response Centers) throughout the Corridor. Of the 35 centers, it is estimated that 22 centers that operate traffic control devices will place synchronous communications demand on the network.

+ In summary, from a communication point of view, each RTIC will be required to interface to 7 operations centers on average, only 5 of which are generating synchronous data. Based on these conditions the following bandwidth is required for each RTIC:

((640 links/RTIC * 610 bytes/link) * 8 bits/byte) / 60 seconds/minute) = 52K bps

2.3.2 RTIC to RTIC Assumptions:

+ In order to support inter-regional traveler information and seamless information access by users and ISPs, RTIC to RTIC communications will be required.

+ The type of communications between RTICs will included at minimum various types of asynchronous data. This includes incident reports and event plans (including special events and construction activities). These communication activities will typically be communicated between RTICs on an as needed basis. In addition, various types of static data, such as transit schedules and road restrictions will be transmitted on an as needed basis, preferably during off-peak hours.

+ As project #2, Incident Management - Detection, Response and Operations has identified, the focus of the Corridor's information exchange and coordination is on incidents that have regional and Corridor impact. Regional and Corridor incidents are those that have durations greater than 2 and 4 hours, respectively, with substantial capacity reductions.

+ Synchronous data exchange (i.e., real-time link status information) between RTICs may take place, but less frequently. Synchronous data between RTICs is assumed to consist primarily of link-status information, updated once every 3 minutes (as opposed to once every minute from TOC to RTIC). Alternatively, synchronous data exchange between RTICs may only be required during incidents having a Regional or Corridor Impact.

+ Inter-regional data exchange may also be supported by the private sector (not necessarily RTIC to RTIC, but ISP to ISP). An ISP may offer Corridor-wide traveler information services and take the responsibility for integrating data from many RTICs. This would support, for example, a user requesting traveler information services about Boston from an ISP in Baltimore. The user may have their response fulfilled by an ISP-provided internal network that connects to a sister ISP office in Boston, which in turn connects to the Boston RTIC.

2.3.3 RTIC to ISP Assumptions:

+ The RTIC to ISP communication has similar requirements to the TOC to RTIC link. The primary difference, however, is the private-sector will likely provide the communication infrastructure and associated costs.

2.4 CTIS DEPLOYMENT VISION

The I-95 Corridor Traveler Information Service will evolve over a period of years, going through three identifiable stages, each with its level of technology, public and private partnership funding, and level of TIS demand, and inter-jurisdictional collaboration.

2.4.1 Phase I Deployment (Years 0 - 2)

Phase I-Baseline Information Dissemination (Years 0 - 2) - this phase is focused on rapidly deployable, baseline information dissemination to the broadest possible public, at little or no charge. This includes, the use of dial-in bulletin boards and Internet web pages, faxes, and pagers.

As an illustration, Figures 2-10 and 2-11, identify CTIS architecture elements that are readily deployable.

Figure 2-10 identifies a telephone traveler information system that uses audiotext technology. This architecture element could be provided by either the public or private sector and is one of the direct interfaces to the public. The system could be implemented by using an 800 number or, if possible, by providing the same number in each area code in the Corridor. This architecture element provides real-time traffic and transit reports to anyone with a touch-tone telephone. Access to the information would be menu-driven and delivered in the form of a human recorded, synthesized or digitized voice. A top-level menu structure, broken down by region, is depicted in Figure 2-10.

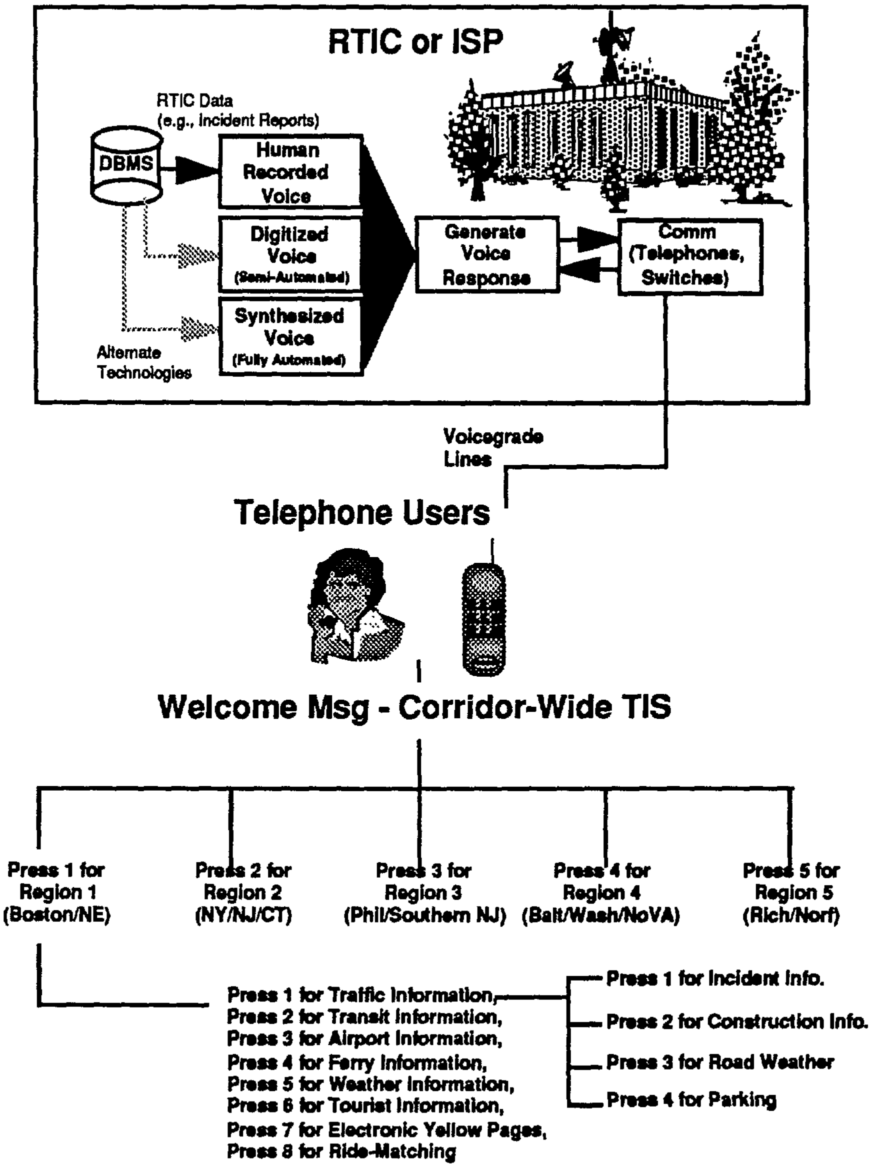


Figure 2-10. Candidate Architecture for a CTIS Audiotext System

Figure 2-11 identifies a candidate architecture for a World Wide Web (WWW) home page or dial-in Bulletin Board Service. The use of the Internet to disseminate traveler information as well as a myriad of other types of information (entertainment, technical, etc.) is becoming much more pervasive. Internet users are now estimated to be approach the 40 million mark. Delivery of traveler information through the World Wide Web (WWW) is an emerging technology. Probably the most advanced of such technology in this country is a service providing real-time traffic conditions in Southern California (San Diego and Los Angeles). The use of a specialized Bulletin Board Service provided by the CTIS may offer another alternative to disseminate information electronically. A BBS could be developed during Phase I to provide information to ISPs only. The general public would not interface directly to the BBS, as this capability would best be incorporated into existing on-line service providers (e.g., America Online, Prodigy).

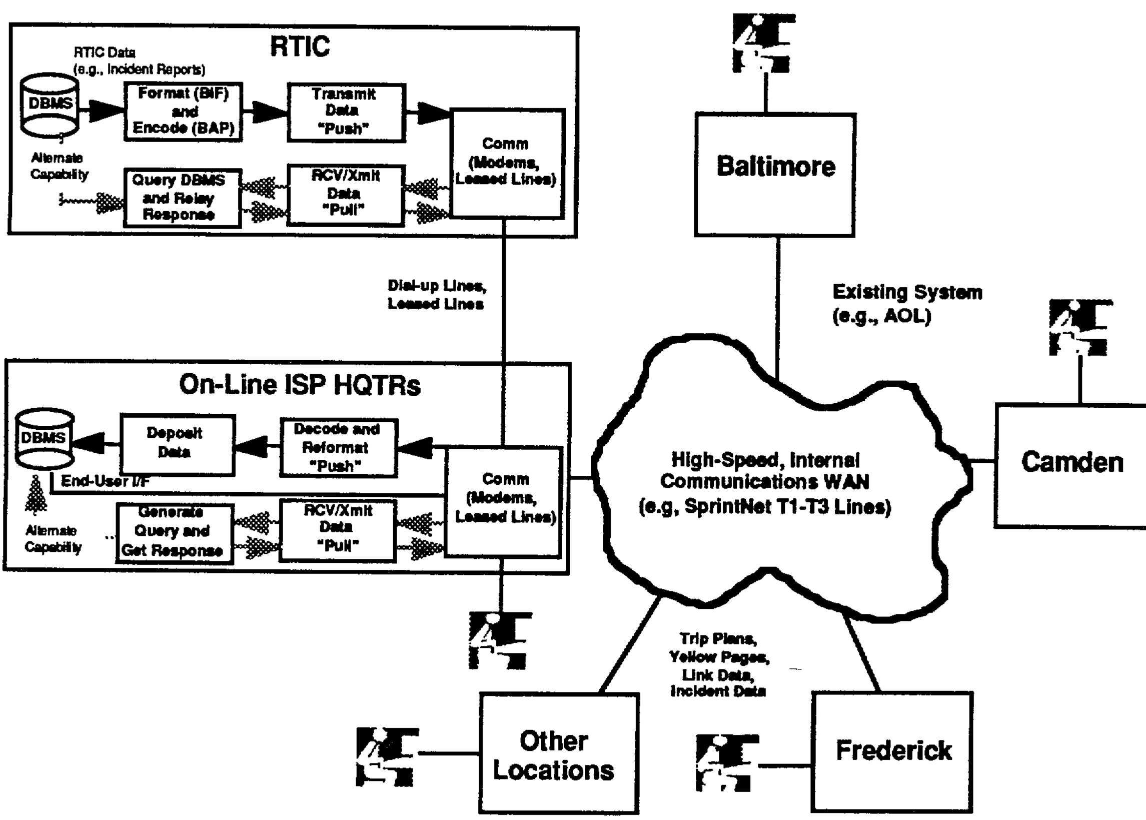


Figure 2-11. Candidate Architecture for a CTIS WWW/BBS Service

2.4.2 Phase II Deployment (Years 2 - 5)

Phase II—Multimedia, Interactive Information Dissemination (Years 2- 5) - this phase is significantly different to the end-user. Induced in part by the widespread dissemination and utilization of baseline information in Phase I, more sophisticated private-sector information dissemination media proliferates. As an illustration, Figures 2-12 - 2-14, identify CTIS architecture elements that are anticipated for deployment during Phase II.

Figure 2-12 identifies a candidate architecture for interfacing an RTIC with an existing on-line service provider such as, America Online or Prodigy. As depicted, two alternatives are provided in the architecture: 1) the on-line ISP may receive synchronous data through a "push" strategy or may alternatively request data on an as needed, on demand basis. Information obtained from the RTIC database is then incorporated into the Online ISP database and then made available to their users via existing client communications and display software. To transmit data from the RTIC to the Online ISP will require the use of formatting and encoding standards. The recommended formatting standard is version 3.1 of the International Traveler Information Interchange (ITIS) Bearer Information Format (BIF) and Bearer Application Protocol (for encoding). These standards are currently being finalized by Enterprise and field tested by many U.S. Field Operational Tests. It is anticipated that most of the data currently earmarked for dissemination to ISPs (and wireless receivers) is supported by BIF/BAP. Lessons learned from other FOTs have revealed, however, that additional messages and codes maybe required to support the Corridor's RTIC traveler message subset. Finally, the specific BAP (e.g., FM subcarrier) to be used for the wireless communications is deferred until the implementation process when additional design considerations (e.g., coverage areas, functionality, duplicity, bandwidth) can be evaluated.

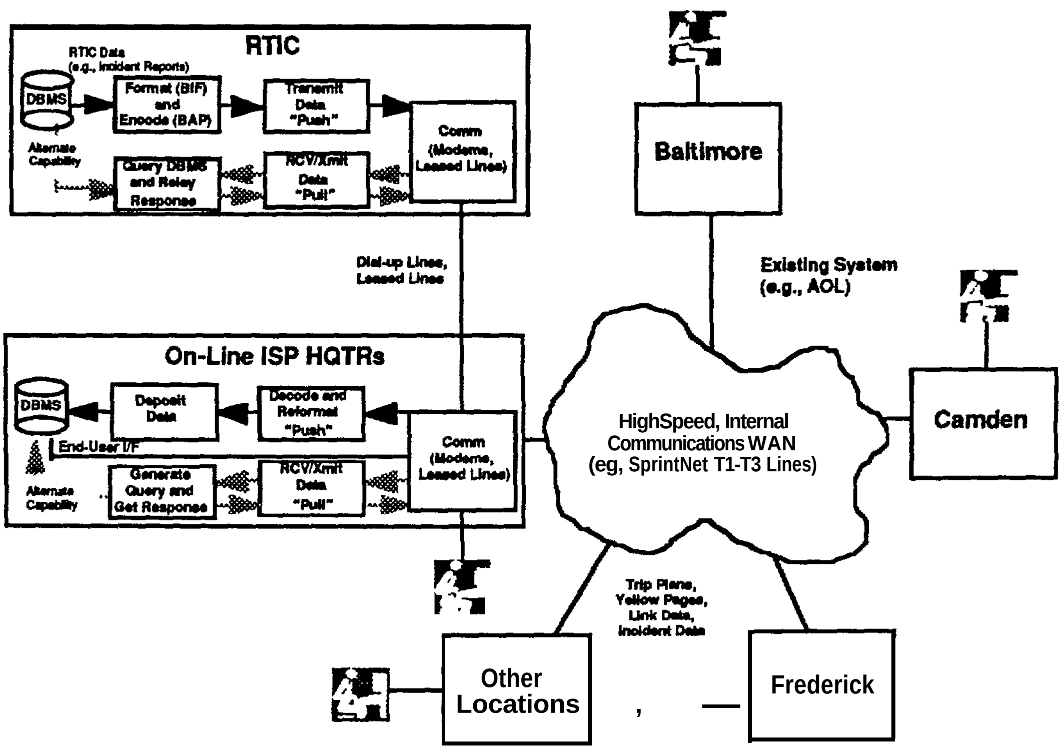


Figure 2-12. Candidate Architecture for Providing an On-Line ISP Interface

Figure 2-13 identifies a potential architecture for disseminating information to hand-held devices. This architecture element requires the use of a wireless communication infrastructure, typically owned and operated by private-sector communication companies. To transmit data from the RTIC to the ISP and from the ISP to the user will require the use of formatting and encoding standards. The ITIS BIF and BAP standards are also suggested for use here.

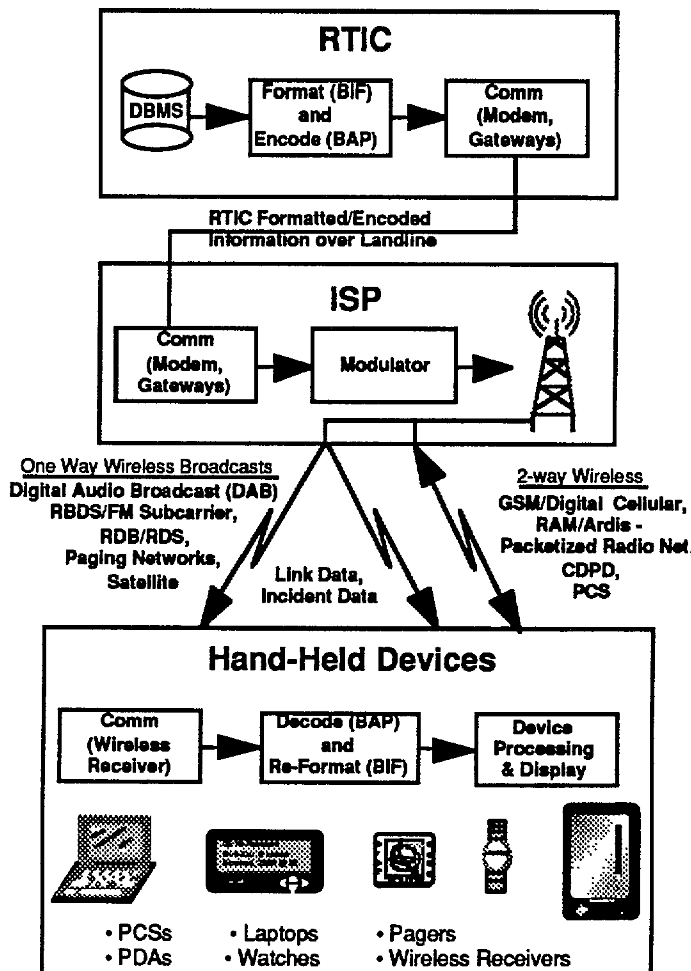


Figure 2-13. Candidate Architecture for Disseminating Information to Hand-Held Devices

Figure 2-14 identifies a potential architecture for interfacing to an existing Kiosk ISP (e.g., Discover America). This architecture mirrors very closely that of the RTIC to Online ISP previously presented in Figure 2-12.

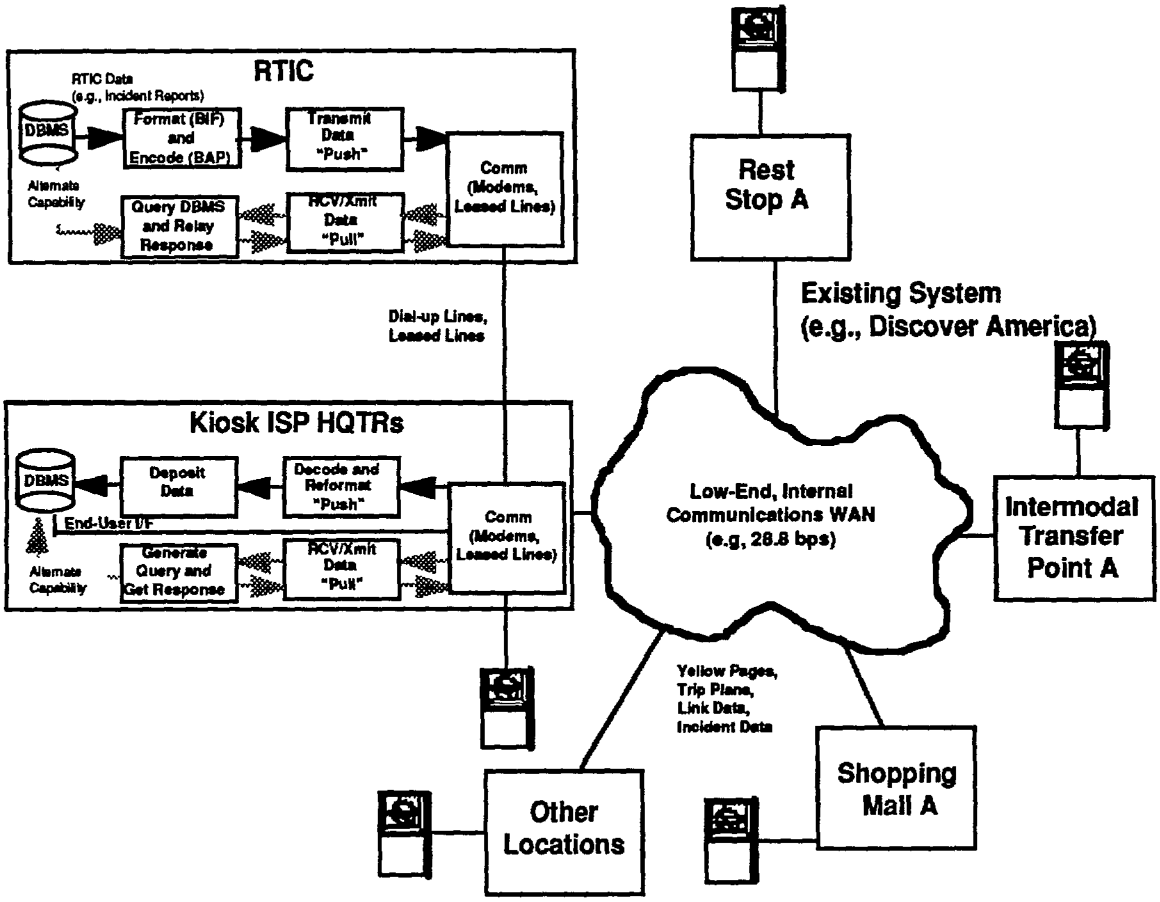


Figure 2-14. Candidate Architecture for Providing an Interface to a Kiosk ISP

2.4.3 Phase III Deployment (Years 5 - 10)

Phase III—Real-time, In-vehicle Information Dissemination/Internally Contained (Years 5- 10) - in Phase III, heavy emphasis in CTIS shifts to widespread deployment of in-vehicle navigational devices displaying real-time, multimodal navigational information.

As an illustration, Figure 2-15 identifies a candidate architecture for providing in-vehicle traveler information. The basic infrastructure for communicating information to an ISP is similar to that in the architecture elements shown in Figures 2-12 - 2-14. Note that the architecture provides support for various types of in-vehicle services, including yellow pages, route guidance, parking data, incident data an link data. In addition, mayday requests and probe-data may flow back to the ISP, where two way communication infrastructures exists. The RTIC to in-vehicle architecture supports varying levels of sophistication in terms of route guidance. No assumptions are made or requirements levied with respect to the positional accuracy of the vehicle (in the event of on-board GPS) or the degree of coupling between routing and control. This architecture does assume, however, than an ISP will handle the communication, processing, and display of information to in-vehicle devices, entirely provided by the private sector.

As illustrated in the Figure, two communication architectures will evolve or co-exist: 1) two-way, interactive and 2) one-way broadcast. The ultimate ISP will be responsible for selecting the most beneficial carrier and technology.

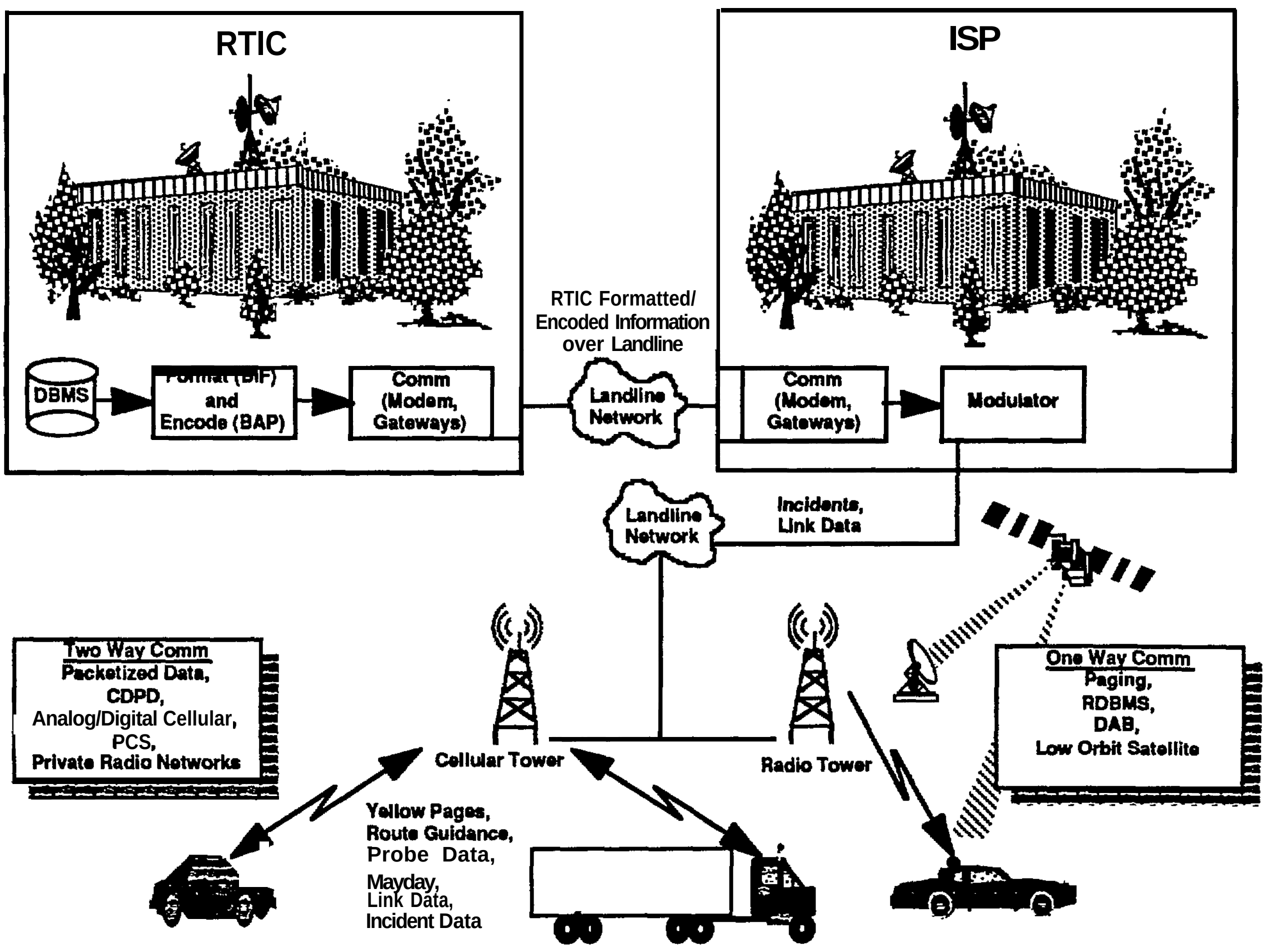


Figure 2-15. Candidate Architecture for Disseminating In-Vehicle

Table 24, summarizes the deployment schedule and the service provider of various TIS technologies. This table does not preclude the opportunity for services transitioning from public to private operation.

Table 2-4. Service/Deployment Phasing

Service	Deployment				Service Provider				
	Baseline	Year 2+	Year 5+	Year 10+	RTIC	ISP	Transit	Media	TMS/TOC
On-line Computer Service		X			X	X			
In-vehicle Device				X		X			
HAR	X								X
Public Kiosks			X			X	X		
VMS	X								X
Cable TV		X						X	
Network TV		X						X	
Telephone Menu	X				X	X	X		
Pagers		X				X			
Hand Held Devices			X			X			

2.5 STANDARDS

The Corridor-wide Traveler Information System will conform to relevant industry standards and conventions to ensure that the system is modular, interoperable, and extensible by third parties. In particular CTIS will:

- maximize the use of standard interchange formats such as ITIS BIF/BAP for traveler information, and SDTS for spatial data.
- use a common geocoding and mapbase for all data with a geographic referent .
- conform to industry established and *de facto* communication standards.
- comply with the ANSI Structured Query Language for the data management subsystem.

+ use ANSI C and C++ for the programming languages.

+ conform to Motif and XWindow standards for the operator interface.

+ use POSIX-compliant Unix and/or Windows NT for the operating system.

2.5.1 International Traveler Information Interchange Standards

The ENTERPRISE program, a forum of several American states and a Canadian provinces for collaborative activities in intelligent transportation systems, is pursuing the development of the International Traveler Information Interchange Standard (ITIS) for advanced traveler information systems applications. ITIS is an open, non-proprietary, modular set of standards intended to serve the public interest by facilitating interconnection and interoperability of traffic and traveler information systems. ITIS has been developed in accordance with the "virtual architecture" concept. In this approach, the information system architecture is transparent to users and system operators alike. Rather than attempting to impose a single, fixed solution to this system architecture challenge, ITIS supports multiple compatible solutions, or flexible architectures, through the adaptation of common information language or subsystem interconnection and integration.

The ITIS approach offers machine-selectable language independent information dissemination, non-proprietary coding, consistent data interchange between traffic operations centers, and the ability to use a variety of communications media to meet specific needs. Potential ITIS communication bearers include AM and FM radio subcarriers, television subcarriers, radio paging, and cellular radio, and emerging approaches such as low-earth-orbit satellite or digital audio broadcasting. ITIS comprises a set of separate but related volumes, which together specify the proposed modular set of standards intended to serve the public interest by facilitating interconnection and inter-changeability of traffic and travel information systems. The Bearer-Independent Format (BIF) defines those parts of ITIS that are applicable to all communications media or bearers. Other volumes-the Bearer Applications Protocol (BAP) specifies means Of applying the BIF to given bearers (i.e., rules to format messages for specific communications media).

ITIS BIF format specifies the contents of travel data records which can be exchanged between centers in language independent formats suitable for automated processing, sorting and selection. The travel information covers traffic event, route guidance, parking and transit. It defines the relevant data dictionary, the structure and content of data records and their presentation to the user.

2.5.2 Common Geo/Link Referencing System

For in-vehicle navigation and other advanced traveler information system applications, a basic prerequisite is a computerized road map, or to be more precise, a digital toad network structured into links and nodes, together with other traffic and service-related attributes such street names, street directions, turn restrictions, road classifications, business listings, plus a host of other items, to provide a geographically referenced system. This section discusses the standards, and data requirements for the digital map database in TIS applications.

2.5 2.1 Types Of Standards for Digital Map Databases

Standards for digital map databases must be available or developed to permit database vendors to consistently and accurately describe their products and to permit application developers to match available databases to their needs. There are four basic standards applicable to digital map database:

+ Truth-in-Labeling Standards.
+ Transfer or Interchange Standards.
+ Content or Minimum Performance Standards.
+ Standard Nationwide Database.

The first two standards, Truth-in-Labeling and Transfer or Interchange Standards, are the major North American initiatives in digital map database standards. Truth-in-Labeling standards is developed by the Database Standards Committee under the ITS Division of the Society of Automotive Engineers. The initial scope of Truth-in-Labeling standards is digital maps for passenger vehicle applications. The U.S. Geological Survey (USGS) has developed a Spatial Data

Transfer Standards for the purposes of establishing transfer or Interchange Standards. These two standards establish the framework and guidelines in the two most important areas for digital map database, and will be discussed in more details in this section. The last two standards will be discussed very briefly for information only and are not considered suitable for the application of TIS.

Truth-in-Labeling Standards provide a consistent method for describing and comparing map database, and consist of definitions to identify relevant database items and relationships, as well as mechanisms for database producers to consistently specify the degree of quality (coverage, accuracy, currency, completeness, distribution of errors, etc.) of their databases.

The Truth-in-Labeling Standards are composed of three kinds of specifications related to the content and characteristics of a digital map database:

+ Definitions: define precise specifications of the entities to be included in database;

+ Metrics: provide scales or criteria for consistently measuring database quality;

+ Tests: score the entities against each of the corresponding metrics.

A Truth-in-Labeling standard allows a system developer to choose the database most appropriate for his particular application. However, a Truth-in-Labeling standard does not specify minimum requirements such as quality or content standards, which will surely be different from application to application; it merely provides a consistent and reliable mechanism for conveying information on database content, coverage and quality.

Transfer or Interchange Standards focus on the transfer of spatial data between databases by specifying common terms and formats for the data. Transfer standards provide a common format to and from which other database formats can be translated. A transfer standard does not prescribe the quality or accuracy of the data, although quality characteristics are often part of the information exchanged.

There are three prominent Interchange Standards that have been developed. They include the American Spatial Data Transfer Standard (SDTS), European Geographic Data File (GDF) and Japan Digital Road Map Association (JDRMA). SDTS is now a Federal Information Processing Standard (FIPS).

SDTS is an open and general standard for the exchange of spatial data and was designed to serve a variety of applications, including cartography, geography, geology and Geographic Information System (GIS). SDTS is made up of three main parts: a logical superstructure, a list of spatial features and attributes, and the encoding method. The logical superstructure provides specifications for the organization and structure of digital spatial data transfer. The list of features and attributes include definitions for those features and attributes. The data transfer encoding method is ISO 8211, an international media-independent interchange format.

Content or Minimum Performance Standards specifies a minimum content or level of quality that a map database must meet for a particular purpose. Since different applications have substantially different performance requirements, one set of content standards developed for a specific requirements generally is not applicable to other applications. Therefore, content standards must be carefully tailored for specific and well-defined applications.

Standard Nationwide Database is the approach of the Japan Digital Road Map Association. With a standard nationwide database, transfer of information from one system to another is relatively simple. On the other hand, a standard nationwide map database is very expensive to create and maintain. This approach is unlikely to be applied in the U.S. because privately created map databases are already widely available.

2.5.3 Reference/Coordinate System for Digital Map Database

Basic reference/coordinate system requirements for the digital map databases are defined as follows:

+ The map represented by the database is a two-dimensional topological model composed of nodes (e.g., points for intersections, vertexes for roadway end-points, etc.) and links (arcs for boundaries, line segments for roadway segments, etc.) imbedded in a planar surface. In this case, the two-dimensional surface is an ellipsoid representing the earth's surface.

+ Geodetic coordinates (geographic reference points whose precise location is well-known and generally agreed upon) and the ellipsoid conform to the specifications of WGS-84, the 1984 World Geodetic System. WGS-84 is the basis for specifying coordinates using the U.S. government's satellite-based global positioning system (GPS) and has rapidly become the accepted standard for applications which involve identifying precise locations on the earth surface.

2.5.4 Data Requirements of Digital Map Database for TIS Applications

As discussed in the previous sections, data requirements for a digital map database are difficult to specify if the application is not well-defined. This section will define the data requirements for the digital map database for the purposes of TIS applications, in particular, in-vehicle navigation.

A navigable database shall consist of both basic elements and optional features. Optional features can be superimposed upon the database as additional layers to meet the requirements of specific applications. The basic database elements include:

+ Topological features, including accurate and current road geometry for map display and map matching purposes. Accurate geometry can be defined as roadways digitized to within 15 meters or less of their ground truth,

+ Physical and funcitonal road classifications. Physical classification is based on a roadway segment's physical attributes, such as a fully-access or restricted access highway and speed limits. Functional classification indicates how the roadway is used to move traffic from one place to another, such as roadway capacities.

+ Addressability, the ability to locate and pinpoint any location or address stated within the covered area. This includes street names, range of addresses, individual address, ascension or descension of the addresses based on the direction of travel.

+ Value-added navigation information, including but not limited to street directions, turn restrictions, physical dividers, one-ways time-of-the-day restrictions, flow restricted roadways (e.g., HOV lanes), construction activities (e.g., detour), and signage that indicates entrances and exits of a limited access roadway.

+ points of interest, such as important landmarks, tourist attractions and business listings.

Optional features may include:

+ ZIP codes;

+ jurisdictional boundaries;

+ demographics;

+ cartographic advances to make the map display more attractive and features more recognizable.

2.5.5 Communications Standards

The CTIS will use compatible standards to provide the communications between CTIS equipment. These standards will allow the use of commercial off-the-shelf technologies within the CTIS, thus enhancing the CTIS' communication flexibility. Some of these communications standards are shown in Table 2-5.

Table 2-5. Communlcatlon Standards used in CTIS

Protocol/ Technology	Brief Explanation of Protocol	Potential Use in CTIS
RS232C	Serial communications used between equipment in close proximity and with data rate of less than 38.5Kbps.	Within RTIC facility
HDLC	Used to packetize data for network WANs.	Used between CTIS elements (RTIC WAN)
RS449	Serial communications between equipment less than 1 Mbps using RS442 protocol.	Within RTIC facility
RS485	Differential communications used between equipment which allows for multiple talkers on single data line.	Within RTIC facility
RS530	Serial communications which will supersede RS449 and currently being phased in.	Within RTIC facility
RS422	Differential voltage standard that allows for higher data rates than RS232C.	Within RTIC facility
FM subcarrier Radio	Used with ISPs and potential HAR for in-vehicle communication.	Between ISP and vehicle
DS1	1.544MBPS WAN.	Used between CTIS elements
X.25 Data Packetizing	Packetize protocol used for WAN networks.	Used between CTIS elements
Ethernet (IEEE 802.3)	1 OMBPS network protocol.	Within RTIC facility within
Cellular Radio	A wireless standard which allows for packetizing voice or data to communicate with Cells that are connected together.	Between ISP and user
Analog Voice	Voice transmitted through a public switched network with commercial capability of up to 28.8 Kbps.	Between the RTIC and general public
NTSC Analog Video	Real time Video standard used with commercial media providers.	Between RTIC and Media
H.261 Compressed Video	Compressed video standard used to convey real-time and near real-time video on WAN of 1.5 Mbps.	Between RTIC and Media and other CTIS disseminators
ISDN - Integrated Services Digital Network	Voice protocol standard proposed to take the place of standard analog voice. Allows up to 64 Kbps to be **exchanged** along a phone line.	Between the RTIC and general public or service provider
SONET - Synchronous Optical Network	Fiber optic network communication protocol that communicates at greater than 48 Mbps.	Between CTIS elements
ATM- Asynchronous Transfer Mode	**An** asynchronous network protocol that allows for a combination of full motion video, data and voice.	Between **CTIS** elements

Initially, the minimal RTICs communication shall use the following:

+ Internal LAN Ethernet standard using TCP/IP.

+ External WAN using a Digital Switch standard such as CSU/DSU at the RTIC end connected to a high speed serial protocol such as V.35.

+ Telecommunication equipment with voice grade using a serial standard connection such as RS232 to a server.

These standards allow for the upgrade of the network, equipment, and telecommunication systems within the CTIS at the emergence of new technologies.

2.5.6 Database Standards

The database will be a commercially available Structured Query Language (SQL)-compliant Relational Database Management System (RDBMS) for the storage and retrieval of all alphanumeric data. An SQL C preprocessor will also be used, if necessary. There are a number of commercially available conforming databases, which include Sybase, Oracle, Informix, Ingres.

2.5.7 Standards for Graphical User Interface (GUI)

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

The *OSF/Motif Style Guide* strives to accomplish the following [OSF/Motif '91][1]:

a. Adopt the user's point of view.
b. Give control to the user.
c. Use real-world metaphors.
d. Keep interfaces natural (intuitive).
e. Keep interfaces consistent; common "look-and-feel" for all interface elements.
f. Communicate application actions to the user.

1 Open Software Foundation (OSF), *OSF/Motif Style Guide,* Prentice-Hall, Inc., 1991.

g. Avoid common design pitfalls.

In addition to conforming to the OSF/Motif Style Guide the GUI will follow recognized principles of successful interface design:

a. Give feedback - acknowledge user inputs: update displays to reflect a new state; highlight mouse selections.
b, Help the user learn - computer-guided training: on-line tutorials; on-line documentation; regular context sensitive help:
C. Response time - immediate response to keyboard and mouse input; quick, consistent response to commands, selections.
d. Consistency - system actions have the same meaning throughout the system.
e. Structure - uncluttered, logical layout of screen areas.
f. Coding - increase recognition speed through color and shape encoding.
g. Minimize memorization - menus; pop-up help windows so context is not lost.
h. Ease of Use - focus on minimizing the burdens and distractions of the operator while maximizing the speed and ease of use.
i. Levels of Expertise - Support various levels of user expertise: beginner, novice, expert. Provide the advanced user with the ability to define function keys or other short-cuts.
j. Window Management - a task specific, yet user definable, priority system for window overlapping based on importance, relevance and frequency of change of the information in the window.
k. Spatial Reference - geographical orientation/reference of information as appropriate, i.e., use of the spatial relationships and geographical reference to keep information organized.

2.5.8 Proarammina Lanauaaes

The programming language to be used shall be ANSI-compliant C or C++. Utilization of extensions to the programming languages provided by specific vendors is to be avoided, for portability.

2.5.9 Operating Systems

The operating system needs be a POSIX-compliant Unix or Windows NT plaftorm. At a minimum, POSIX 1003.1 (a.k.a. POSIX.1- System Application Program Interface [C Language], POSIX 1003.2 (a.k.a. POSIX.2 - Shell and Utility Interface), and POSIX 1003.4 (a.k.a. POSIX.4 - Real-time Services) need to be met.

3.0 COMMUNICATIONS SUBSYSTEM

The general philosophy of the CTIS architecture is to provide controlled access to pertinent traveler information on an as needed basis to all CTIS partners (i.e., public agencies and private sector participants). The two principal requirements for the CTIS communication subsystem are

+ Allow dynamic and static data to be shared among the CTIS elements and its partners.

+ Provide travel information on demand to the general public, and ISPs.

Typically the communication subsystem network will be functionally connected to the regional and sub-regional network, where both static and dynamic data are exchanged, fused and correlated prior to distribution to the traveler.

Traveler information will be communicated through public switched equipment and ISPs. This data is distributed from the CTIS asynchronously based on a query/response protocol. The communication subsystem will support diverse set of communication devices including handhelds, in-vehicle devices, audiotext, and Internet services.

3.1 CANDIDATE CTIS NETWORK

The candidate I-95 CTIS network is comprised of five Regional Traveler Information Centers (RTIC) communicating with one another through a common IEN communications network (see Figure 3-1).

This candidate network includes various communications media such as direct point-to-point and network interfaces using switched components and a variety of communications standards to enhance its flexibility.

The CTIS also communicates with ISPs and other CTIS partners using separate networks connected to the RTICs. Sub-regional networks are defined based on the geographical proximity of the ISP/Partner to an RTIC. The ISP/Partner can acquire corridor-wide information through the RTIC interface using gateways between the sub-network and the RTIC internal network. Sub-regional networks may include interface with the IEN and other dedicated networks to communicate with local elements such as TOCs, airports, parking garages and other local information suppliers and disseminators.

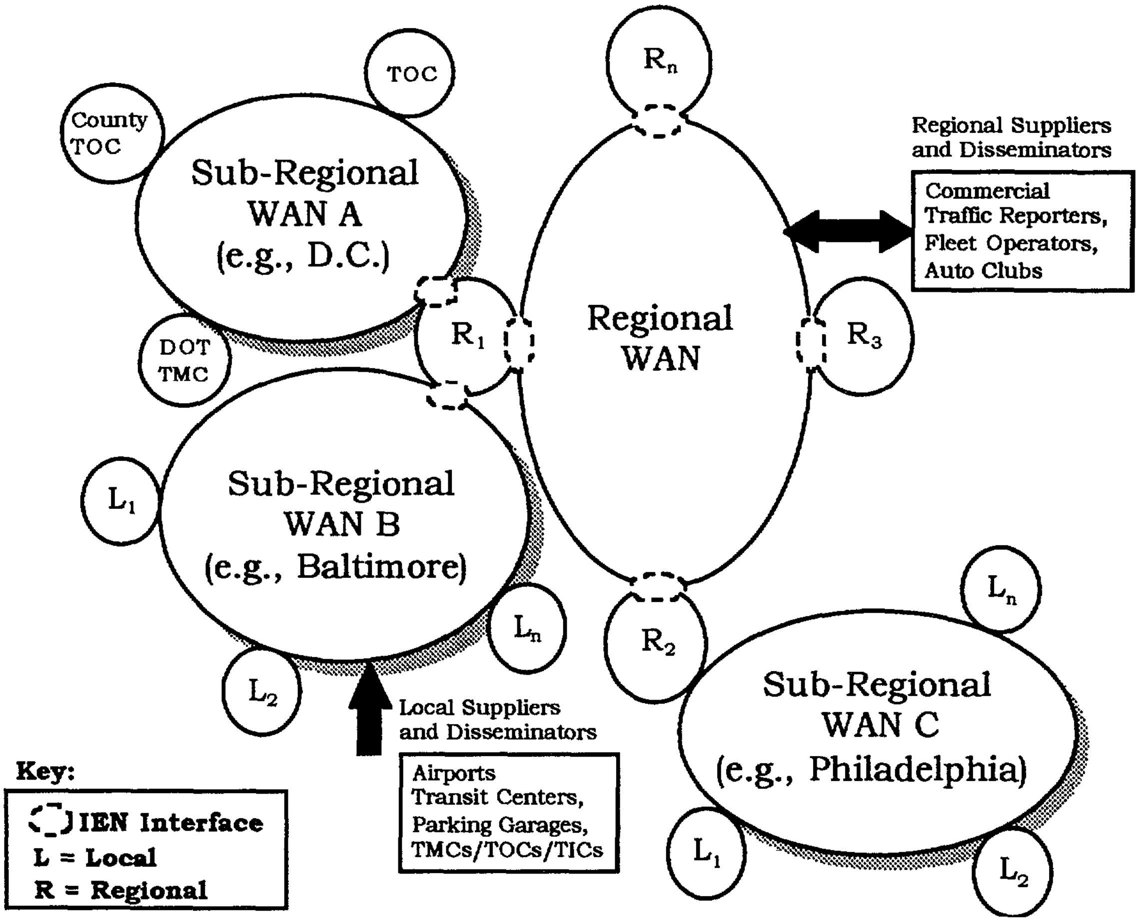


Figure 3-1 Candidate CTIS Network Architecture

The use of gateways will allow the candidate CTIS network to be easily integrated with current or planned networks because they can accommodate diverse network protocols.

The CTIS network design concept also includes local TICs located within an RTIC's sub-regional network. These local TICs are used to support local travel information needs not normally handled by the local TMC/TOC (such as parking and transit information). The principal functional differences between a RTIC and a local TIC can be characterized as follows:

- The RTIC has direct access to the CTIS network, the local TIC does not.
- The RTIC supports a large number of leased lines for public sector queries, the local TIC does not.

+ The RTIC supports both local and regional disseminators, the local TIC supports only local disseminators.

+ The RTIC contains detailed regional CTIS information, the local TIC has access to only summary regional CTIS information.

The distribution of regional and local responsibilities allows the CTIS communication architecture to grow as the traveler information needs of the corridor increase.

3.2 GENERIC CTIS COMMUNICATION NETWORK

The CTIS network handles both synchronous and asynchronous data need by the local TOCs/TMCs, CTIS elements, and ISPs. The network connection between the CTIS elements is shown in Figure 3-2. This regional network architecture allows for a direct connection or a public switched network interface between the RTICs. This regional network also allows the acquisition and dissimulation of regional data between the RTIC and regional ISPs Each RTIC also has access to its own local network through a local gateway. This local network allows an ISP or a CTIS partner to disseminate or access information depending on the particular agreements. The candidate CTIS network should have a combination of Wide Area Network (WAN), modem or other communication equipment types. This allows other communications routes to be used when the bandwidth of the primary network is exceeded. For example, a dial up modem interface between RTICs can be used when the primary IEN network interface is down or overloaded.

Each data element in the CTIS network is given a priority identifier to define an hierarchy in the data stream. This identifier enables the network to pre-emptively inject critical data (incident data) between less critical data (static data). In such cases data packet delimiters will be used to signify the temporary interruption of the data being transmitted.

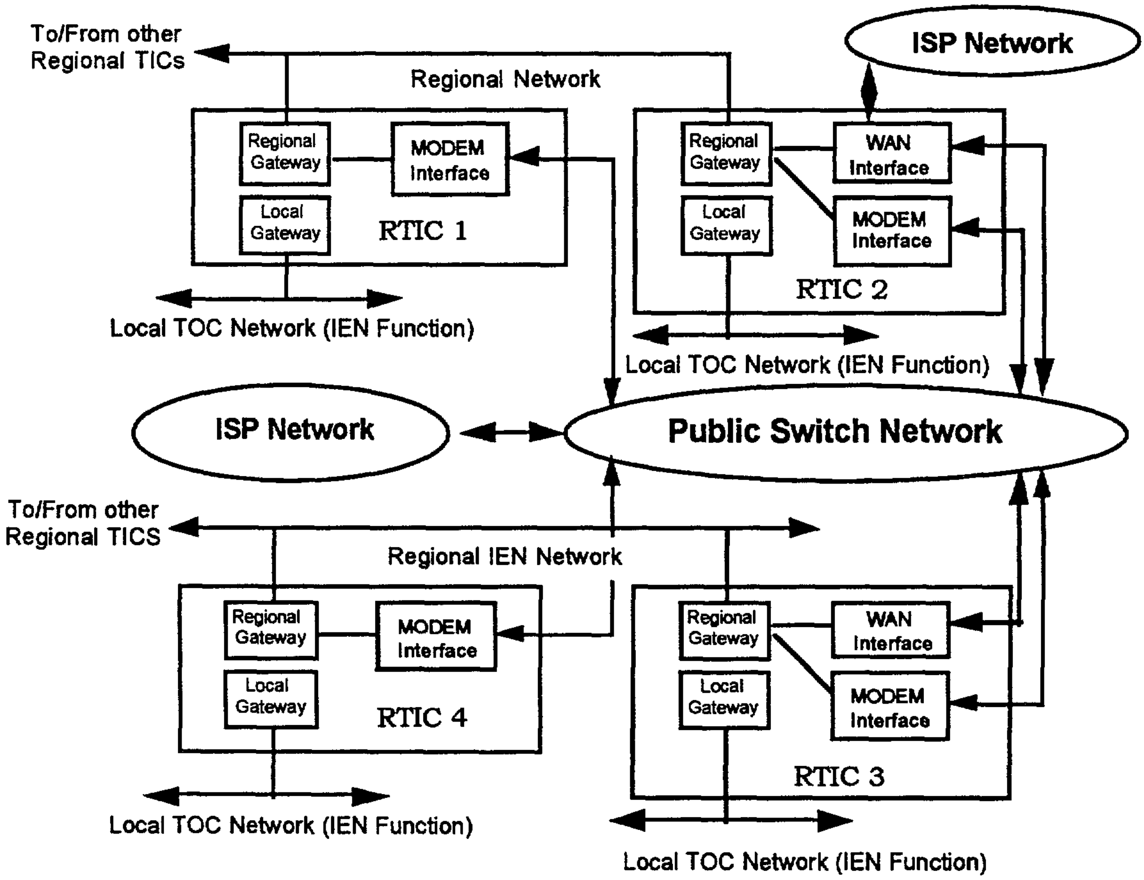


Figure 3-2 Generic CTIS Communications Network Architecture

3.3 RTIC COMMUNICATIONS NETWORK

The typical RTIC communications network contains interfaces for local networks, Wide Area Networks, and switch elements which connect to public phone lines. Figure 3-3 shows how a typical RTIC will interact with the various CTIS communication elements. The RTIC exchanges data with many TOCs/TMCs (the RTIC may be co-located within the TOC/TMC building) via a local gateway. This network interface allows for the exchange of data between the RTIC data processing equipment and the Regional TOC. The regional TOC/TMC network(s) are isolated from the other CTIS elements since the data exchange is controlled by the local gateway. This interface can be a network, such as Ethernet, using compatible communications equipment connected to a subnetwork. This subnetwork allows for the distribution of RTIC network information among the various data processing equipment within the CTIS.

Separate CTIS and inter-regional data networks are configured using the same gateway approach to allow the exchange of data to be controlled by the RTIC. Again these networks can be Wide Area Networks (WAN) using a compatible protocol such as DS1. The equipment used here may include the following:

- Network modem(s) - Used to connect to the public switch or the landline network
- Bridge(s) - Used to modify the WAN format to a local network protocol

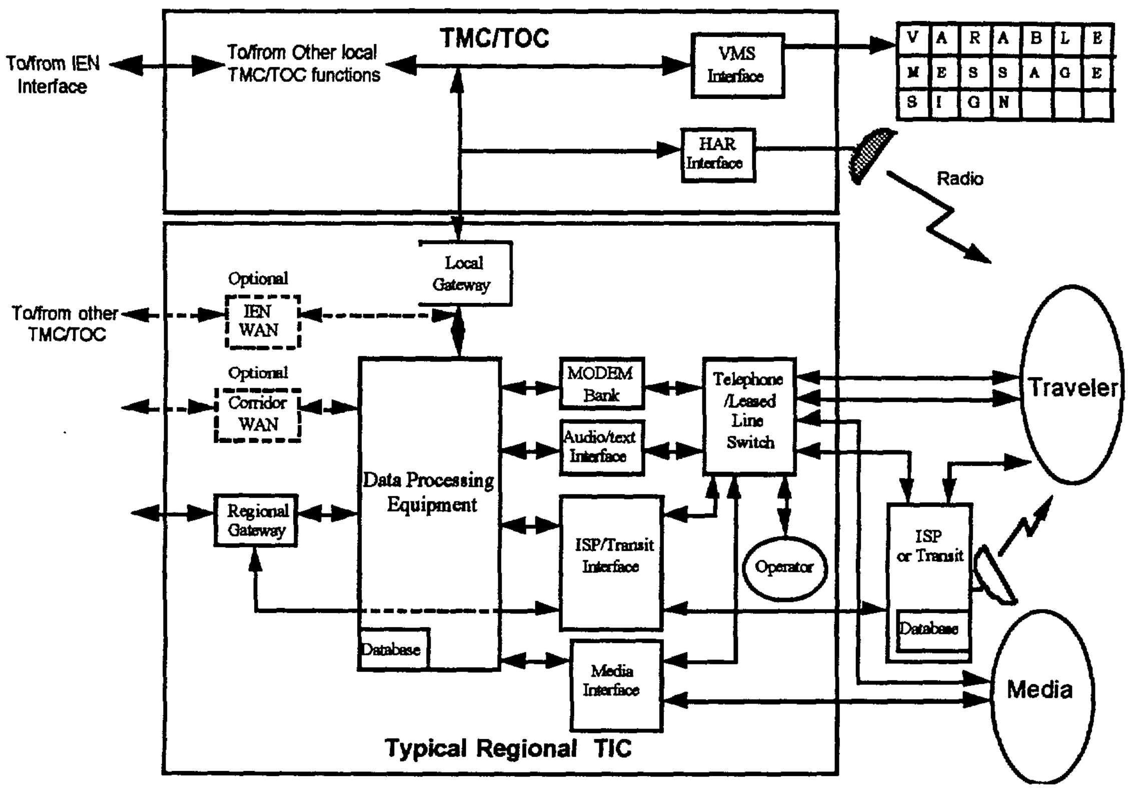


Figure 3-3 RTIC Communication Network

The RTIC's processing equipment will have the capability of monitoring the WAN for operational functionality and detect malfunction within the network.

At the local level, an ISP or media enters through a dedicated interface or through a dial-up modem. This interface allows the service provider controlled access to the CTIS's data and satisfies the specialized data requirement of the ISP/partner. The typical equipment used here is analog and digital video/voice equipment, specialized modems, and network switch components.

The traveler has access to the CTIS via the RTICs leased tines. Here queries enter the CTIS via commercial modem, or audiotext equipment connected to the RTIC's data processing equipment. Flexibility for the RTIC's leased lines are maintained since the dial-up services are muted through a switch network to the communication equipment within the RTIC. This allows the communication subsystem to select the most appropriate resources based on the dial-up users communication equipment. Provisions will be made to optionally include a human operator for queries which cannot be addressed by audiotext equipment.

3.3 1 RTIC-Audiotext Service

The RTIC audiotext interface is one of the direct interfaces to the public. This interface which typically dispenses information based on the travelers' queries, is currently accomplished in one of two ways. The first approach is to use the pulse or tone produced by a telephone to activate a menu system within the RTIC. Response to these queries shall be either pre-recorded voice or digitized voice controlled by the data processing equipment.

The optional second method is to use a voice recognition equipment located within the data processing equipment. Here the voice will be directly interpreted using an acoustical pickup located either within the data processing equipment or the modem. The data processing equipment will then interpret the query and issue the response in the same manner as the pulse/tone method.

3 3.2 RTIC-VAR External Interface Network

The RTIC-VAR external interface provides access to a TIC through a dedicated network connection. This network interface allows for the two way distribution of audio, video, and data between the RTIC and the VAR. This interface enters the RTIC through a WAN which is attached to a modem. The modem in-turn is connected to a gateway which provides a controlled access to the RTIC's LAN (see Figure 3-3). The VAR can then request information from the RTIC's data processing equipment. The bandwidth of this network shall be able to sustain its worst case communication rate up to and including full motion video.

The VAR will also be able to use a dial-up service to query the RTIC's database. This interface is identical to the traveler's interface with the exception of the use of additional security to protect the VAR's data.

3.4 REQUIRED HARDWARE

The CTIS shouid support the required hardware for the services shown in Table 3-1. The minimal RTIC requirements indicate the minimum equipment at initial deployment whereas nominal RTIC relates to equipment to be phased-in within two years of initial deployment. It was determined that 50 phone lines will support 100,000 calls per month per RTIC at initial deployment. A more detailed rationale for the determination is given in section 3.6.1.6 (RTIC-Public User interface). The required equipment will support a combination of network and subscriber service equipment to convey traveler information.

The communication hardware required are divided into network and public switched elements. The network elements shall have provisions for both local and WAN communications. All communications equipment shall be rack mountable to facilitate maintenance and allow the equipment to be easily upgraded.

Table 3-1 CTIS Required Communications Services

Equipment	Type of TIC Equipment is used	
	Minimal RTIC	**Nominal RTIC**
Phone lines	20 lines	50 lines
Regional Networks	CTIS only	CTIS and inter-regional
Sub-regional Network	IEN only	IEN and dedicated
ISP/Media Network	Transit Only	ISP, Transit, and Media
Commercial Modems	10	25
Data Exchange	Audiotext, and data	Audiotext, video, voice and data

The WAN shall at a minimum include a modem connection to the IEN planned frame relay network WAN. Other interfaces include the use of Digital Switch (DS1 through DS4), Channel Service Unit/Data Service Unit (CSU/DSU) or fiber optic modems connected to a public communications service. Figure 3-4 shows how two entities(RTICs, TOCs) will communicate with each other using a CTIS WAN.

Figure 3-4 CTIS WAN Communications

The local network should be at a minimum Ethernet compatible using 10Base-T(10 Mbps twisted pair Local Area Network). All hardware devices should be connected to the RTICs LAN except for the public switch elements or equipment attached to outgoing communication line. For a minimal RTIC option, the LAN shall use a packetized TCP/IP protocol. Packet filtering should be employed at the gateways to control access to the RTIC's LAN from an external network interface. Provisbns should be made for network expansion using fiber optic protocol such as SONET.

Voice grade lines will be able to interface with the telecommunications switching equipment located within the RTIC. This equipment will be directly connected to the voice lines and be distributed to modems, Audiotext equipment or optionally to an operator. This switching equipment should he controlled by the data processing equipment to allow the RTIC to manage the telecommunication I/O. Modems connected to these voice grade lines should, at a rninimum, be able to receive and transmit at 28.8 Kbps rate using MNP5 data compression. These modems should also be connected to the RTIC LAN either through a server or through the RTIC's data processing equipment.

The CTIS should be compatible with new communications types such as in-vehicle or handheld devices. These new communication devices should be typically employed by a ISP, Transit Service, Media, or TMC/TOC service providers. Since the RTIC supplies this information to the service providers, the data format should also be compatible with these new communication devices. This implies that whenever new services become available the RTICs should incorporate these new technologies (such as compressed and anabg video) in order to disseminate this information through the appropriate communications media to the service provider.

3.5 COMMUNICATION SUBSYSTEM DESIGN

The CTIS will have provision for several types of communicatbn interfaces including RTIC-TOC, RTIC-Transit, RTIC-Fleet, RTIC-RTIC, RTIC- CTIS partners, and RTIC-User. The diversity of these interfaces requires the CTIS to manage each of these communications segments using different techniques. This includes issues such as access to the CTIS database, availability of CTIS resources, and managing demands placed on networks controlled by the CTIS. The requirements of these service providers suggest that data must be handled in both periodic and on-demand basis. Therefore, the CTIS' s data will contain both static and dynamic data messages that will be distributed both asynchronously and synchronously to the service providers. Synchronous data messages may be interrupted by critical asynchronous data messages, which are dynamic in nature, and should take precedence over static messages.

3.5.1 External CTIS Interfaces

The CTIS shall provide interfaces to external TIS entities such as TMC/TOCs, ISPs, transit operators, travelers, and commercial providers. The provider will connect to the CTIS via networks and dial-up mechanisms. The network connections will be used by those providers that require comprehensive data based on time-critical requirements. This type of connection will allow the usage of both asynchronous and synchronous messages based on the requirements of the service provider. At a minimum the following information shall be included within the message to facilitate proper data communication:

+ Source address (or ID).
+ Destination address (or ID).
+ Length of query (or response).
+ Sub-packet identifier and 'length (if any).
+ Query/Response message.
+ Checksum or other error detection/correction code.
+ Acknowledgment (or request for re-transmission code) to the message sender.
+ Authentication code used during the initiation process.

The network connection may be done through a virtual socket transaction (a temporary network connection established between two entities for the purpose of relaying information), a dedicated WAN, or a sub-network connection through an existing network (such as the use of a DSO element within a DS1 service).

Dial-up users will have access to the CTIS data based on non real-time data requirements. Here the dial-up entity will initiate a query, the entity queried will then respond to the query on the same interface. This interface will use an asynchronous communications protocol to convey messages between the CTIS and the external CTIS entity. Optionally, provisions will be made to re-transmit the query/response based on an error detected by the receiving entity. Provisions should also be included to use data compression to facilitate efficient usage of the dial-up line. At a minimum the following information shall be included within the message to facilitate proper data passage:

+ Source address (or ID).
+ Sub-packet identifier and length (if any).
+ Query/Response message.
+ Checksum or other error detection/correction code.
+ Acknowledgment (or request for re-transmission code) to the message sender.
+ Authentication code used during the initiation process.

The dial-up connection may be conducted through a single or multiple phone lines to the RTIC.

3.5.1.1 RTIC-TOC Connection

The communications between the RTIC and TOC will be done through a IEN wide area network connection. This connection will be accomplished via a modem attached on one side to the IEN provided network connection and the other end attached through a firewall server or gateway to the RTIC's local area network. This connection should allow the use of dissimilar network protocols by converting the messages communicated between the networks to compatible formats on either end of this network connection.

Provisions should be made to allow information to be exchanged between the RTIC and the various TOCs through a distributed network. An example of which is shown in Figure 3-5.

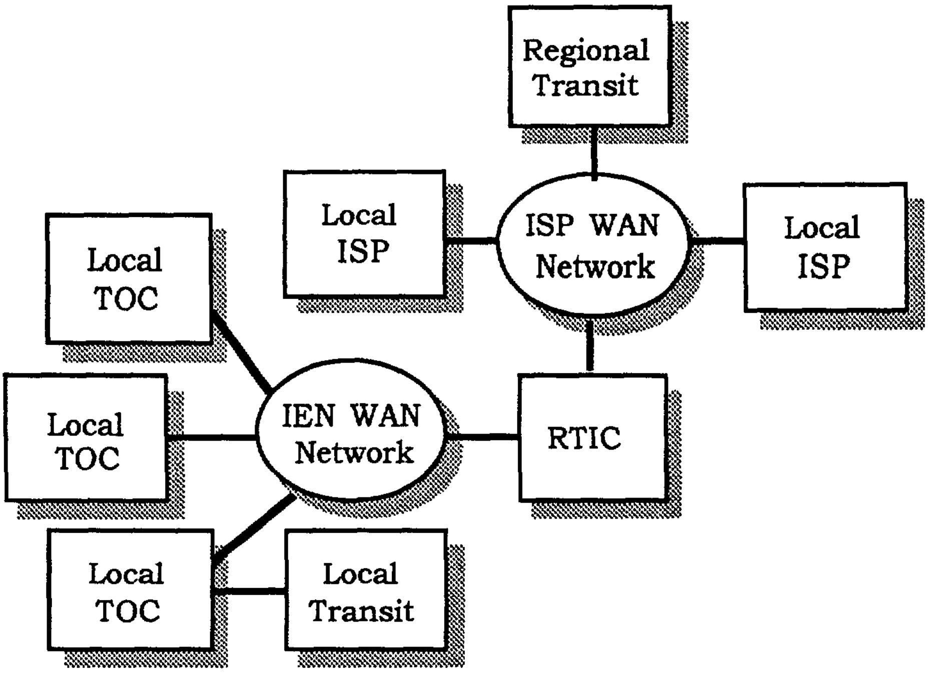


Figure 3-5 Distributed TOC to RTIC Network

With this method the RTIC summarizes information acquired by the local TOCs and then distributes this information to ISP and other users. Data requests from ISP are transmitted via the RTIC asynchronously to the individual TOC or transit agency which, based on available time slots within the network, responds to these data requests. The RTIC also has the capability of "eves dropping" on critical asynchronous data passed between the TOC, as in the case of incident data. Dynamic data is also transmitted to the RTIC from the TOCs or transit agencies synchronously. These elements are transmitted by the TOC (or transit agency) based on assigned time slots within the network and are identified by a packet identifier type and link identifier. An example of this synchronous parsing is shown in Figure 3-6.

Preamble	TOC id	RTIC id	Time Stamp	Link 1	Link 1 data	Link 2	Link 2 data	•••	Link N	Link Ndata	Check bits

Figure 3-6 An Example of Synchronous Data

Using this synchronous transfer method the transmitting entity transmits the packet, the receiving RTIC then sends an acknowledgment, upon receipt of an error free data packet, to the transmitting entity. The TOC then continues to transmit these packets and acquiring the acknowledgments until its entlre synchronous data has been transmitted. Similarly each TOC transmits of its data until the pattern repeats itself.

Assumptions

The data exchanged between the RTIC and the TOC contains static, dynamic and asynchronous on demand data. A summary of these data types can be seen in Table 3-3. These data messages represent the bulk of transmitted information over this network, however ISP request issued through the RTIC to the TOC or transit agencies may also be present.

Incident and critical messages (such as a HAZMAT incident) will be transmitted from the TOC to RTIC in an asynchronous manner. The TOC determine whether the message is critical enough to warrant interrupting the periodic message being sent between the TOC and RTIC. The critical message will then be transmitted after which the periodic messages will then be allowed to continue. These critical data messages will be transmitted on a "first come first served" basis. This allows the data messages to be processed efficiently without implementing a priority scheme. Another TOC can transmit its critical message when the first TOC has completed it' s critical message. In other words, TOCs will only be allowed to interrupt periodic message but will not be allowed to interrupt a critical message.

It is also assumed that these asynchronous data messages will not occupy more than 25% of the network utilization time. Provisions can be made to off-load these messages on to an alternate communications means such as dial-up modem in the event that the TOC-RTIC networks bandwith is fully used.

Dynamic data is information transmitted on a periodic basis due to the critical nature of the messages. These near real-time messages are based on traffic information associated withroad-link data and traffic demands.

Periodic data will be transmitted based on a minimal update rate of 1 minute. The actual transmission of these messages will be done when the data exceeds a pre-determined threshold. In the case of traffic data this threshold is established when the link's traffic speed changes more than 25% or based on events that are predefined by the RTIC and it's TOCs (such as a link receiving snow).

Table 3-3 TOC data Assumptlons

Data Name	Communication Composition Sync/Async	# of Bits	Update Rate	Static/Dynamic
Real-Time Traffic & Road information	Update only	200 byte per link	1 min	Dynamic
Incident Data/Logs	Async	500 Bytes per incident	N/A	Dynamic
Event Plans/Status	Sync	20K byte for corridor	Daily or as required	Static
Static Network Data	Sync	10K byte for corridor	Daily or as required	Static
Traffic Demands/Trends	Update only	100 bytes per link	1 min	Dynamic

The static data elements are transmitted based on non-time critical requirements (such as data transmitted on a weekly or daily basis). These data messages are transmitted over the network during times when the TOC is experiencing tow link activity.

Bandwidth Calculations for RTIC-to-TOC Network

The minimum bandwidth requirement for the RTIC to TOC connection is dependent on the amount of dynamic data used within the network. Within a region it is assumed that the dynamic data will occupy no more than 50% of the daily bandwidth of the network. Of the remaining 50%, 25% is used for asynchronous incidents and static data and 25% reserved for growth.

Based on these assumptions, the following equation is used determine the bandwidth.

Bandwidth = 2 x (maximum dynamic data + network overhead)

The network overhead is associated with framing and packetizing the data for the network. If the message overhead for each TOC is assumed to be less than 2% of the information, the above equation then becomes:

Bandwidth = 2 x (maximum dynamic data (1+.02)) = 2.04 x maximum dynamic data

Each road link data consists of real-time traffic data (200 bytes) and traffic demand/trend data (100 bytes).

Within the I-95 corridor, the total number of links is estimated to be up to 3200 and the number of TOCs 30. This implies that there is on an average of :

3200 links/30 TOCs = 107 links per TOC

If we also assume a variance of up to 20% from the mean, then each TOC must manage between 86 to 128 links.

On the average an RTIC must acquire information from 6 TOCs (30 TOCs/ 5 RTICs). The amount of information per TOC can be calculated as follows:

(107 Links/TOC * 300 byte-min /link/ * 8 bit/byte * 2.04 (associated with overhead, asynchronous data, and growth))/ 60 sec/min = 8.73 Kbps

If all 6 TOC are connected to a IEN WAN then the total amount of data entering the RTIC is,

6 *TOC • 8.73 Kbps/TOC = 52.39 Kbps*

which can be accommodated on a 56 Kbps WAN.

If the maximum number of links (128) were used for all 6 TOCs, then the WAN must support 62.67 Kbps. Remember this includes the aforementioned 25% data growth. Omitting this 25% from the information bandwidth yields;

(6 TOCs • (128 links/TOC • 300 byte-min /link/ * 8 bit/byte * (1.02) ● 7.5) / 60 sec/min = 47 Kbps

The 56 Kbps wan can support the maximum amount of regional link data but allowing only a small growth margin (9 Kbps).

Number of LInks Supported as a Function of Data Rates

As an extension of the previous section, Table 3-4 lists the total number of road links that can be supported by each media type and its associated data rate.

For example consider an example, consider an Ethernet network having a maximum data rate of 10 Mbps.

Maximum Dynamic Data Rate = 10 Mbps/2.04 = 4902 Kbps

# of road links = 4902 Kbps * 60 sec/min • 1 link/ 300 byte * 1 byte/ 8 bits * 1 min

= 122,550

This table assumes that the dynamic data's content is exclusively RTIC to a single TOC.

Table 3-4 Network Types vs. Dynamic Data Requirements

Network		Dynamic Data	
Type	**Max Data Rate**	**Amount of dynamic data**	**# of Road Segments per min.**
Ethernet	10 Mbps	4,902 Kbps	122,550 links
DSO	56 Kbps	-27.5 Kbps	688 links
CSU/DSU or **DS1**	**1.544 M** bps	756.9 Kbps	18,923 links
SONET OC1	48 Mbps	23,529 Kbps	588,225 links
Dial up Modem	*28.8* Kbps	1411 Kbps'	353 links

3.5.1.2 RTIC-Transit Connection

Transit information enters the RTIC through two communication paths. Regional transit operations is directly transmitted to the RTIC, whereas local transit operations information, if needed, is transmitted via the TOC. The composition of this data includes both dynamic and static data elements. Table 3-5 shows the assumed amount, type and composition of the transit data.

Table 3-5 Transit Dispatch Center Information

	Communication	Composition		
Data Name	**Sync/Async**	**# of Bits**	**Update Rate**	**Static/Dynamic**
Real-Time Transit Information	update only	1 K bytes per transit	5 min	Dynamic
Static Transit Data	update only	1K for corridor	Daily	Static
Traffic Demands/Trends	update only	**100** bytes **per link**	10 min	Dynamic

As in the case of the RTIC to TOC data, the dynamic data reported is only reported when the data exceeds a predetermined threshold. This network connection will allow for asynchronous queries to the RTIC from the transit facility or kiosk operations.

3.5.1.3 RTIC-FLEET CONNECTION

Information distributed to a fleet operation can be transmitted either via a network or via a dial-up modem. Through the network service, dynamic data is maintained at a near real-time rate to the service provider (see Table 3-6). When the fleet operation is connected directly to the RTIC or to a local TIC, with direct connection to the RTIC, this interface is a separate network from the RTIC-TOC network and therefore will not affect its utilization. If however, the fleet operation is connected to a local TOC the amount of data between the RTIC and regional TOC will increase.

Table 3-6 Fleet Information

Data Name	Communication Composition			
	Sync/Async	**# of Bits**	**Update Rate**	**Static/Dynamic**
Real-Time Traffic & Road Information	update only	***200*** byte per link	1 min	Dynamic
Incident Data/Logs	Async	***500*** Bytes per incident	N/A	Dynamic
Event Plans/Status	Sync	1K byte for corridor	Daily	Static

When the fleet operation uses a dial-up modem, dynamic data and asynchronous data will not be updated in the same manner as when a network connection is used. Through the dial-up modem interface only updates of the dynamic data will be given dating from time the service provider last contacted the RTIC **(or visa versa).** The **asynchronous** data (incident data) will be reported in its entirety to the dial-up entity based on the service provider last contact. The principal difference is that the asynchronous data are reported in entirety whereas dynamic data is not.

3.5.1.4 RTIC - RTIC Connection

The interface between RTICs is an IEN interface operating at frame relay speed of 56 Kbps. Table 3-7 shows the type of data, amount, and portion of WAN network bandwidth utilized, for a 56 Kbps IEN network. This table is constructed by assuming the two way communications between two RTICs only. Other RTIC or service providers connected to this WAN will significantly alter the utilization percentages of this table. The total number of bits required to transmit real-time traffic and road information per region every 3 minutes can be calculate as follows.

Total # bits = 768 links/ 3 min . min/ 60 sec *200 bytes/ link *8 bits/ byte

***= 6.83 K** bits/sec*

Table *3-7 RTIC Network Assumptions*

Data Name	Communication Composition		
	# of Events or frames	**Total number of bits /region**	**Percentage of 56 Kbps WAN**
Real-Time Traffic & Road Information	768 links per region per 3 min	6.83K bits/sec	12.2%
Incident Data/Logs	est. 50 per minute per region	3.33K bits/sec	5.94%
Event Plans/Status	static data/day	100K bits	0.12%
Static Network Data	static data/day	100K bits	0.12%
Traffic Demands/Trends	768 links per region per 3 min	3.41 K bits/sec	6.1%
Real-Time Transit Information	5 transit centers per region	67 bits/sec	0.12%
Static Transit Data	static data	1.00K bits/day	0.12%
Event Plans/Status	static data	1.00K bits/day	0.12%
Weather and Environmental Information	768 links per region	1.02K bits/sec	1.83%
Parking Data	5 transit centers per region	27 bits/sec	.048%
Event Plans/Status commercial interface	static data	100K bit/day	0.12%
Total percentage of 56 Kbps WAN used			**26.84% used**

As can be seen in table 3-7 the total utilization of a 56 Kbps WAN is less then 30%. This implies that 70% of the WAN can be utilized for other information.

3 5.1.5 RTIC-CTIS PARTNERS CONNECTION

The communication demands of the CTIS partners on the RTIC incorporate many information types including external database, disseminators, and non-I 95 corridor information. Because this information is so diverse the bandwidth and type of connect-on for these partners constitute a unique set.

Table 38 list some of the expected data types. This information may enter the CTIS at both the local and regional level. With the exception of fleet probe data these services will be allowed to enter the RTIC network at the closest geographical location to the service.

Table 3-6 External-CT& Database/ information

Data Name	Communication Sync/Async	Composition # of Bits	Update Rate	Static/Dynamic
Weather and Environmental Information	update only	50 byte per link	10 min	Dynamic
Parking Data	update only	200 Byte per Center	10 min	Dynamic
Fleet Probe Data	Async	10K Byte per probe	N/A	Dynamic

Since External-CTIS Database Information is dynamic the standard interface for this connection is a network. However, this information/requests may also enter the RTIC via dial-up modems if the dynamic update rates are waived.

Dissemination Partner information is used to provide RTIC information to a partner connected at the RTIC only. Data is furnished to this partner only on a demand basis and hence is an asynchronous interface. Table 3-9 lists the data set in this category.

Table 3-9 Dissemination Partner Information

Data Name	Communication Sync/Async	Composition # of Bits	Update Rate	Static/Dynamic
Information Requests	Async	1K Bytes	N/A	Dynamic
Access Grants	Async	50 Bytes	N/A	Static
Requested Data	Async	100K Bytes per request	N/A	Dynamic

Data is fed **to** the disseminator via a virtual network connection, where the connection is maintained only for as long as information is flowing, or through a dial-up line. Figure 3-7 shows the handshaking process for such a connection.

Non-corridor type information is distributed to entities that are associated with other corridors. This information is used to convey corridor activities to these outside agencies so that they may assist traveler entering or leaving the CTIS area. Information about severe weather conditions, airport closures and rail derailments are some of the information that might be communicated to these outside-the-corridor agencies. This information will be distributed through a dedicated interface directly connected to a RTIC. Table 3-10 shows the information types used in this interface.

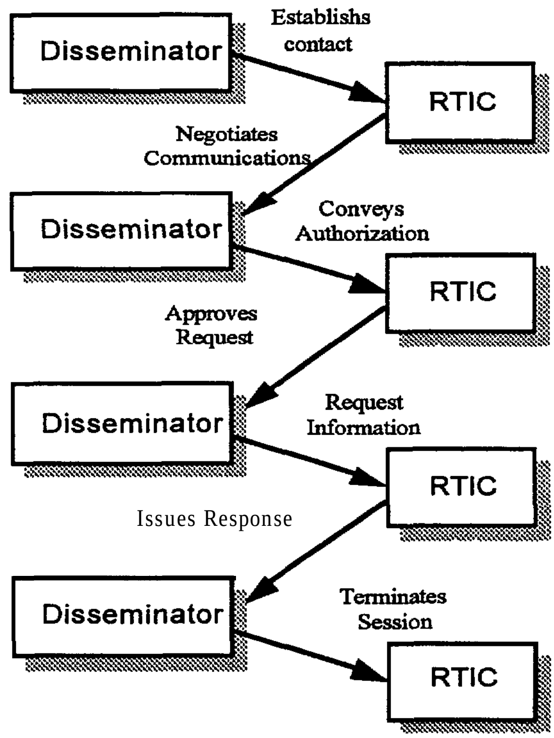


Figure 3-7 Process Flow between Disseminator and RTIC

Table 3- 10 Non-Corridor information

Data Name	Communication Composition		Update Rate	Static/Dynamic
	Sync/Async	# of Bits		
Inter-Regional TIC Information	Async	100K bytes	N/A	Static
Inter-Regional TIC Information	Sync	100K byte per corridor	5 min	Dynamic

Based on the update rate for the synchronous data element, the worst case bandwidth associated for this interface is derived as follows:

Bandwidth = (# of bit x 2)/update rate per second = 2(100K x 8)/ (5 x 60) = 5.33 Kbps

The 2x multiplier is used to accommodate an asynchronous data transfer within the 5 minute update period. This data rate suggests that during the initial deployment, a common modem of 9600 bps could accommodate the data exchanged between two inter-regional TIC entities. After deployment is achieved it is recommended that a inter-regional WAN be established at each RTIC so multiple non-corridor entities could be sewed.

3.5.1.6 RTIC-Public Users Interface

Public user information is conveyed synchronously to and from the RTIC. This interfaces directly to the RTIC or via one of the ISPs connected to the RTIC. This data allows the traveler to directly acquire RTIC information based on a query/response mechanism. Table 3-11 shows public user information types from the RTIC.

Table 3-11 Public Users Information

Data Name	Communication Composition			
	Sync/Async	# of Bits	Update Rate	Static/Dynamic
Real-Time Traffic & Transit Information	Async	50 byte per link	N/A	Dynamic
Modal Travel Time Comparisons	Async	1K Byte per comparison	N/A	Dynamic
Weather and Environmental Information	Async	50 byte per link	N/A	Dynamic
Traffic Forecasts, Demands, Trends	Async	50 bytes per link	N/A	Static
Trip Itineraries	Async	500 Bytes	N/A	Dynamic
Static Traffic and Transit Information	Async	10K Bytes per request	N/A	Static
Emergency Services	Async	500 Bytes per request	N/A	Static
Traveler Services Information	Async	1K Byte per request	N/A	Static
Trip Plans and Queries	Async	10K Bytes per request	N/A	Dynamic

This communication type enters the RTIC predominantly through two communication methods. The first, is a direct connection to the RTIC through a dial-up line. Here data is exchanged asynchronously by Audiotext menus, or via a commercial modem. This communication exchange is based on a first-come-first-served basis. The suggested number of phone lines each RTIC will need for this interface is derived using the following assumptions.

- 100,000 calls per month per RTIC.
- 1.5 minutes per Audiotext call.
- 5 minutes per modem call.
- 70% of the call are made during 6-9 A.M. and 3-7 P.M. Monday through Friday.
- 10 % of all calls are modem calls.

Using these assumptions the number of phone lines needed per RTIC can be calculated as follows.

*Number of Lines = ((minutes * Audiotext %) + (minutes * modem %)) * (calls * % peak period calls)) / usage period*

*= ((1.5 mins * .9) + (5 mins * .1)) * (100K calls / mth * .7)) / 8400 mins / mth*

= 16 phone lines

Therefore 16 phone lines per RTIC will allow 100K/month calls to be made for travelers requests.

*Number of modems required = ((mins * modem %) * # peak period calls) / # peak mins*

*= ((5 * .1) *(100K /mth / 20 days)) / 420 mins*

= 6 modems

Six modems must therefore be dedicated to travelers request during peak hours.

The second method used for a direct traveler connection uses a virtual socket connection on a network. Here the traveler submits queries to the RTIC via a network connected to a public communication provider. This connection is implemented via a digital switch network connection which allows intermediate service providers to directly interface with the traveler. This connection allows the traveler to use a network browser (such as gopher or Mosaic) to communicate with the RTIC network socket. Since the RTIC socket is interrogated and closed on completion, engagement time between the traveler and the RTIC is short. This allows several traveler to be serviced by one network connection.

The RTIC will support communications to the Traveler via sub-carrier FM, CDPD, in-vehicle devices, pagers, etc. The information will first be distributed to an ISP who will provide the conversion to the unique protocol required for dissemination to the travelers' devices. The RTIC will support unique ISP protocols which are associated with the travelers' devices based on agreements reached between the CTIS agencies and the ISPs.

3.6 COMMUNICATION SUBSYSTEM FUNCTIONAL DECOMPOSITION

The decomposition for the CTIS communication subsystem is shown in Figure 38. This decomposition includes both hardware and software elements in controlling and manipulation of the various communication data.

The following provide a summary of the communication subsystem elements:

+ Communication Manager - Provides the overall connection and processing management of the communication subsystem.

+ Communication Interface - Provides for the direct control of the communication network and public interfaces.

+ Data Input - Provide the mechanism to interpret the communications into data processing information.

+ Data Output - Provide the mechanism to interpret the data processing information into output communication compatible standard.

+ Data Translation - Provides for the error determination and packet interpretation (or communication sub-structure element) of the data.

+ Data Conversion - Provides for the packetization or similar communication sub-structure and installs error detection within the communication protocol.

+ Data Accumulator - Provides for the registration of data elements broken up by packetization, or interruption in the data stream by asynchronous data elements. This interface also allows for packetization or framing of the data.

These processes provide the necessary elements in controlling the communications subsystem within each of the CTIS elements.

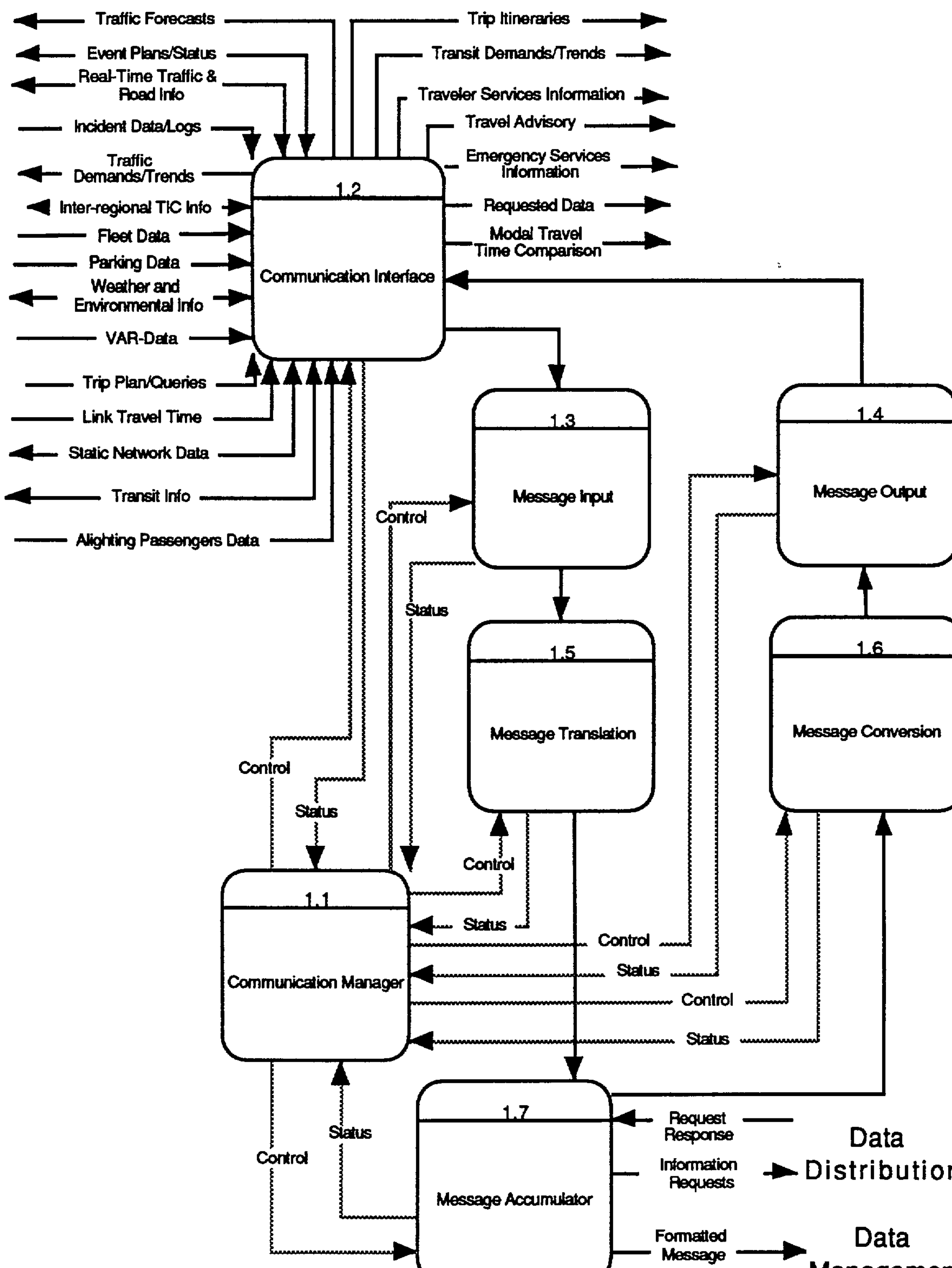


Figure 3-8 Communication Subsystem Decomposition

4.0 DATA MANAGEMENT SUBSYSTEM DESIGN

This section presents the conceptual design summary for the core of the CTIS data management subsystem. In this section, a conceptual illustration of the functions fulfilled by a data management capability will be presented. This section is intended to provide a high-level understanding of the Data Management subsystem. To support this conceptual design a very detailed analysis of the CTIS database structure was performed. These supporting design by-products, including a database schema and entity definitions are attached in Appendix I.

The success of CTIS depends on the ability to obtain traffic and travel related data from various sources, integrate that data, and disseminate the data in a useful form to a large number of users with different needs. The Data Management subsystem supports these requirements by providing the processing necessary to receive traffic and travel related data from the Communications subsystem, translate/convert the data to a CTIS data format, store the data in the CTIS database, and disseminate the data to other CTIS applications.

Each type of data that is maintained has a distinct purpose (e.g., to convey information about a roadway link). The definition of the format of this data is crucial, because in addition to being used by the CTIS system itself, the format may impact all external systems that supply or receive CTIS data. Compatibility concerns dictate that these outside systems must supply the data either in the format designed for CTIS, or in a format that can be translated by the CTIS into a CTIS format. Similarly, output from the CTIS to outside systems must be in a form that is understood directly by those systems or in a form that can be translated by those systems.

The definition of the input data, output data, and database records are crucial components in ensuring the creation of an interoperable system. The definition of input and output data is especially critical for the CTIS system to interact with existing facilities that have collected data, and existing facilities that are capable of displaying data.

The Level 1 Decomposition of the Data Management subsystem (Figure 4-1) resulted in the identification of the following modules:

- Data Ingest Manager
- Data Translation/Conversion
- Database Management System (DBMS) Server
- Data Monitoring

The functionality of these modules is described in the following sections.

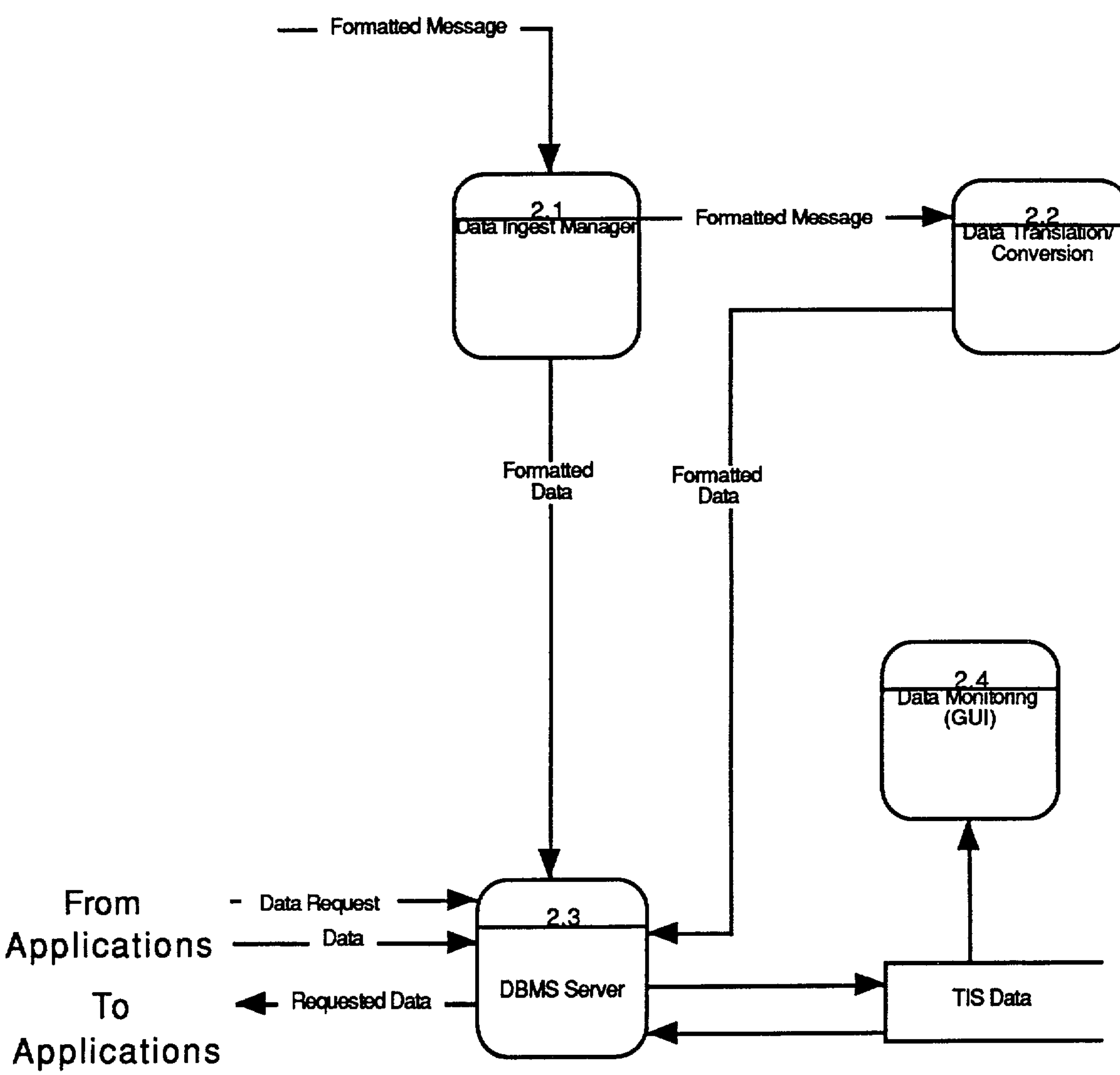


Figure 4-1. Data Management Subsystem Decomposition

4.1 DATA INGEST MANAGER

The Data Ingest Manager process is a continuously running process that receives data from the Communications subsystem. The Communication subsystem receives external data such as event plans, traffic data, road condition data, static network data, transit data, inter-regional TIC data, weather/environmental data, probe data, CVO fleet data, parking data, and VAR data. The Communication subsystem formats the raw external data for processing by the Data Ingest Manager.

The Data Ingest Manager process determines if the data is in a standard CTIS database format. If the data is not in a standard format, the data is converted by the Data Translation/Conversion process. The Data Ingest Manager sends the data that is received in a standard format to the DBMS Server.

4.2 DATA TRANSLATION/CONVERSION

Although the data received by the Data Ingest Manager is in a format that can be processed, the actual definition of the data may not be a standard CTIS database format. For example, traffic volume stored in the CTIS database may be stored as a numeric value, but the data received by the Communications subsystem may be a character representation of the value. If the data is in a format that is not a standard CTIS database format, the Data Ingest Manager sends the data to the Data Translation/Conversion process for translation/conversion into the standard format. It is expected that only some of the data will require translation/conversion (it is assumed that data received via an IEN interface with be in a canonical form). Translated/converted data is sent to the DBMS Server.

4.3 DATABASE MANAGEMENT SYSTEM (DBMS) SERVER

The Database Management System (DBMS) Server provides relational database management system (RDBMS) capabilities. Many of the capabilities provided by this process will be supported from commercial-off-the-shelf (COTS) RDBMS technology (e.g., Sybase, Oracle, Ingress, Informix).

The primary functions of the Database Management Server process are to receive requests from application processes for inserting/updating/deleting data and querying data. Validated data is sent to the DBMS Server for storage in the CTIS Database. The DBMS Server can simultaneously process multiple requests from applications such as Data Validation, Data Distribution, Trip Planning and Trip Monitoring.

CTIS users do not directly query the DBMS Server. User requests are processed by the Data Distribution subsystem. The Data Distribution subsystem makes data requests on behalf of the user, formats the data in the proper dissemination format, and it sends these results back to the user. CTIS support personnel (Database Administrator (DBA), System Administrator (SA), etc.) are the only individuals that will directly interface with the DBMS Server.

4.4 DATA MONITORING

The Data Monitoring process is a tool to perform the following functions on the CTIS Database:

1. Query Data
2. Generate Reports
3. Update Data
4. View Data
5. GIS Graphic Display

The Data Monitoring process will consist of a GUI interface, a reporting software tool and a MAP GIS. These tools will be used by authorized users such as DBAs, SAs and operators.

5.0 DATA DISTRIBUTION

The data distribution process provides the functionally to accept requests from client applications for data in the form of text, graphics, video clips, and audio. This capability will determine which RTIC application process should serve the client and route the request to the appropriate application. The response from the application will be routed to the original client.

While this architecture depicts a logical design, it is conceivable that some of the functions identified under this subsystem could be satisfied by related functions at the implementation stage. It is important to note that while the architecture does not dictate an implementation process, it identifies all of the functional requirements that need to be satisfied by each of the major capabilities. As a minimum, the data distribution capability would contain the following processes:

1. Query/Response Manager.

2 Application Router.

3. Report Generator.

Figure 5-1 shows the level 2 data flow diagram for the data distribution capability. As previously illustrated in the level 1 DFD, data distribution interfaces to other subsystems including communications, data management, trip monitoring, trip planning and dissemination applications. The logical architecture depicted here is modular in nature to facilitate fully distributed deployment across the network.

The phased deployment of each RTIC, as envisaged, requires precise interface formats and protocols. This would facilitate a fully distributed expandable and flexible data distribution architecture which can be deployed as and when required.

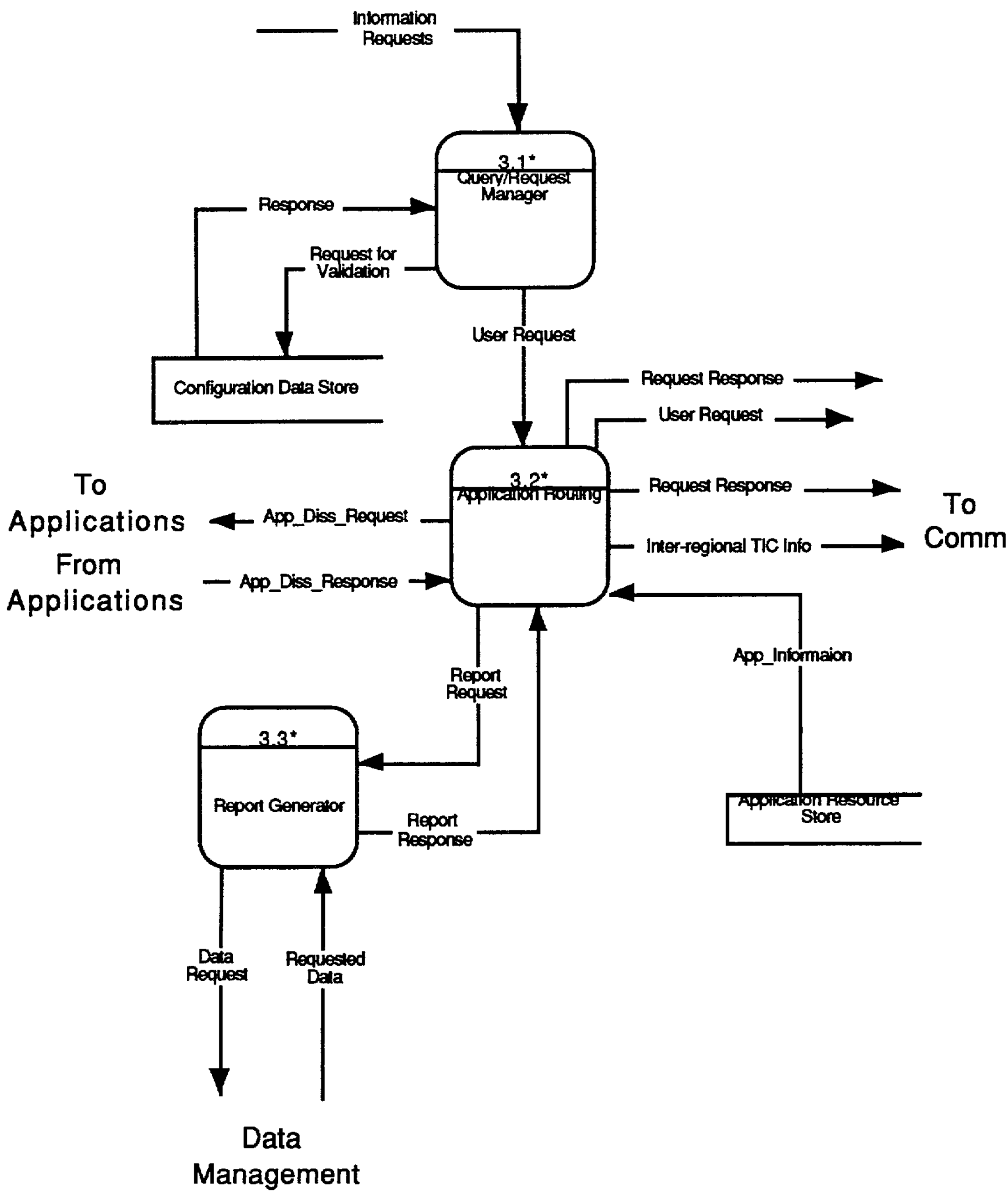


Figure 5-1. The Data Distribution Subsystem

5.1 QUERY RESPONSE MANAGER

This function essentially handles all external information requests obtained by the RTICs and routes the queries to the application routing process to disseminate to the specific applications.

A primary function of this process is request validation. This is done through a series of data/integrity tests that have been predetermined by a configuration process. As shown in Figure 5-2, the query request manager is further decomposed in this architecture to the following:

1. Information Request Handler.

2. Validation Process.

3. Information Response Handler.

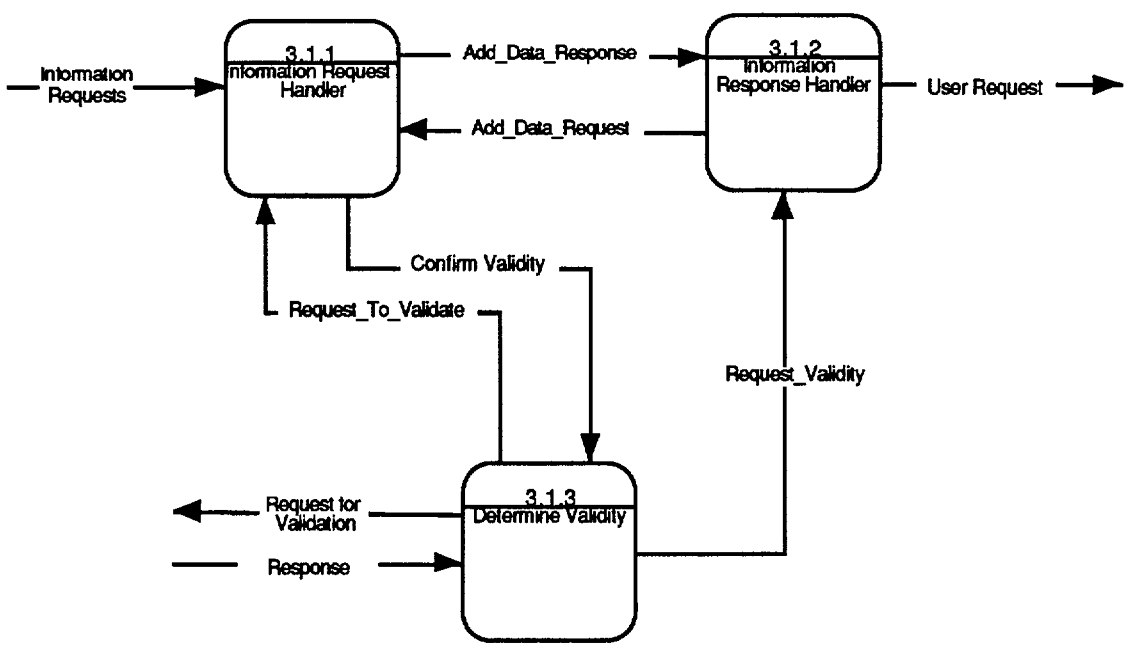


Figure 5-2. Query Request Manager Decomposition

5.1.1 Information Request Handler

This function essentially entertains the external information request from any of the nodes within the CTIS network and preprocesses the request before it is sent to the validation process. This process also requests additional data if required before a request is processed and provides acknowledgment of request to external entities.

5.1.2 Validation Process

This function essentially handles the validation of any external information requests before it is redirected to an application process for response processing. As part of the validation process, this function queries the configuration data store of the database for the required validation of data.

5.1.3 Information Response Handler

This function gets validated external information requests and directs it to the application router function for final application process destinations. This function checks for valid data in the request and, if required, will request from the information request handler more data before external information request is processed.

5.2 APPLICATION ROUTING PROCESS

This process essentially acts as a traffic router with respect to query requests made by external entities. It channels external information requests to dissemination applications as well as trip planning and trip monitoring applications. It receives external request responses from applications such as trip planning, trip monitoring and dissemination processes.

Another capability that the application routing process provides is external information requests for report generation. The report generator process executes the required report and returns the packaged response to the application router. The application router uses the communications subsystem to transmit the response back to the user.

This process also provides support for transmitting inter-regional TIC data between RTIC nodes. The details of the inter-regional TIC information has already been detailed in the logical architecture and in the communication subsystem.

As shown in Figure 5-3, the application routing process is further decomposed in this architecture to provide the following functions:

1. Boundary Process.

2. Application Selection.

3. Application Interface.

52.1 Boundary Process

The main function of this process is to determine the extent of the data request with respect to regional boundaries (and the location of necessary data to fulfill the user request) and to cross check against the configuration data store within the CTIS. It interfaces directly with the application selector and application interface functions to provide application search requests and receive application request rejects.

5.2.2 Application Selector

The function of this process is to identify the applications which the requests are destined for when external information request is received by the application routing process. It interfaces directly with the application resource storage which contains information about specific applications integrated within the CTIS. The external data flows from the application selector to the communication subsystem include the request response and inter-regional TIC information.

$2.3 Application Interface

The primary purpose of this function is to identify the specific interfaces required for the various applications that constitute the CTIS. Since the logical architecture is developed in a modular fashion, different applications would be integrated with specific interfaces that reflect capabilities of individual applications. This process will handle all of the translation and mapping required with respect to application interfacing of real-time requests and response by external entities to the CTIS.

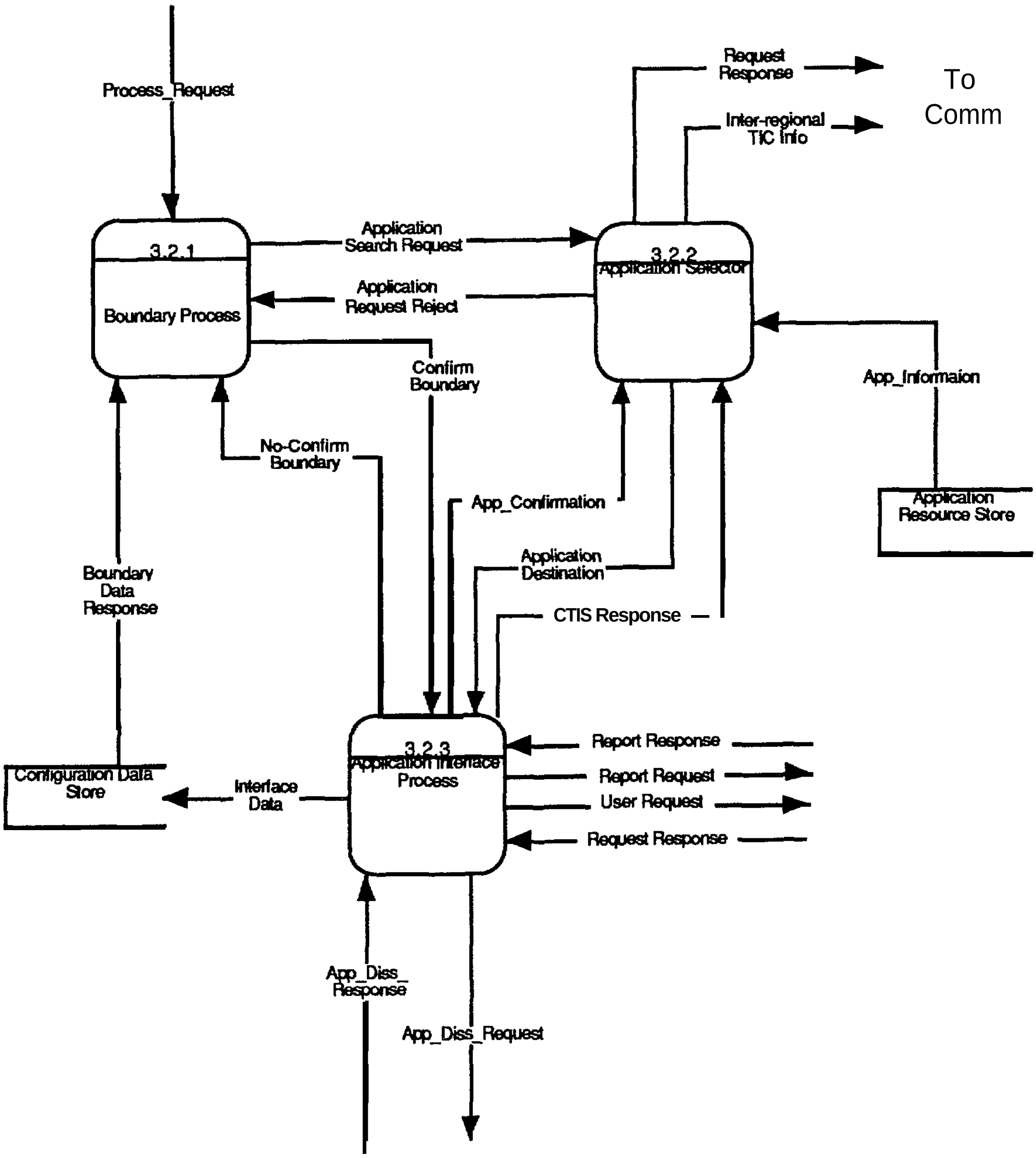


Figure 5-3. Application Routing Process Decomposition

5.3 REPORT GENERATOR

This capability essentially satisfies all the requirements in generating reports for any queries made by end users with respect to traveler information. It performs analysis and prepares reports on demand as well as on a periodic basis. Typical report generating capabilities are satisfied by the relational database management system.

As shown in Figure 5-4, the report generation process is further decomposed in this architecture to the following processes:

1. Report Manager Assessment.
2. Report Scheduler.

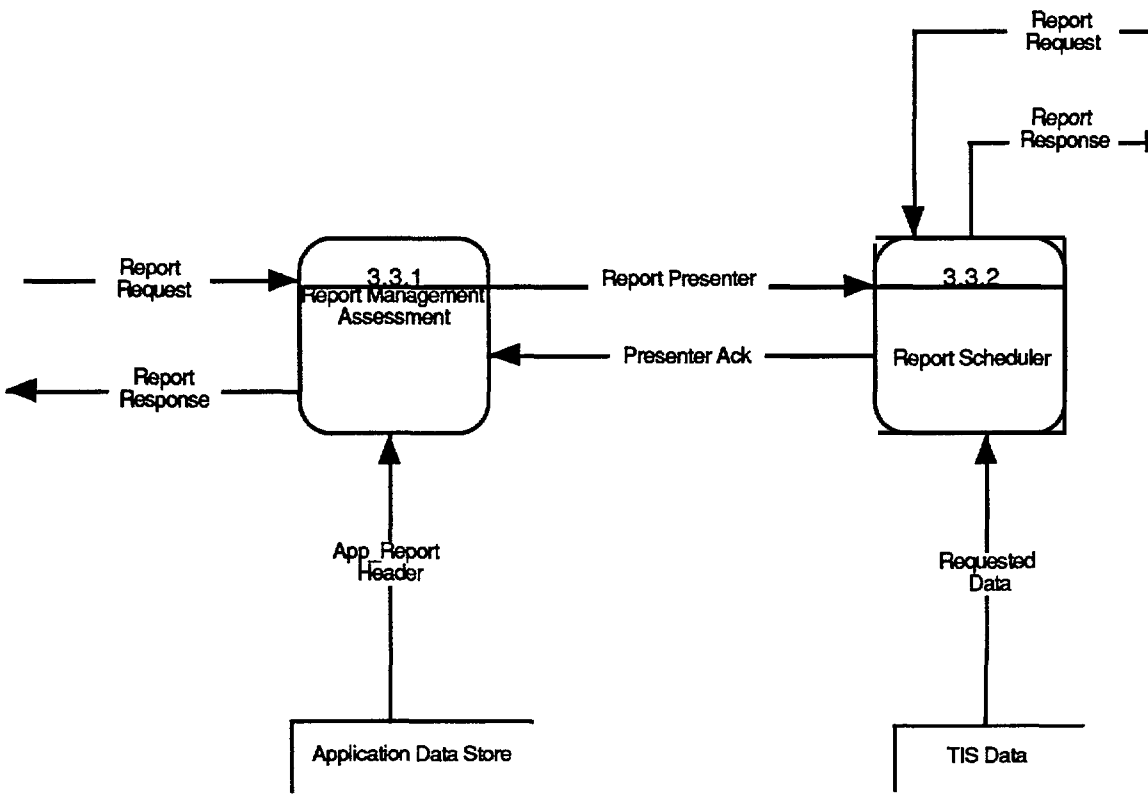


Figure 5-4. Report Generation Process Decomposition

5.3.1 Report Manager Assessment Process

This function assesses any external requests for report generation and queries with respect to traveler information within the CTIS. It queries the application data store to obtain correct information related to any requests before a report request is granted.

5.3.2 Report Scheduler

The basic functionality of this process is to schedule the report requests to be sent to the database management system as a report command. It interfaces directly with the relational database management system. Report generation capability to provide information so that specific reports are generated at specific time intervals.

6.0 TRIP PLANNING

The Trip Planning subsystem pertains to in-vehicle and out-of-vehicle trip planning. The Trip Planning subsystem allows a user to plan a trip from a specified origin to a specified destination and at a specified time. The subsystem offers the user the opportunity to choose among alternative roadway routes as well as among aiternative modes of transportation. It also supplies users with information on events that impact traveling, traveler services and accommodations, and weather conditions.

Trip planning can be done at a terminal located in a kiosk, at places where a user can connect a personal computer to an on-line service, in a vehicle equipped with a vehicle-to-roadside communication system supporting computer network communications, or in a vehicle with computer having access to roadway map data (e.g., map data stored on CD-ROM). It is likely that many of the databases needed to do trip planning will be created and maintained by public agencies or by private traffic information service providers. Some private traffic information service providers may also develop their own trip planning applications to serve their customers

The Trip Planning subsystem consists of the following components (see Figure 6-l):

1. User Trip Planning Interface.
2. Road Route Planner.
3. Public Transit Planner.
4. Travel Instruction Generator.
5. Road Traffic Status Lookup.
6. Event Lookup.
7. Services Lookup.
6. Weather and Environmental Condition Lookup.

A detailed description of each of the above components is provided in the following paragraphs. This description focuses on the system elements or processes necessary for trip planning. It also covers the specific features and data requirements of the sub-system's design concept.

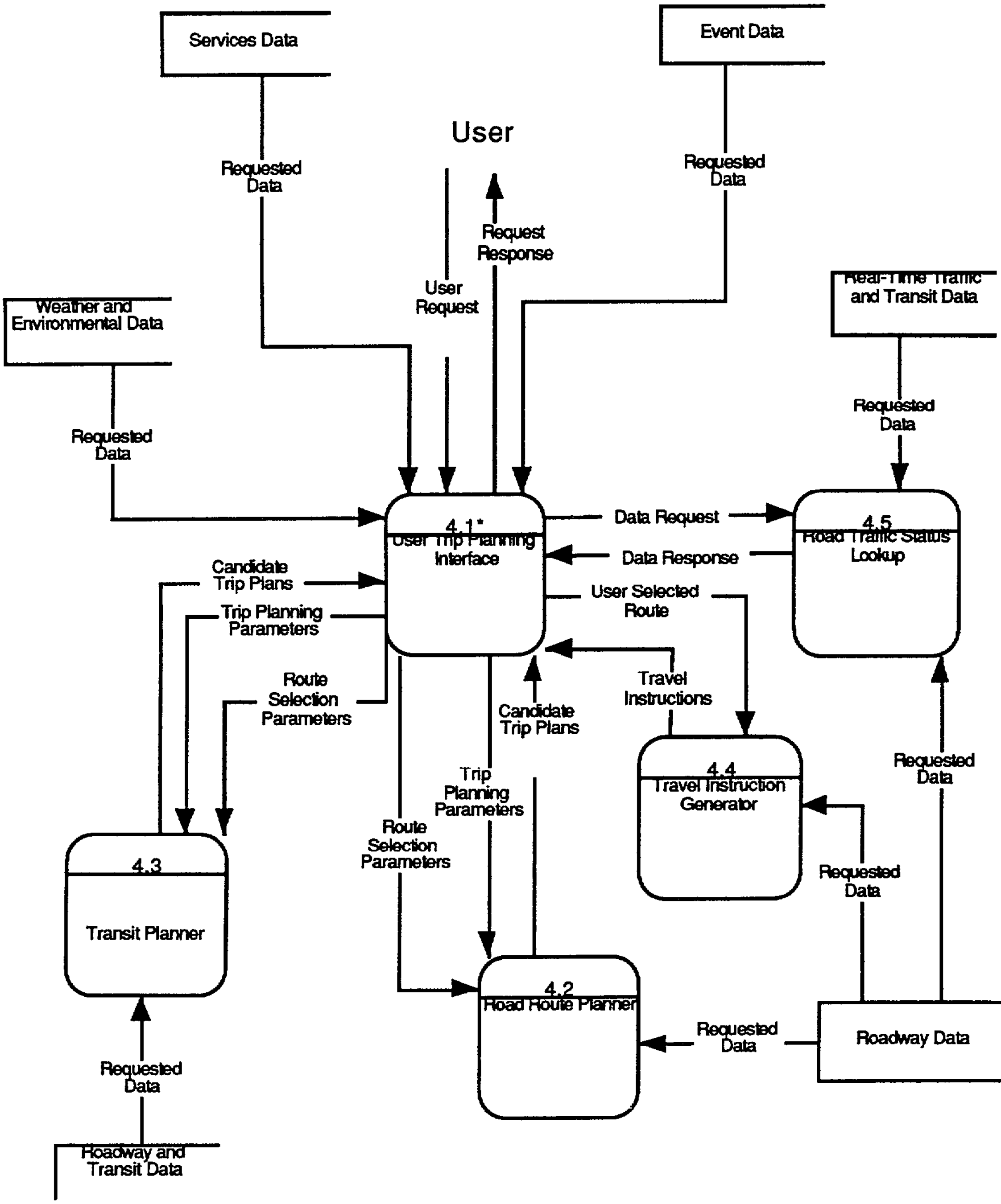


Figure 6-1 Trip Planning Subsystem

6.1 USER TRIP PLANNING INTERFACE

This component provides a mechanism for the user to enter travel information requests and to receive responses from the CTIS. It is composed of three elements (see Figure 6-2):

1. Planning Request/Response Formulation.

2. User Request Processor.

3. User Information Integrator.

The Planning Request/Response Formulation element receives requests from the user and displays system's responses to the user. It can be implemented either outside of a vehicle (e.g., at a kiosk), or in a vehicle equipped with a vehicle-to-roadway communication system, or in a vehicle equipped with an internal planning database (e.g., CD-ROM). The User Request Processor translates the user's request into system's instructions to provide the appropriate information to the user. The User Information Integrator collects the results of the User Request Processor and organizes them according to the user's specifications before displaying them to the user.

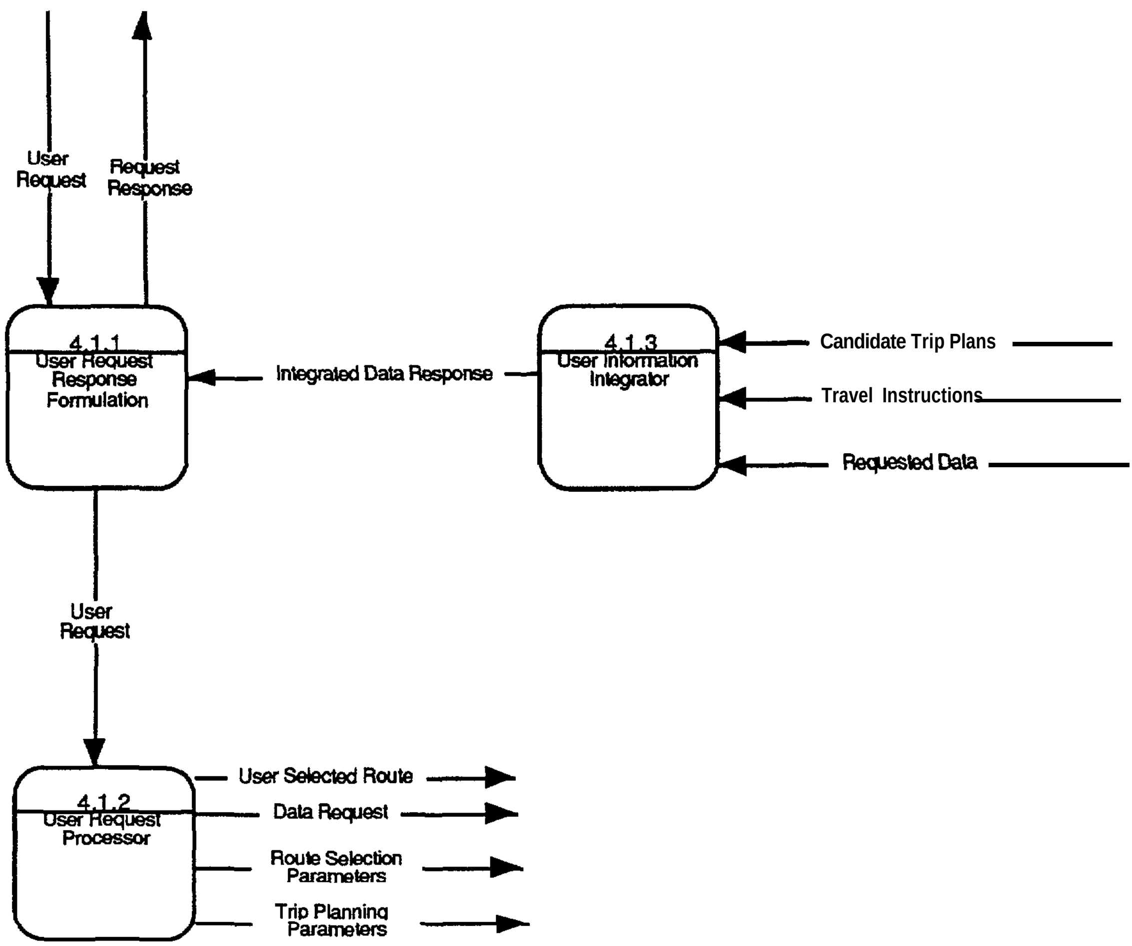


Figure 6-2 User Trip Planning interface Component

6.1 .1 Planning Request/Response Formulation

There are several kinds of information that a traveler can request:

1. Roadway touting between an origin and a destination for a trip to begin at a user specified time and date. The user may also request one or more intermediate points be included in the route.

2. A list of travel services available within a specified geographic area during a specified period of time.

3. A list of events of interest within a specified geographic area during a specified period of time.

4. The weather in a specified geographic area and during a specified period of time.

A user can also specify the parameters defining his or her preferences for the travel information to be provided. These parameters are the functional specifications for the system conceptual design as described below.

Request Preference Specifications

The system shall provide a capability for the user to:

1. Select values for a set of 'global parameters" that apply to all trips planned within a single session. If the user does not specify these parameters, the default parameters shall apply. The system's capability shall allow the user to override a global parameter with another parameter for any specific plan.

2. Specify his or her acceptable modes of transportation (e.g., private vehicle, specific common carrier services, specific transit service, or specific paratransit services).

3. Select criteria for ranking possible travel options (including both mode and route). The general criteria shall include: travel time, distance, fuel/energy consumption, and cost. The specific criteria for auto travel options shall include the difficulty of driving (e.g., due to road conditions, weather conditions, etc.), the closeness to amenities (e.g., food and lodging), and ride sharing availability. The specific criteria for transit travel shall include the number of transfers and seat availability.

4. Indicate whether scenic trip options are desired.

5. Specify what types of roads should be included or excluded from the trip plan (e.g., no freeways) .

6. Specify a distance or travel time from the roadway or from the user's current location, beyond which no traveler service facilities shall be recommended.

In addition, the system shall be able to rank each of the acceptable modes and provide novice users with a very simple interface for trip planning and, as an option, offer a more sophisticated interface to experienced users.

Trip Specifications

The system shall provide the user with the capability to:

1. Specify the origin, destination, time the trip is to commence, and an optional set of intermediate points to be included in the route.

2. Describe the origin or destination as the intersection of two roads or as the distance from the intersection of two roads.

3. Describe the origin or destination as one of a set of pre-defined areas or as the location where trip planning is made. The system shall map a predefined area to a specific location on a specific roadway.

4. Describe the origin or destination as one of a set of predefined landmarks. The system shall map a predefined landmark to a specific location on a specific roadway.

5. Describe the origin or destination by street address. The system shall map a street address to a specific location on a specific roadway.

Once the trip is defined, the system shall then display candidate routes ranked by the user-specified criteria. Each route shall include an estimated travel time and an estimated travel cost.

Roadway Information

Upon the selection of a roadway route, the system shall provide the user with the following information about the route:

1. Summary of on-going traffic incidents.

2. Summary of current traffic congestion.
3. Summary of each scheduled events that is known to affect traffic along the selected route (e.g., roadway construction and maintenance, parades, or sporting events).
4. Traveler advisory information for the route.
5. Road surface conditions.
6. Road weather conditions.
7. Road environmental conditions (e.g., air pollution levels).
8. Road restrictions (e.g., vehicle height and weight limits, turn restrictions, choke points, 4-wheel drive requirement).

The summary of each ongoing traffic incident shall include:

1. The impacted roadway.
2. The impacted direction of traffic flow.
3. The location along the roadway.
4. The lanes affected by the incident (e.g., two left lanes).
5. The cause of the incident (if available).
6. The time the incident occurred.
7. Free form comments on the incident.
8. An indication of the incident's severity (e.g., estimated time to clear).

The system shall include notifications of traffic incidents that are outside of the users specified area of interest, if those incidents are severe enough to impact the traveler's plans.

The summary of each traffic related event shall include:

1. The type of event (e.g., construction, sporting, parade, etc.).
2. Free form comments on the event.

3. The time and date of the event's occurrence and duration.

4. An indication of the incident's severity (estimated delay introduced by the event).

Common Carrier Informatlon

If a travel plan includes travel on a common carrier, the following information shall be provided:

1. Name of the common carrier.

2. Route number or other identifier.

3. Starting point and scheduled starting time.

4. Ending point and scheduled ending time.

5. Fare.

If a travel plan requires transfers, the system shall provide transfer instructions.

The system shall provide modal travel time comparisons among all possible route plans even for those modes that are not selected by the user. A travel mode that would yield a substantial time savings (time savings threshold is to be defined to reflect local transportation goals) compared to that of the user-selected mode shall be brought to the user's attention.

Pre-Trip Route Guidance

After presenting all the travel plan options, the system shall let the user select one of the travel plan options. It shall offer the user options for obtaining a step-by-step printout of the travel plan and/or a graphical representation of the route. The step by step instructions for a road travel portion of a plan shall include maneuver instructions (e.g., turn right on to Main Street), distance and average travel time to the next maneuver (e.g., go south on Main Street for 2.3 miles), and landmarks along the way, particularly at the point of the maneuver.

Miscellaneous Inquiries

The system shall allow the user to make the following ad hoc requests and shall provide the requested information:

1. Alternative routes to avoid known roadway congestion.

2. Current status of a route of a transportation mode.

3. List of events of public interest in a specified area during a specified period of time.

4. Real time status of a route in a transportation mode.

5. List of all current incidents on a specified section of road.

6. List of all scheduled events that will impact traffic on a specified road during a specified time period.

7. The current status of a specified incident.

8. List of all on-going events that are currently impacting traffic on a specified road.

9. List of people seeking to carpool from a specified origin to a specified destination.

10. Route, fare, and up-to-date schedule information on common carrier, public transit, and paratransit routes.

11. Parking location, availability, and cost information for a specified area and intended time of use.

12. Directions to a selected destination.

13. Weather forecast for a specified area and during the intended time of travel.

14. A list of all the currently congested points along a specified section of roadway and during the user's intended time of travel.

15. Estimated time to travel along a specified section of roadway and during the user's intended time of travel.

16. A list of historical sites and other places of interest within a specified area, including the fee schedule for attendance, current business hours, and telephone number of each available site.

17. A list of lodging facilities within a specified area, including room rates, rating (e.g., AAA) if available, telephone number, and address of the facility.

18. A list of the restaurants and food services within a specified area, including hours of operation, type of cuisine, rating if available, and telephone number.

19. A list of all automobile service facilities within a specified area including hours of operation, area of specialty, phone number, and address.

20. A list of current road restrictions along a specified section of road.

21. A list of current travel advisory information along a specified section of road.

22. A list of hospitals in a specified area, including the telephone number, emergency room's hours of operation, and address.

23. A list of public telephone locations in a specified area.

24. A list of police stations in a specified area, including the address and telephone number of each police station.

25. A list of all emergency service telephone numbers (e.g., fire department and hospital) within a specified area.

26. A traffic condition map of a specified roadway or geographic area showing roadway segments for free flowing, congested, and slow moving roadway segments.

5.1.2 User Request Processor

The system shall validate all commands and parameters specified by the user. It shall notify the user of any data entry errors and shall provide enough information for the user to correct the problem. The system shall then interpret all valid commands and shall invoke the appropriate functions to process the user's request. This processing shall take into account all of the default and user-specified trip planning parameters that are in effect at the time the request is made.

6.1.3 User Information Integrator

Once all the information associated with a single user request has been computed the system shall combine the information for display to the user. As part of the display, the system shall rank travel route alternatives in a manner that is consistent with the user-specified weightings. For each candidate road-trip plan, the following information shall be displayed to the user:

1. Distance of the trip.

2. Estimated time of the trip.

3. Estimated toll charges.

4. Estimated fuel cost.

5. "Scenic rating factor" of the trip.

For each candidate trip plan that includes public transportation segments, the following information shall be displayed to the user:

1. Distance of the trip.

2. Estimated time of the trip.

3. Estimated travel cost.

4. Number of mode transfers.

If the user has specified other trip planning criteria such as ride sharing possibilities, closeness to amenities, difficulty of driving, likelihood of getting a seat, etc., the system shall display the information for each applicable candidate trip plan.

The system shall offer the user an option to obtain a graphical display or a printed list of travel instructions for any candidate trip plan. The results of all user inquiries shall be displayed in a manner that is easy to understand.

6.2 ROAD ROUTE PLANNER

Given an origin, a destination, and an optional set of intermediate points, the system shall compute the shortest route by distance and the shortest route by time. All computations shall be based on the assumption that the trip will be continuous from the time of departure until the time of arrival at the destination. The shortest route based on distance or time shall be determined using the roadway network and the known schedule of roadway closings or construction activities at the time the trip.

The shortest route by time shall be computed based on the historical travel times of each link at the anticipated time that the link will be traversed. For travel that is to be done within one hour of the inquiry, actual current link travel times shall be used for links that will be traversed within one hour of the time the travel request is made.

The system shall also be capable of planning scenic routes. Each roadway link shall be designated as being highly scenic, moderately scenic, or not scenic. If the user requests that scenic routes be planned, the system shall include all feasible routes and show the additional travel time and distance over those of the shortest non-scenic route.

The system shall report the following routes:

a. The shortest route by distance.

b. The shortest route by travel time.

c. Up to two alternative routes that are up to, say, 125% of the shortest distance route.

d. Up to two alternative routes that are up to, say, 125% of the shortest travel time route.

The system shall be capable of referencing data that provides a description of the connectivity of the roadway, the scenic rating of each roadway link, current travel times of each roadway link, historical travel times of each roadway link, and scheduled roadway closures affecting each link.

6.3 PUBLIC TRANSIT PLANNER

Given an origin, a destination, and an optional set of intermediate points, the system shall compute, the shortest route by distance, and the shortest route by time, and the cheapest route by fare cost. All computations shall be based on the assumption that the trip will be continuous from the time of departure until the time of arrival at the destination. The shortest route by distance or time computation shall be based on the public transportation connectivity network and the known dynamically updated schedule of public transportation systems. The system shall consider trips that involve all transportation modes. The system shall report on those trip plans that involve transportation modes that are acceptable to the user, or those trip plans that involve a mode that not specified by the user, but still may be attractive to the user because of a substantial savings in travel time (the threshold of time savings is to be determined before system implementation) from the quickest public transportation mode requested by the user. The system shall consider intermodal trips as appropriate to meet the users travel objectives.

The system shall report the following characteristics of the planned trips:

a. The shortest route by travel time.

b. The cheapest route by cost.

c. Up to two alternative routes that are up to, say, 150% of the shortest travel time.

d. Up to two alternative routes that are up to, say, 150% of the lowest cost.

6.4 TRAVEL INSTRUCTION GENERATOR

Once the user selects a plan, the system shall be capable of translating the plan into both of the following formats:

1. A graphical display of the route on a map.

2. A printed set of detailed instructions.

The detailed instructions shall include maneuver-by-maneuver instructions for each roadway route. This shall include information about making left and right turns onto particular streets and indications of landmarks and cross streets that precede maneuver points.

Detailed instructions for trip plans involving public transportation shall include the location of all public transportation terminals and stops along the route, ground transportation arrangements for mode transfers, and schedule and fare information.

6.5 ROAD TRAFFIC STATUS LOOKUP

The system shall be capable of accessing static and dynamic database to answer users inquiries regarding travel conditions on the roadways (e.g., scheduled maintenance events, current congestion areas, roadway advisories, parades, and so on).

6.6 EVENT LOOKUP

The system shall be capable of accessing static and dynamic database to answer user's inquiries regarding events of public interest such as festival, concerts, etc.

6.7 SERVICES LOOKUP

The system shall be capable of accessing a database to answer user's inquiries regarding services such as hotels, food, medical, and police.

6.8 WEATHER AND ENVIRONMENTAL CONDITION LOOKUP

The system shall be capable of accessing a database to answer user inquiries regarding services such as weather and pollution conditions in an area.

7.0 TRIP GUIDANCE

The trip guidance subsystem provides maneuver instructions to guide a vehicle through a user selected route. The system shall support the implementation of Trip Guidance via two methods (see Figure 7-1): centralized guidance and on-board guidance.

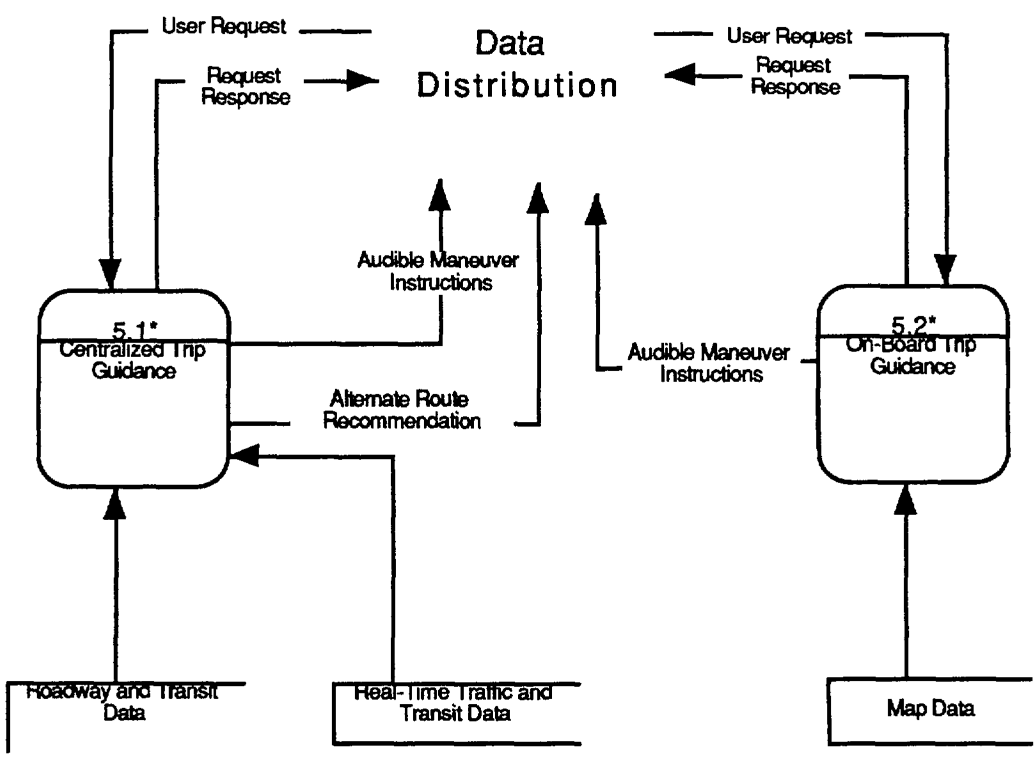


Figure 7-1 Trip Guidance Subsystem

In the centralized guidance, each subscriber's vehicle (or participant's vehicle such as that of an emergency-response agency or a Hazmat carrier) shall be equipped with a vehicle location determination and a vehicle-to-roadside communication system. The on-board computer shall report the user's selected route to the central monitoring system, as well as the vehicle's position along the selected route (on a periodic basis).

he central monitoring system shall track each vehicle's progress along the selected route, and provide maneuvering instructions to the vehicle's driver before each maneuvering point is reached. It shall also determine whether current road congestion will delay the vehicle. If so, it shall determine whether there are viable alternative routes. If an alternative route is available, the central system shall send a message to the vehicle asking if the driver wishes to use the alternative routes to minimize the potential delay. If the driver accepts the recommendation, the central monitoring system shall issue instructions for the new route.

The second method is via on-board trip guidance. The system shall support vehicles equipped with a device that can determine the vehicle's current location. Given the vehicle current location and a user-specified route, the on-board system shall be capable of generating audio and visual instructions at points prior to required maneuvers. The on-board trip guidance system is not aware of the downstream traffic congestion unless the vehicle has a system to receive one-way traffic reports (e.g., via an FM subcarrier frequency).

7.1 CENTRALIZED TRIP GUIDANCE

The Centralized Trip Guidance component has three elements (see Figure 7-2):

1. Front End Processing.
2. Location Determination.
3. Guidance Instructions.

7.1.1 Front End Processing

The in-vehicle unit shall be capable of providing the user with all the trip planning functionality described earlier. In addition the system shall allow the user to select a candidate trip plan and the plan to be implemented and monitored by the system.

7.1.2 Location Determination

The in-vehicle unit shall be capable of determining its location by using one or more of the following technologies: the Global Positioning System (GPS), differential corrections to the GPS, dead reckoning, and triangulation based on known locations of commercial radio signals. The in-vehicle units shall periodically report its location to the central monitoring system.

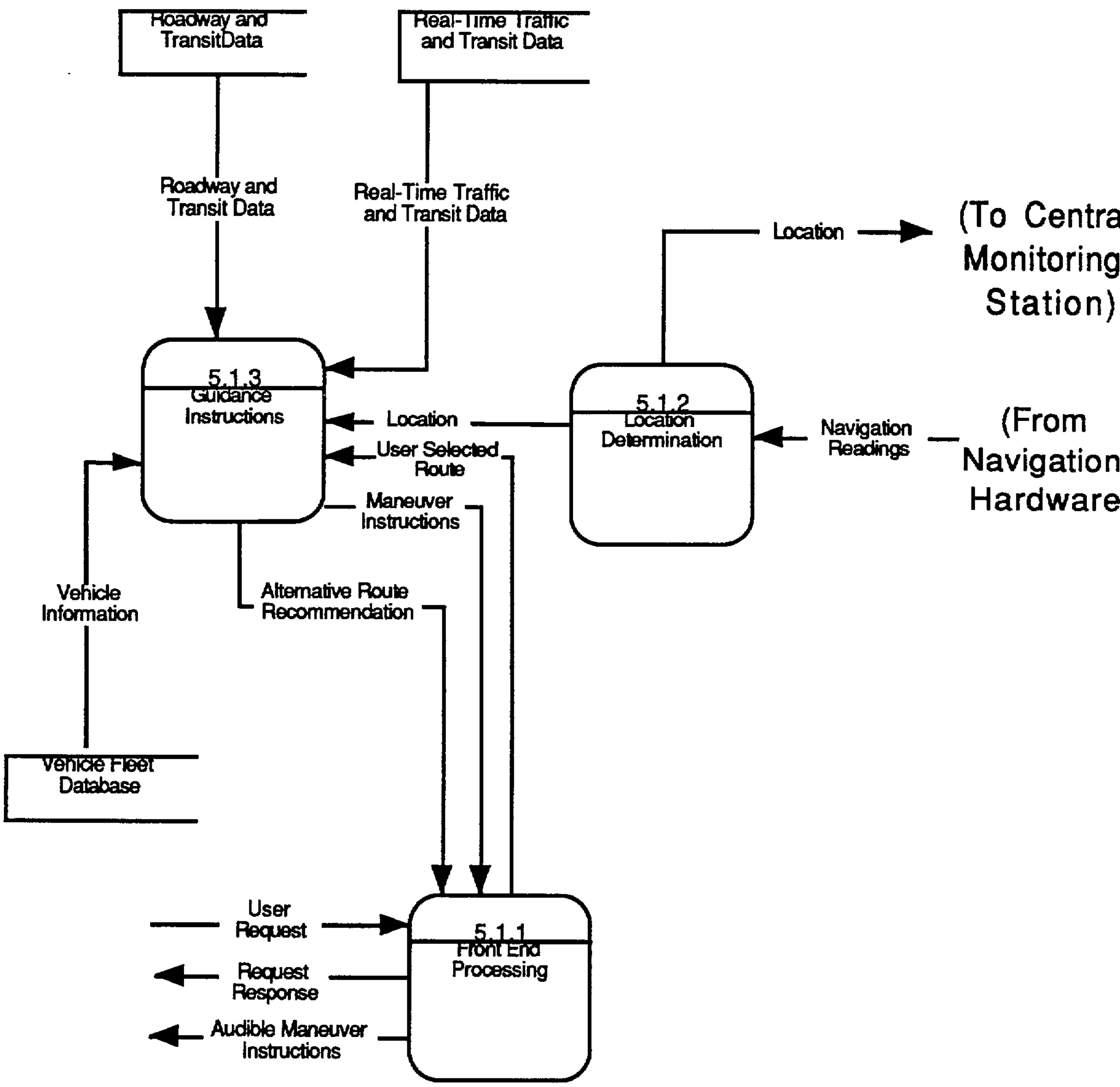


Figure 7-2 Centralized Trip Guidance Component

7.1.3 Guidance Instructions

Once the user has selected a road trip plan, the central monitoring subsystem of the system shall generate maneuver instructions that include street/road names and landmarks (e.g., two block after Memorial Hospital then turn left onto Chestnut Street). These instructions shall be delivered in a form that the in-vehicle unit can translate into audio and visual directions. If the central monitoring system detects that the user has made a mistake in following the instructions, it shall issue a warning to the driver and shall generate instructions to help the driver navigate to the final destination from his or her current location.

The central monitoring system shall monitor real-time traffic incidents and schedule events in order to determine if any will impact the travel time of the selected route. The system shall base its determination of impact based on the projected arrival time of the vehicle to an area of congestion. The system shall warn the driver of any anticipated delays along the entire route. The system shall recommend alternative routes to the driver in order to avoid the anticipated congestion. The system shall offer the driver the ability to selected one of the recommended routes, or to define his or her planned route.

7.2 ON-BOARD TRIP GUIDANCE

Similar to the Centralized Trip Guidance, The On-Board Trip Guidance component has three elements (see Figure 7-3):

1. Front End Processing.
2. Location Determination.
3. Guidance Instructions.

7.2.1 Front End Processing

The in-vehicle unit shall be capable of providing the user with a subset of the trip planning functionality. The trip planning functions shall be restricted to using the on-board database (e.g., using a CD-ROM). In addition, the system shall allow the user to select a candidate trip plan and the plan to be implemented and monitored by the on-board system.

7.2.2 Location Determination

The in-vehicle unit shall be capable of determining its location by using one or more of the following technologies: the Global Positioning System, differential corrections to the GPS, dead reckoning, and triangulation based on known locations of commercial radio signals.

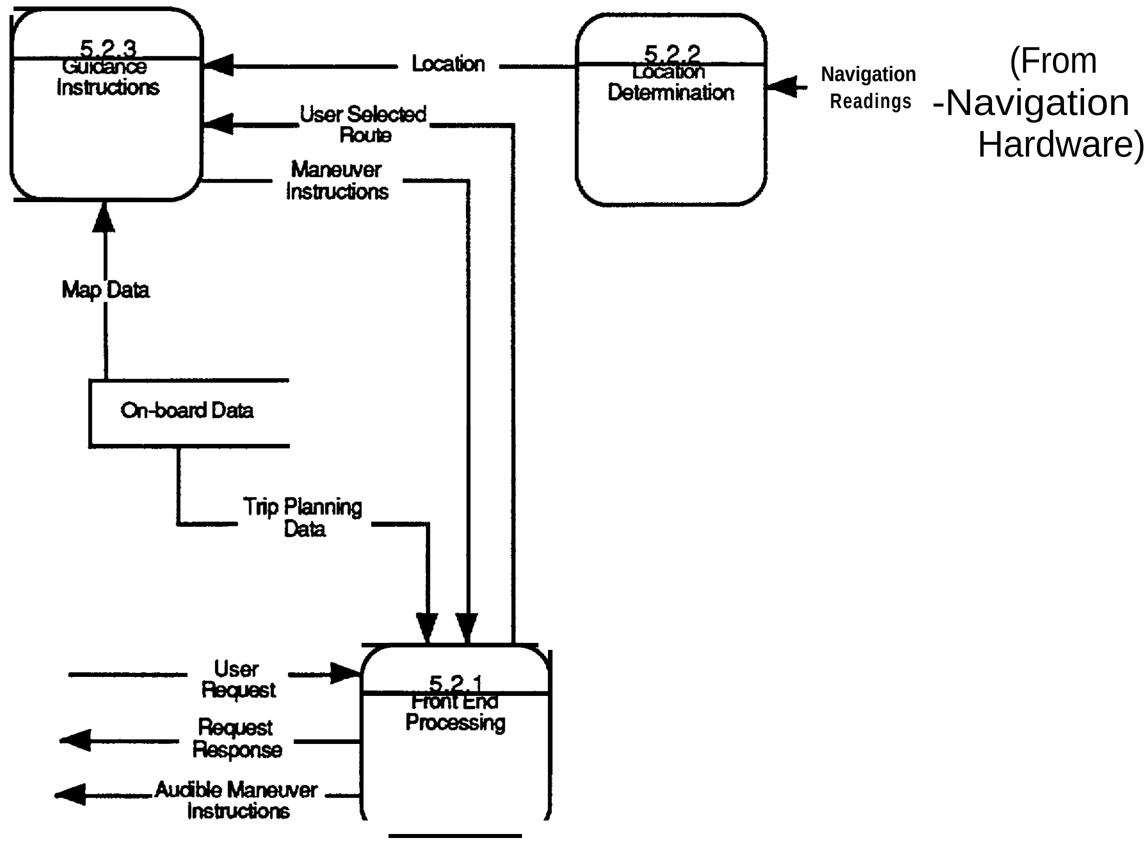


Figure 7-3 On-Board Trip Guidance Component

7.2.3 Guidance Instructions

Once the user has selected a road trip plan, the system shall generate maneuvering instructions that include street/road names and landmarks. These instructions shall be delivered by voice and visual means. If the system detects that the user has made a mistake in following the instructions, it shall issue a warning to the driver and shall generate instructions to help the driver reach the final destination from the current location.

8.0 DISSEMINATION APPLICATIONS

This subsystem provides a "generic" design for interfacing to the two primary CTIS clients, ISPs and end-users. Due to the fact that each dissemination technology and ISP will require different data, at different intervals, using heterogeneous communication protocols, this design attempts to capture the essence of how data is disseminated in a general fashion.

8.1 DISSEMINATION TO ISPS

As shown in Figure 8-1, two paths of dissemination are possible. The first path is dissemination to the various participating ISPs. ISPs may consist of firms such as Discover America (kiosk vendor), America Online (on-line service provider), and Motorola (communication and paging company). Each ISP may have different requirements for what data is transmitted, when it is transmitted and over what communication medium. A unique process may be required for each ISP and dissemination combination. In most cases, it is envisioned that ISPs will have a dedicated line into the CTIS. In addition, some ISPs may desire to have CTIS data delivered synchronously to them (i.e., "pushed-out"), while other ISPs may desire to have data available to them on demand (i.e., "pulled-out"), for use in infrequent ***ad-hoc*** queries. Process 6.1 in Figure 8-1 must be designed to handle both of these requirements.

8.2 DISSEMINATION TO END-USERS

The second path of dissemination is illustrated in process 6.2 of Figure 8-1. This process handles dissemination directly to end-users. This path does not preclude the opportunity for ISPs to be users (i.e., the ISPs desired interface to the system may be no different than an end-user: hence, not dedicated interface will be required). The CTIS shall have the capability to disseminate traffic and transit status reports directly to users possessing faxes, pagers, cellular-telephone-equipped digital personal assistance, telephones (users may call the system on their telephone or the system may call their telephone) and various other devices. Some of these information dissemination mechanisms may be used by TV and radio stations to broadcast the traveler information to their audiences.

The design requirements for fax, pager, cellular-telephone-equipped digital personal assistance, call-out telephone, and call-in telephone information dissemination are as follows.

8.2.1 Fax Data Dissemination.

The system shall have the capability to send traffic and transit information via fax machines to a pre-defined list of subscribers according to the subscribers' pre-defined schedule and upon the occurrence of a traffic or transit incident or event that will impact the subscribers' travel plan. The subscribers shall have the capability to modify the schedule to fit their individual needs (e.g., no information delivery during holidays).

The system shall also accommodate user-specified roadway sections and/or transit routes. Faxed reports shall include a list of on-going events (both traffic and non-traffic related) affecting the roadways and/or transit routes of interest, as well as scheduled events that are due to start, say, within the next four hours.

The system shall have the capability to send a fax upon receipt of a dial-in touch tone menu request from a subscriber. It shall also support the billing for each faxed report that is not included in the base subscription price.

8.2.2 Paaer Dissemination.

The system shall have the capability to send pager notifications to a pre-defined list of subscribers who have each specified a set of roadways an&or public transit routes and times and days of the week for which they want to be alerted to scheduled events or incidents, When an incident is confirmed or, say, 30 minutes before a scheduled event is set to begin, the system shall send an alphanumeric message via pager to all interested subscribers. The message shall provide an indication of the problem to the maximum extent permitted by the message capacity of the subscriber's pager. The message shall also include a code number from which a subscriber may use to obtain additional information about the incident or about alternative travel plans.

8.2.3 Cellular-Telephone-Equipped Personal Digital Assistants.

The system shall have the capability to send notifications to a pre-defined list of subscribers who

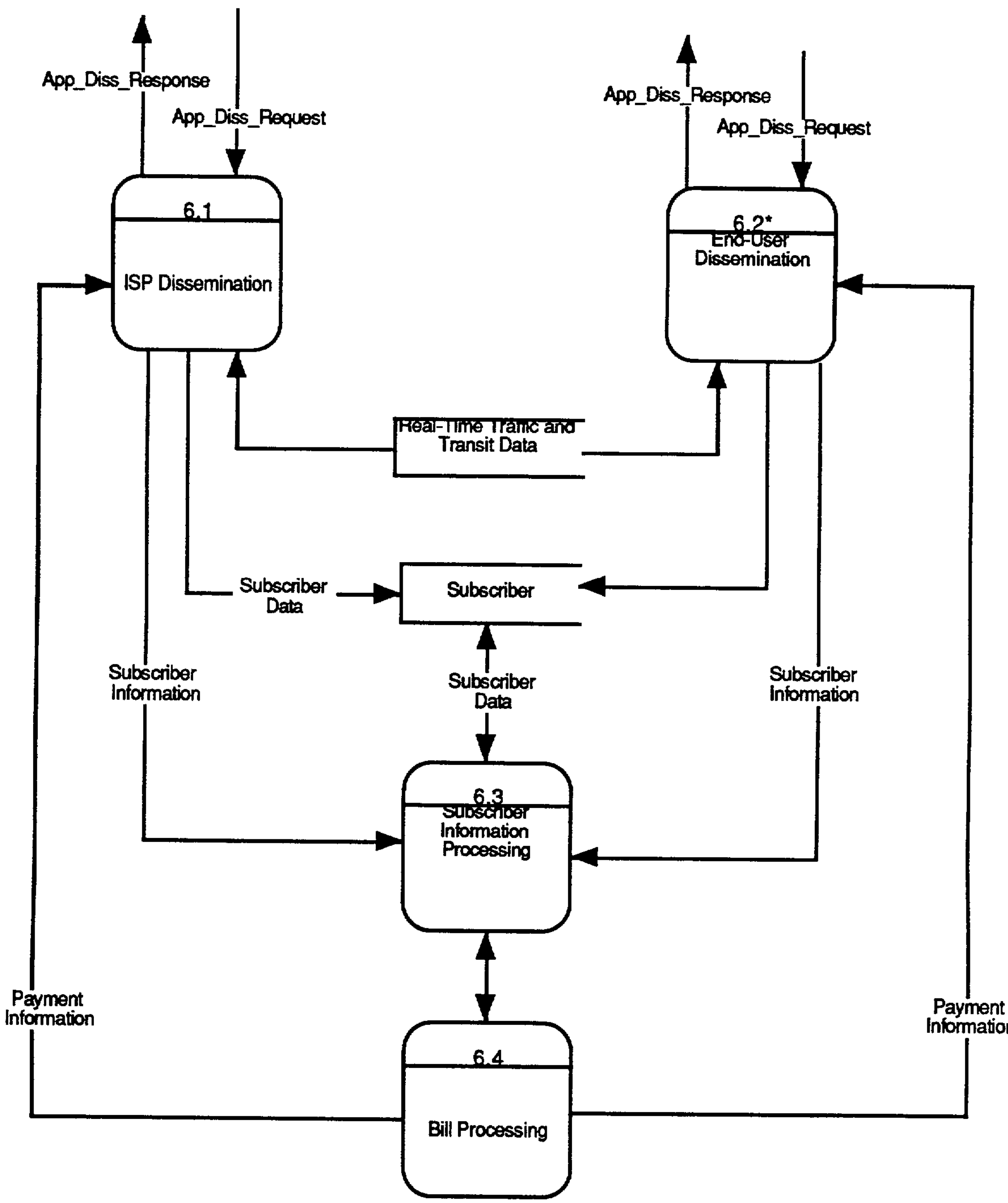


Figure 8-1. Information Dissemination Subsystem

have each specified a set of roadways and/or public transit routes and times and days of the week for which they want to be alerted to scheduled events or incidents. When an incident is confirmed or, say, 30 minutes before a scheduled event is set to begin, the system shall send messages to all interested subscribers. The message shall provide an indication of the problem; and the system shall allow the user to obtain more information about the problem and/or a list of alternative travel plans.

8.2.4 Call-Out Telephone Dissemination.

The system shall have the capability to send audio notifications to a predefined list of subscribers who have specified a set of roadways and/or public transit routes and a reporting schedule. Each subscriber shall have the option to specify one or more telephone numbers (e.g., office number and cellular number) and the time periods during which each number may be used. When an incident is confirmed or, say, 30 minutes before a scheduled event is set to begin the system shall call all interested subscribers. The message shall provide an indication of the travel problem and a list of ways to avoid the problem.

8.2.5 Call-In Telephone Dissemination.

The system shall offer each dial-in user a touch-tone menu format with which to select a roadway or public transit route of interest. (Some call-in services may be free-of-charge to the users.) The system shall report the current traffic conditions on the route and shall provide the user with the time at which the traffic information is entered. For a description of a candidate call-in audiotext capability for the I-95 Corridor, reference section 2.2 of the physical architecture.

8.3 SAMPLE DESIGN OF END-USER DISSEMINATION APPLICATION

As previously discussed, the architecture of this subsystem must be optimized to provide generic support for the dissemination of traveler information to ISPs and end-users, who have access to a variety of advanced technology devices. To understand in more detail, how a dissemination application might work, a conceptual design of a sample application will be discussed. This application would be an example of a process similar to 6.2 in Figure 8-1.

The sample dissemination application provides support for access to information via telephone as well as information delivered via faxes, pagers, and PDAs. The subsystem consists of the following components (see Figure 8-2):

1. Call-In Telephone Processor.
2. Traffic Report Scheduler.
3. Traffic Initiated Notification.
4. Traffic Status Lookup.
5. Traffic Data Formatter/Transmitter.

8.3.1 Call-In Processor

This system shall have the capability to receive phone call from the public and shall have the capability to provide them with a touch-tone menu system with which they may select current traffic and public transit status information (some features of this service may be free-of-charge to the users). The system shall provide the information in an audio format over the phone with the date and time of the roadway or transit route status is entered as part of the message.

The system shall also provide a menu option for pager to get more information about traffic by specifying the code number that appeared on their traffic or event notification.

8.3.2 Traffic Report Scheduler

The system shall have the capability to track all subscribers who have scheduled traffic reports to be sent to them via fax, pager, telephone or personal digital assistant. At the predefined time, the system shall initiate a process that will lookup the traffic or transit conditions of interest to a user and shall cause the information to be transmitted to the user.

8.3.3 Traffic Initiated Notification

Upon notification of the start of an incident or a scheduled event, the system shall determine which subscribers are to be received the incident/event at the current time and shall initiate a notification to the subscriber via the subscriber's selected media.

8.3.4 Traffic and Transit Status Lookug

Upon notification of a scheduled reporting time for a particular set of roadways or transit routes, the system shall query the real-time traffic database and shall send a report to the appropriate subscribers.

8.3.5 Dissemination Data Formatting

Upon the creation of a scheduled, or event- initiated, or subscriber-initiated traffic and/or public transit status report, the system shall format the data for the appropriate media and then initiate the transmission of the information to the subscriber . As previously discussed in section 2.5 (CTIS Standards) the formatting of data disseminated to ISPs or end-users is likely to utilize the ITIS BIF/BAP version 3.1 standard.

8.3.6 Additional Functions

In addition to the previous five functions, this application would also provide support for subscriber information processing and bill processing (as previously shown on Figure 8-l).

8.3.6.1 Subscriber Information Processing

The system shall provide the capability to add, modify, and delete TIS subscriber information. In addition, the system shall provide the capability to bill subscribers, as appropriate, for scheduled usage, and for on-demand (unscheduled) traffic data reports. Since it is currently envisioned that most information destined directly to end-users is broadcast (not personalized) no billing functions will be required. Billing will likely be a function to generate revenue from wholesale information delivered to ISPs.

SAMPLE APPLICATION

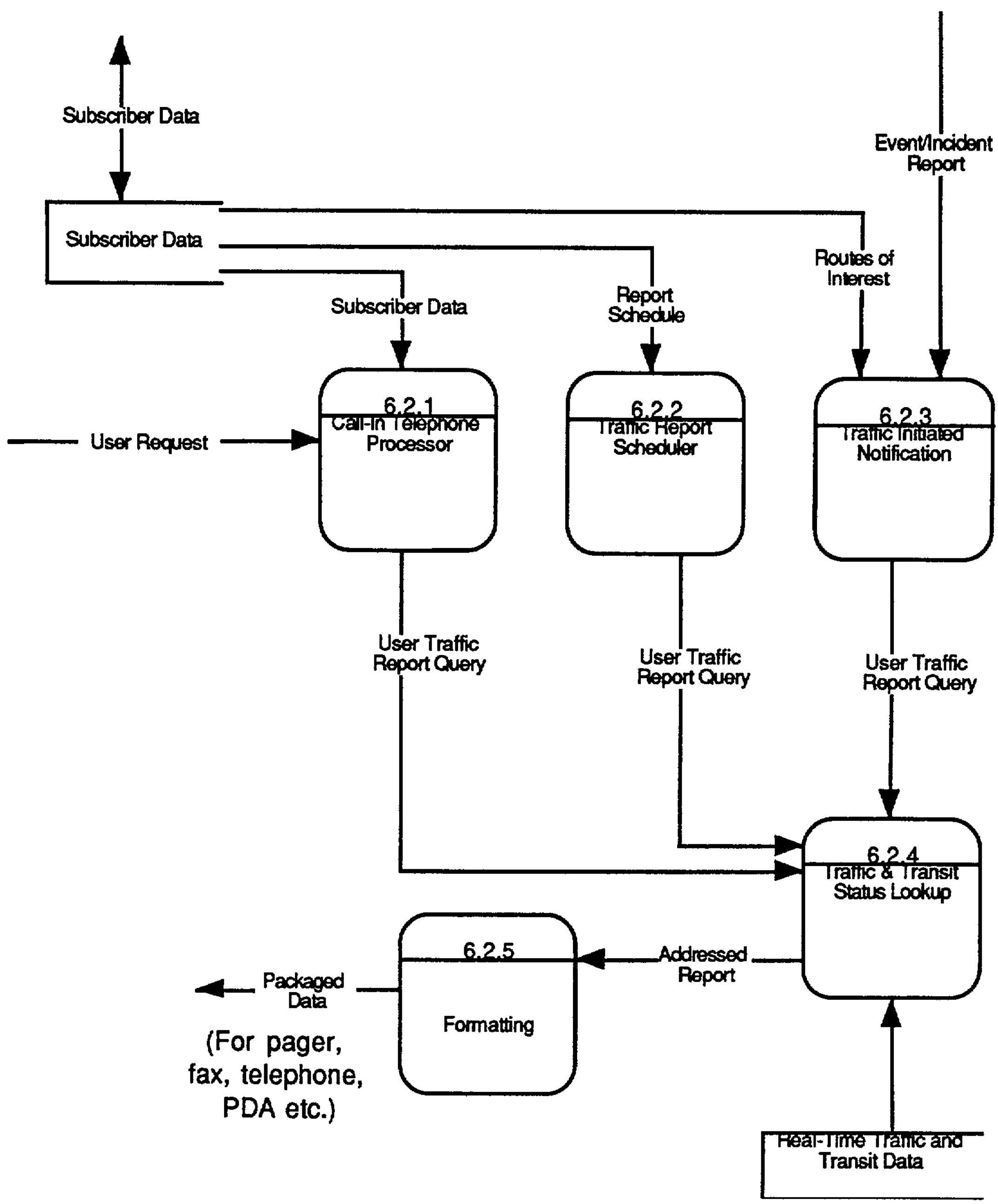


Figure 8-2. A Sample End-User Dissemination Application

8.3.6.2 Bill Processing

The system shall track the usage of each subscriber and shall bill them accordingly. The system would then be capable of recording the payment status of each subscriber account, and shall deny services to delinquent subscribers. The bill processing function shall be able to accommodate both individual users (i.e., the travelers) and organizational users such as the ISPs.

9.0 COMMON SERVICES

The Common Services subsystem provides capabilities required by all of the CTIS components, most notably the Graphical User Interface (GUI). With the exception of the GUI, all of the others in this subsystem are development by products and are available through Commercial-Off-The-Shelf (COTS) products, The Common Services subsystem consists of the following:

a. Graphical User Interface (GUI).

b. Software/Hardware Monitoring.

C. Security.

e. System Management.

f. Inter-Process Communication (IPC).

9.1 GRAPHICAL USER INTERFACE

This section will present design considerations for the RTIC's operator interface.

9.1.1 GUI Paradigm and Framework

This section will provide input into the details of the RTIC GUI design and demonstrate via discussions how the GUI will look and feel.

The interface between the operator and applications is important since it provides the framework for interactions necessary for the effective and efficient operation of the system. Figure 9-1 provides a sample illustration of an RTIC operator screen. To ensure that all user interfaces are well designed and easy to use, all user interface development will conform to the *OSF/Motif Style Guide.*

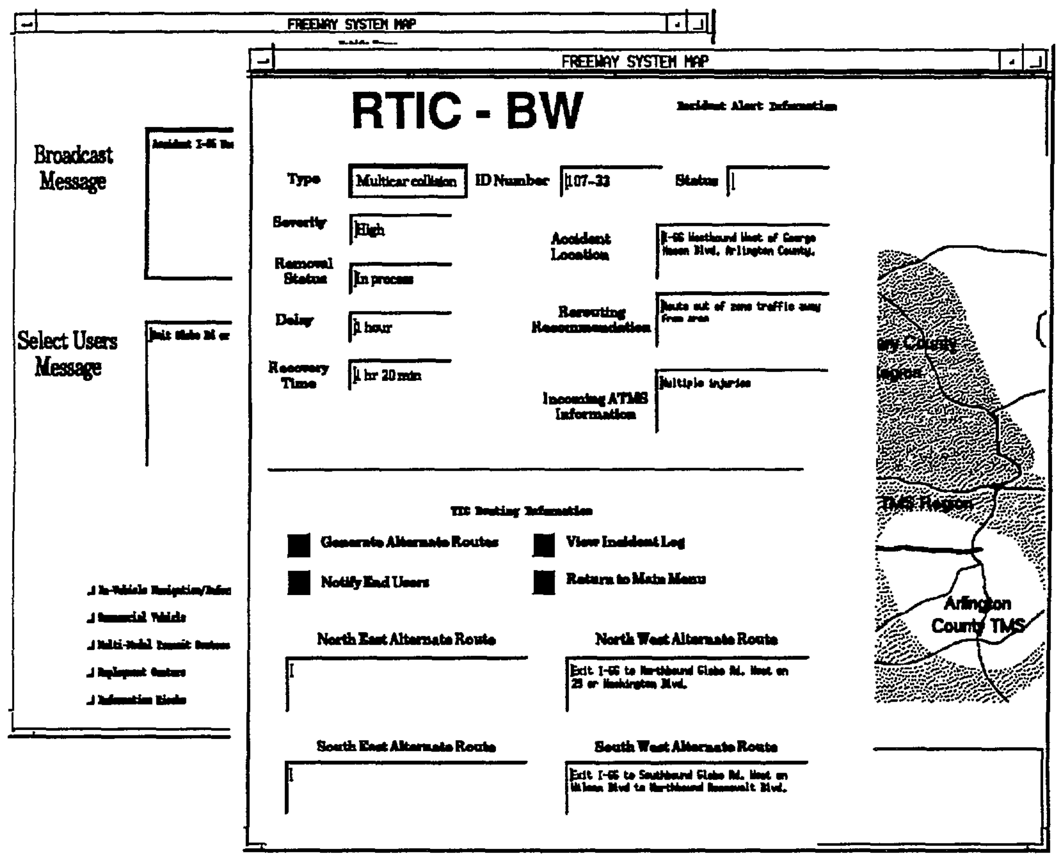


Figure 9-1. Sample RTIC User Interface

The *OSF/Motif Style Guide* strives to accomplish the following [OSF/Motif '91[1]]:

a. Adopt the user's point of view.

b. Give control to the user.

c. Use real-world metaphors.

d. Keep interfaces natural (intuitive).

e. Keep interfaces consistent; common "look-and-feel" for all interface elements.

1 Open Software Foundation (OSF), OSF/Motif Style Guide, Prentice-Hall, Inc., 1991.

f. Communicate application actions to the user.

g. Avoid common design pitfalls.

In addition to conforming to the OSF/Motif Style Guide, the GUI will follow recognized principles of successful interface design:

a. Give feedback - acknowledge user inputs; update displays to reflect a new state; highlight mouse selections.

b. Help the user learn - computer-guided training; on-line tutorials; on-line documentation: regular context sensitive help;

c. Response time - immediate response to keyboard and mouse input: quick, consistent response to commands, selections.

d. Consistency - system actions have the same meaning throughout the system (red is always critical; yellow is warning; green is normal).

e. Structure - uncluttered, logical layout of screen areas.

f. Coding - increase recognition speed through color and shape encoding.

g. Minimize memorization - menus; pop-up help windows so context is not lost.

h. Ease of Use, not ease of implementation - focus on minimizing the burdens and distractions of the operator while maximizing the speed and ease of use.

i. Levels of Expertise - Support various levels of user expertise: beginner, novice, expert. Provide the advanced user with the ability to define function keys or other short-cuts.

j. Window Management - a task specific, yet user definable, priority system for window overlapping based on importance, relevance and frequency of change of the information in the window.

k. Data Abstraction - a well established hierarchy of information based on information persistence (such as information that is always available) and information exceptions (such as communication errors or special messages). In addition, a hierarchy of information aggregation levels should be maintained.

l. Spatial Reference - geographical orientation/reference of information as appropriate, i.e., use of the spatial relationships and geographical reference to keep information organized.

9.1.2 Interfaces to Third Party Software

Relevant third party software should be accessible from each GUI component. The third party software should not be accessed through a generic process, but should be accessed within the appropriate framework with the appropriate information automatically loaded to support the decision making task. Full inter-operability (such as cut and paste, publish and subscribe, etc.) should be supported between the GUI components and the third party software applications. In addition, OSF/Motif compliance should be adhered to by all products. It is currently envisioned that the following types of interfaces will exist for third party software:

1. GIS
2. Map Database
3. DBMS
4. Statistical Analysis Toolset
5. Camera Configuration
6. Graphical Display Toolset
7. GUI Builder Toolset

9.1.3 Human Factor Considerations

Some key human factor considerations that are important to the implementation of the GUI include the following:

a. Window Management - providing the user maximum flexibility in managing multiple overlapping windows without confusion and system performance. Maximum flexibility should be provided to manage multiple simultaneous displayed windows. Windows should be organized and grouped together by type (e.g., relating to same incident). They may also be color coded. In addition, parent-child relationships are maintained so that the user can iconify or restore related windows together.

b. Data Presentation/Abstraction - providing the user with abstracted or summary level data for monitoring, with easy direct access to low level data elements on demand.

c. Alarms - allow all audible and visual alarms to be enabled/disabled, sorted and filtered to a user-specified area of interest.

d. Orientation - provide sufficient support for orientation with spatial and temporal components of the system (e.g. map interface, CCTV control).

9.2 H/W AND SIW MONITORING

The RTIC Hardware and Software Monitoring subsystem provides the necessary interfaces to monitor the RTIC assets for failure detection. Once a failure is detected it is entered in the tables of the RTIC DBMS, reported to the Maintenance Management subsystem, and displayed to the operator through the GUI. This subsystem is invoked for user access through the CTIS Window Manager by an invocation request and concluded by a termination request. This subsystem allows the user to monitor the performance of RTIC assets through the user GUI.

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

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

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

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

d. DBMS. Database usage (table counts, utilization, response times, etc.) and database sizing (database size, table size, etc.).

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

There are two scenarios in which the RTIC Hardware and Software Monitoring subsystem is invoked to provide failure status on RTIC assets. The first scenario involves the GUI. An operator may wish to initiate an interactive monitoring session in which he/she uses the Motif interface to select and monitor the RTIC hardware and software assets. It should be pointed out that the operator will be able to monitor both local and remote assets. What the operator can monitor is determined by the privilege level maintained for him/her in the DBMS. For example, a system administrator is capable of monitoring the software servers running everywhere on the LAN while a RTIC operator might only have access to the sewers that are run local to his/her machine.

The second scenario in which this subsystem can be invoked is when a failure is detected through one of the RTIC hardware or software assets. A message is sent to the event log informing the operator of a failure.

9.3 SECURITY

The security aspects of the system that will be addressed in the RTIC software include the following key areas:

a. Access to workstation and CTIS software shall be protected to prevent unauthorized users from logging into the system. The system will use a log name/password combination to track authorized users. All attempts (either by a valid or invalid user) to login to the system will be logged. After three unsuccessful attempts by a user to bg the system, the bgin prompt will be deactivated for 30 seconds.

b. Access to critical applications/data will be enforced by granting special privileges to authorized users. Critical applications that require special protection mechanisms include direct access to operating system-level commands and to SQL-level interfaces provided by the DBMS. To accomplish this the system shall support security levels. Security levels prevent authorized users, without the correct security level, from using certain applications (e.g., Database Updates). The logon name/password combinations and associated security levels for all users and applications shall be reconfigurable (add, delete, change). The configuration or reconfiguration of this data is permitted only by the System Administrator.

c. The system shall not permit the user to start new applications on a node that will cause it to exceed peak utilization of available resources (CPU, Disk, I/O). This requirement works in conjunction with the operating system requirements that establish high priorities for real-time or time-critical software processes.

The primary security requirements for CTIS are summarized as follows:

a. Use of user bgins and passwords.

b. Logging of all login attempts.

c. Granting of privileges users, groups, roles.

d. Login shutdown after three unsuccessful login attempts.

e. Application level security labeling.

9.4 SYSTEM MANAGEMENT/EVENT LOGGING

The System Management subsystem manages CTIS assets. This subsystem will facilitate the display of events that are generated from various applications of the system. Events by definition are any action conducted by either the system or the operator. The following is a summary of event logging capabilities:

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

- Events shall include at minimum the following:

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

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

- Each event shall contain data that describes the following:

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

  b. Event type.

  c. Time/date the event was generated.

  d. Any length message describing the event.

  e An event priority.

- All events shall be logged to a separate system file.

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

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

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

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

+ The event display shall be scrollable.

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

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

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

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

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

9.5 INTER-PROCESS COMMUNICATION

Inter-process communication (IPC) a mechanism by which two or more software processes can exchange messages. As illustrated in Figure 9-2, IPC handles point-to-point, multicast, and broadcast communications. It is envisioned that the majority of the IPC software for the CTIS will take advantage of software IPC COTS products. In addition, the requirements for an IPC package include the following:

a. Execute and port to all major Unix platform

b. Provide message passing via TCP/IP sockets and datagrams, shared memory, and POSIX message queues.

c. Provide application API that allows structured messages to be passed between two or more unrelated software processes (not only among parent and children). Processes may reside on different nodes (processors) on the LAN or within the same node.

d. The API will provide transparency as to the underlying communication protocol and the location of the destination process. The API will provide parameters for the data to send, the destination process, and options that characterize the type of transmission required.

e. Provide dynamic support to communicate with new processes started during run-time.

f. Support, at minimum, point-to-point and broadcast transmissions. It may be determined for performance reasons (during prototyping) that the need for a multicast capability also exists.

g. Support both blocking and non-blocking reads and writes.

h. Support both synchronous (periodic) and asynchronous (aperiodic) communications.

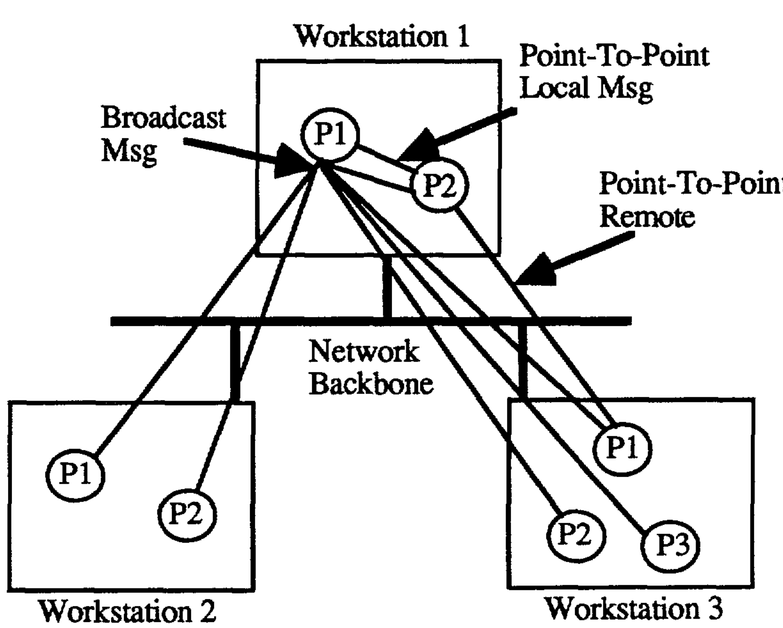


Figure 9-2. Inter-Process Communication Functionality

10. COST ESTIMATES

The entire system cost will be borne by both the I-95 Corridor Coalition agencies as well as private sector entities, such as ISPs. The cost calculation presented in this chapter takes into account the anticipated cost share of public agencies. The costs incurred to the private sector are excluded from this calculation.

Roth capital costs, and operations and maintenance (O&M) costs are calculated. Capital costs are further broken down into three elements, namely, hardware, sottware and installation. O&M costs are broken down into separate operations and maintenance items.

A three phase deployment (short, mid, long-term) of RTIC was assumed for the calculation of system cost. The corresponding deployment phases are years 0-2, 2-5, and 5-10 respectively. The costs were estimated for individual deployment phases.

The following summarizes the major assumptions made in estimating the system costs:

- The cost is calculated for one (1) regional traveler information center (RTIC). The total system cost can easily be computed by multiplying the individual RTIC cost by the number of RTICs and adding the cost of communication to connect these RTICs.
- Computation is based on the publicly funded system components.
- Costs are calculated for the items identified under Cost Elements (Section 10.1). Also, one (1) unit of each cost element is considered in the system cost calculation.
- Costs are calculated in terms of 1995 dollars.
- For the communication cost calculation, it was assumed that the IEN will provide the initial installation of 56 kbps frame relay communication lines. A total of 20 phone lines were also assumed for the initial installation.

10.1 COST ELEMENTS

The following cost elements constitute the total RTIC system cost presented in this section:

- RTIC Core Element
- Communication Network (within the RTIC region)
- Audiotext
- Dial-in Bulletin Board System (BBS)
- Internet
- Automated Fax
- Media Voice
- Information Kiosks

Although the cost for information kiosks is calculated, it was not included in the entire system cost estimate, because, the kiosk installations are not envisioned to be public sector responsibility. However, the cost information for kiosks is provided for reference only.

Tables 10-1 through 10-8 provide the cost estimates for individual cost elements.

Table 10-1 Cost Estimate for RTIC Core Element

RTIC-Core Element (1 Unit)	Hardware Cost ($, thousands)			Software Cost ($, thousands)			Integration/Installation Cost ($, thousands)			Operations Cost/Year ($, thousands)			Maintenance Cost/Year ($, thousands)		
	0-2 Yrs	2-5 Yrs	5-10 Yrs	0-2 Yrs	2-5 Yrs	5-10 Yrs	0-2 Yrs	2-5 Yrs	5-10 Yrs	0-2 Yrs	2-5 Yrs	5-10 Yrs	0-2 Yrs	2-5 Yrs	5-10 Yrs
Processing Functions	70	70	100	200	300	400	50	100	150	50	50	60	40	40	30
Database Functions	50	50	70	70	200	500	40	60	100	50	50	70	60	50	50
Interface Functions	20	50	100	100	250	400	20	20	50	20	40	50	40	30	40
Comm Functions	20	50	100	50	100	200	20	20	50	50	70	50	40	30	50
Output Functions	30	50	120	90	150	200	20	20	50	30	40	100	30	30	50
Non Computer Functions	30	30	50	30	50	80	10	15	30	100	100	100	50	70	100
Sub Totals	*220*	*300*	*540*	*540*	*1050*	*1780*	*160*	*235*	*430*	*300*	*350*	*430*	*260*	*250*	*320*

Table 10-2 Cost Estimate for Communication Network Within the RTIC

Communication Network (1 Unit)	Hardware Cost ($, thousands)			Software Cost ($, thousands)			Integration/Installation Cost ($, thousands)			Operations Cost/Year ($, thousands)			Maintenance Cost/Year ($, thousands)		
	0-2 Yrs	2-5 Yrs	5-10 Yrs	0-2 Yrs	2-5 Yrs	5-10 Yrs	0-2 Yrs	2-5 Yrs	5-10 Yrs	0-2 Yrs	2-5 Yrs	5-10 Yrs	0-2 Yrs	2-5 Yrs	5-10 Yrs
WAN Functions	15	20	7	8	10	12	10	7	7	10	12	15	12	14	17
Gateway Function	18	22	25	10	12	15	12	8	7	5	7	10	10	14	18
LAN Functions	10	12	20	5	8	14	12	15	20	5	8	15	10	12	14
Public Comm Functions	5	10	15	7	10	12	8	12	14	7	18	22	12	14	17
Comm Power Functions	5	3	3	2	2	2	5	3	3	3	3	3	8	8	8
Comm Cable Functions	8	5	5	0	0	0	18	12	10	0	0	0	14	10	8
Sub Totals	61	72	75	32	42	55	65	57	61	30	48	65	66	72	82

Table 10-3 Cost Estimate for Audiotext System

Audio-Text Elements (1 Unit)	Hardware Cost ($, thousands)			Software Cost ($, thousands)			Integration/Installation Cost ($, thousands)			Operations Cost/Year ($, thousands)			Maintenance Cost/Year ($, thousands)		
	0-2 Yrs	2-5 Yrs	5-10 Yrs	0-2 Yrs	2-5 Yrs	5-10 Yrs	0-2 Yrs	2-5 Yrs	5-10 Yrs	0-2 Yrs	2-5 Yrs	5-10 Yrs	0-2 Yrs	2-5 Yrs	5-10 Yrs
Processing Functions	5	10	0	5	10	0	5	8	0	25	35	0	10	30	0
Database Functions	5	5	0	5	10	0	5	8	0	25	35	0	10	30	0
Interface Functions	5	5	0	10	20	0	5	8	0	25	35	0	20	40	0
Comm Functions	5	10	0	10	20	0	5	8	0	25	35	0	20	30	0
Output Functions	10	10	0	10	20	0	5	8	0	25	35	0	30	50	0
Non Computer Functions	2	5	0			0	5	8	0	25	25	0	10	20	0
Sub Totals	*32*	*45*	*0*	*40*	*80*	*0*	*30*	*48*	*0*	*150*	*200*	*0*	*100*	*200*	*0*

Table 10-4 Cost Estimate for Dial-In BBS

Dial-In BBS Elements (1 Unit)	Hardware Cost ($, thousands)			Software Cost ($, thousands)			Integration/Installation Cost ($, thousands)			Operations Cost/Year ($, thousands)			Maintenance Cost/Year ($, thousands)		
	0-2 Yrs	2-5 Yrs	5-10 Yrs	0-2 Yrs	2-5 Yrs	5-10 Yrs	0-2 Yrs	2-5 Yrs	5-10 Yrs	0-2 Yrs	2-5 Yrs	5-10 Yrs	0-2 Yrs	2-5 Yrs	5-10 Yrs
Processing Functions	20	40	50	40	60	80	20	20	30	20	40	60	30	30	50
Database Functions	10	30	40	20	30	40	10	10	20	20	40	60	30	30	50
Interface Functions	10	20	50	40	60	60	10	10	10	20	40	60	30	30	50
Comm Functions	15	25	30	50	60	80	10	10	10	20	40	60	30	30	50
Output Functions	5	10	20	50	50	80	10	10	10	20	40	60	30	30	50
Non Computer Functions	20	20	10	30	30	30	10	10	10	20	40	60	30	30	50
Sub Totals	*80*	*145*	*200*	*230*	*290*	*370*	*70*	*70*	*90*	*140*	*280*	*420*	*210*	*210*	*350*

Table 10-5 Cost Estimate for Internet Component

Internet Elements (1 Unit)	Hardware Cost ($, thousands)			Software Cost ($, thousands)			Integration/Installation Cost ($, thousands)			Operations Cost/Year ($, thousands)			Maintenance Cost/Year ($, thousands)		
	0-2 Yrs	2-5 Yrs	5-10 Yrs	0-2 Yrs	2-5 Yrs	5-10 Yrs	0-2 Yrs	2-5 Yrs	5-10 Yrs	0-2 Yrs	2-5 Yrs	5-10 Yrs	0-2 Yrs	2-5 Yrs	5-10 Yrs
Processing Functions	30	40	50	40	60	80	20	20	30	20	40	60	30	30	50
Database Functions	20	30	40	20	30	40	10	10	20	20	40	60	30	30	50
Interface Functions	10	20	50	40	60	60	10	10	10	20	40	60	30	30	50
Comm Functions	15	25	30	50	60	80	10	10	10	20	40	60	30	30	50
Output Functions	5	10	20	50	50	80	10	10	10	20	40	60	30	30	50
Non Computer Functions	20	20	20	30	30	30	10	10	10	20	40	60	30	30	50
Sub Totals	*100*	*145*	*210*	*230*	*290*	*370*	*70*	*70*	*90*	*140*	*280*	*420*	*210*	*210*	*350*

Table 10-6 Cost Estimate for Media Voice Component

Media-Voice Elements (1 Unit)	Hardware Cost ($, thousands)			Software Cost ($, thousands)			Integration/Installation Cost ($, thousands)			Operations Cost/Year ($, thousands)			Maintenance Cost/Year ($, thousands)		
	0-2 Yrs	2-5 Yrs	5-10 Yrs	0-2 Yrs	2-5 Yrs	5-10 Yrs	0-2 Yrs	2-5 Yrs	5-10 Yrs	0-2 Yrs	2-5 Yrs	5-10 Yrs	0-2 Yrs	2-5 Yrs	5-10 Yrs
Processing Functions	5	10	0	5	10	0	5	8	0	25	35	0	10	30	0
Database Functions	5	5	0	5	10	0	5	8	0	25	35	0	10	30	0
Interface Functions	5	5	0	10	20	0	5	8	0	25	35	0	20	40	0
Comm Functions	5	10	0	10	20	0	5	8	0	25	35	0	20	30	0
Output Functions	10	10	0	10	20	0	5	8	0	25	35	0	30	50	0
Non Computer Functions	2	5	0			0	5	8	0	25	25	0	10	20	0
Sub Totals	*32*	*45*	*0*	*40*	*80*	*0*	*30*	*48*	*0*	*150*	*200*	*0*	*100*	*200*	*0*

Table 10-7 Cost Estimate for Automated Fax System

Automated Fax Elements (1 Unit)	Hardware Cost ($, thousands)			Software Cost ($, thousands)			Integration/Installation Cost ($, thousands)			Operations Cost/Year ($, thousands)			Maintenance Cost/Year ($, thousands)		
	0-2 Yrs	2-5 Yrs	5-10 Yrs	0-2 Yrs	2-5 Yrs	5-10 Yrs	0-2 Yrs	2-5 Yrs	5-10 Yrs	0-2 Yrs	2-5 Yrs	5-10 Yrs	0-2 Yrs	2-5 Yrs	5-10 Yrs
Processing Functions	5	5	0	5	10	0	5	8	0	25	35	0	10	30	0
Database Functions	5	5	0	5	10	0	5	8	0	25	35	0	10	30	0
Interface Functions	5	5	0	10	20	0	5	8	0	25	35	0	20	40	0
Comm Functions	5	10	0	10	20	0	5	8	0	25	35	0	20	30	0
Output Functions	10	10	0	10	20	0	5	8	0	25	35	0	30	50	0
Non Computer Functions	2	5	0			0	5	8	0	25	25	0	10	20	0
Sub Totals	*32*	*40*	*0*	*40*	*80*	*0*	*30*	*48*	*0*	*150*	*200*	*0*	*100*	*200*	*0*

Table 10-8 Cost Estimate for Information Kiosks

Information Kiosk Elements (1 Unit)	Hardware Cost ($, thousands)			Software Cost ($, thousands)			Integration/Installation Cost ($, thousands)			Operations Cost/Year ($, thousands)			Maintenance Cost/Year ($, thousands)		
	0-2 Yrs	2-5 Yrs	5-10 Yrs	0-2 Yrs	2-5 Yrs	5-10 Yrs	0-2 Yrs	2-5 Yrs	5-10 Yrs	0-2 Yrs	2-5 Yrs	5-10 Yrs	0-2 Yrs	2-5 Yrs	5-10 Yrs
Processing Functions	20	40	80	50	100	150	10	20	30	20	40	60	30	25	20
Database Functions	10	30	50	30	50	100	10	20	30	20	40	60	30	25	20
Interface Functions	10	20	30	30	50	60	10	20	30	20	40	60	30	25	20
Comm Functions	5	10	30	20	30	40	10	20	30	20	40	60	30	25	20
Output Functions	5	30	50	30	40	50	10	20	30	20	40	60	30	25	20
Non Computer Functions	5	10	30	10	10	10	10	20	30	20	40	60	30	25	20
Sub Totals	*55*	*140*	*270*	*170*	*280*	*410*	*60*	*120*	*180*	*120*	*240*	*360*	*180*	*150*	*120*

10.2 SYSTEM COST

Table 10-9 provides the breakdown of total cost estimate for one RTIC, derived by aggregating the cost line items from Tables 10-1 through 10-8. As discussed before, the cost for information kiosks was excluded from system cost estimate.

Table 10-9 System Cost Breakdown for a RTIC

RTIC Components	Hardware Cost ($, thousands)			Software Cost ($, thousands)			Integration/Installation Cost ($, thousands)			Operations Cost/Year ($, thousands)			Maintenance Cost/Year ($, thousands)		
	0-2 Yrs	2-5 Yrs	5-10 Yrs	0-2 Yrs	2-5 Yrs	5-10 Yrs	0-2 Yrs	2-5 Yrs	5-10 Yrs	0-2 Yrs	2-5 Yrs	5-10 Yrs	0-2 Yrs	2-5 Yrs	5-10 Yrs
RTIC Core	220	300	540	540	1,050	1,780	160	235	430	300	350	430	260	250	320
Communication Network	61	72	75	32	42	55	65	57	61	30	48	65	66	72	82
Audiotext	32	45	0	40	80	0	30	48	0	150	200	0	100	200	0
Dial-In Bbs	80	145	200	230	290	370	70	70	90	120	240	360	180	180	300
Internet	100	145	210	230	290	370	70	70	90	140	280	420	210	210	350
Media Voice	32	45	0	40	80	0	30	48	0	150	200	0	100	200	0
Automated Fax	32	40	0	40	80	0	30	48	0	150	200	0	100	200	0
Information Kiosks	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Totals	557	792	1,025	1,152	1,912	2,575	455	576	671	1,040	1,518	1,275	1,016	1,312	1,052

Table 10-10 summarizes the cost estimates in terms of capital costs and O&M costs. It indicates that the short, mid and long-term capital costs are $2.2, 3.3 and 4.3 million respectively, which, in turn, indicates a capital cost of $9.7 million for the entire RTIC system . The O&M costs are $2.1 million in the short-term is, $2.8 million in the mid-term, and $2.3 million in the long-term deployment.

Table 10-10 Entire System Cost for a RTIC

Item	0-2 Yrs	2-5 Yrs	5-10 Yrs	
Capital Cost, $1000	2,164	3,280	4,271	*Total RTIC Capital Cost =$9,715*
O&M Costs/Year, $1000	2,056	2,830	2,327	