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SHARED COMMUNICATIONS: VOLUME I. A SUMMARY AND LITERATURE REVIEW

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ABSTRACT

This paper provides a review of examples from the literature of shared communication resources and of agencies and/or organizations that share communication resources. The primary emphasis is on rural, intelligent transportation system communications involving transit. Citations will not be limited, however, to rural activities, or to ITS implementation, or even to transit. In addition, the term “communication” will be broadly applied to include all information resources. Literature references to issues that contribute to both successful and failed efforts at sharing communication resources are reviewed.

The findings of this literature review indicate that:

- The most frequently shared communication resources are information/data resources,
- Telecommunications infrastructure and technologies are the next most frequently shared resources,
- When resources are successfully shared, all parties benefit,
- A few unsuccessful attempts of sharing resources have been recorded, along with lessons learned,
- Impediments to sharing include security issues, concerns over system availability and reliability, service quality and performance, and institutional barriers,
- Advantages of sharing include financial benefits to agencies from using shared resources and benefits to the public in terms of congestion mitigation, information transfer (e.g., traveler information systems), mobility (e.g., welfare-to-work paratransit), and safety (e.g., speed of incident response, incident avoidance),
- Technology-based solutions exist to address technology-based concerns, and
- Institutional issues can be addressed through leadership, enhanced knowledge and skills, open communication, responsiveness, and attractive pricing structures.

1. INTRODUCTION

The purpose of this report is to examine the literature for examples of organizations and agencies that share communications resources. While the primary emphasis is on rural, intelligent transportation system (ITS) communications involving transit, examples will not be limited to rural activities, nor to ITS implementation, nor even to transit! In addition, the term "communication" will be broadly applied to include all information resources.

The first three sections of this document serve to define the meaning of the term "shared communication resources" and to provide examples of agencies that share resources. In these sections, the location (i.e., state or city) of the resource being discussed will be underlined. The fourth section provides a brief literature review of the issues that surround sharing communication resources. Based on the documentation of shared communications and communication issues, recommendations for potential usage are provided in the last section.

The national ITS program has a goal of improving safety and efficiency on highway, transit, and rail systems through both information- and infrastructure-based programs. Rural ITS has many of the same objectives as ITS in urban areas; however, the conditions are very different. Distances are greater, for example, but population density is less. Causes of and responses to traffic incidents are decidedly different. Transit needs are different. Coordination and cooperation among very diverse jurisdictions and groups of public and private stakeholders are very different. This report will attempt to document as many examples of shared communication as possible in order to delineate more clearly these differences between rural and urban conditions and to provide guidelines for successful communication sharing in the future.

The ITS program has six major categories: Advanced Rural Transportation Systems (ARTS), Advanced Traveler Information Systems (ATIS), Advanced Public Transportation Systems (APTS), Advanced Transportation Management Systems (ATMS), Advanced Vehicle Control and Safety Systems (AVCSS), and Commercial Vehicle Operations (CVO). This report focuses primarily on the first three of these, although some examples of shared communication involve the other categories.

2. EXAMPLES OF SHARED COMMUNICATION RESOURCES

Efficient and effective communications are central to transportation improvements using ITS. Communication is critical not only because of its obvious functional necessity; it is also a critical component because of the cost of telecommunications infrastructure. Facilities and other infrastructure, technologies and research, data integration and data mining – all must be accommodated; all must be financed.

The research community, led by the Freeway Operations Committee (A3A09) and Traffic Signal Systems (A3A18) of the Transportation Research Board (TRB), recognized the need to leverage valuable resources for operations. The "Shared Resource" concept was first identified in the 1980s. Regular meetings of the Integrated Transportation Management Symposium (ITMS) began in the 1990s (see, for example, Berman, 2001; Urbanik, 1997A; Urbanik, 1997b; Turnbull, 1997; and Jacobson and Turnbull, 1997).

Due to the limited experience for transportation management across different inherent jurisdictions, the research community defined the shared process to include (1) sharing of physical resources, (2) sharing of personnel/equipment, (3) sharing of development expertise, and (4) identification of the development process that can initiate the sharing or integrated management practice among different operating agencies.

Since this original concept definition, additional areas for sharing resources have been identified. The remaining sections of this chapter contain examples from a literature review by resource types under the following categories: facilities, telecommunications infrastructure, communication bandwidth and frequency, data and information, technologies, and personnel.

2.1 SHARED FACILITIES

In this report, the term "facilities" includes Traffic Management Centers (TMCs), buildings, and broadcasting equipment within buildings.

The Providence, Rhode Island, TMC was unable to effectively monitor highway incidents, the primary cause of congestion and delay around Providence (Levesque, 2002). Because incidents were not being reported to the TMC by the state police, the TMC was relying on media reports, police scanners, and surveillance cameras. The lack of information meant that motorists were not being alerted to the incident in time to take alternate routes, avoiding the incident. The solution was to assign a state police trooper to the TMC to assist in obtaining incident response information. The trooper monitors both the state police radio and surveillance cameras and handles all communication between the police in the field and the TMC personnel. The state police troopers share the TMC facilities with TMC personnel. In addition, information from the TMC's traffic surveillance cameras is shared with the state police, which reduces response times to incidents and enables the police to react to the incident with the appropriate response team.

2.2 SHARED TELECOMMUNICATIONS INFRASTRUCTURE

Shared telecommunications infrastructure, as defined in this report, includes towers and other wireless infrastructure, wireline (coaxial cable, fiber optic, copper) and conduit, cameras and closed circuit television (CCTV), highway advisory radio (HAR), variable message signs (VMS), spare parts, system documentation, local area networks (LANs) and other networks, and the roadside right-of-way.

Telecommunications infrastructure is possibly the most costly part of an ITS implementation, especially in rural areas. Unfortunately there is no "magic bullet" for solving the telecommunications issues. The central issues are distances involved, rapid technological changes in the telecommunications field, and resistance by various jurisdictions to sharing responsibilities, ownership, rights-of-way, financial impacts, etc. (Federal Highway Administration and Federal Transit Administration, 2000B, p. 2).

The literature includes several examples of infrastructure sharing by public-private parties, both in operational and developmental stages, and also by different governmental agencies. As a result of the Telecommunications Act of 1996 and the Federal Highway Administration (FHWA) National Priority Technologies Program, which encouraged regional private-sector partnerships to improve responsiveness to problems and leverage Federal resources, many public-private partnerships were credited in the 90's and beyond. Primarily, the purpose of these partnerships was to share the public resource of roadway right-of-way (RoW) and the private resource of telecommunications expertise and capacity. Sharing resulted in advantages for both parties (Kessler, 1997). The following section presents some of the case studies and projects in this area, as well as a description of the research conducted to study the main issues that emerged from such partnerships.

2.2.1 Roadway Right-of-Way

A very early study (Kerwin and Lutes, 1994) discusses the first attempts of collaboration among different transportation agencies in New Jersey on sharing the communication infrastructure. The study describes the efforts involved in designing new fiber optic links and other facilities specifically to serve multiple agencies. (Some of the participating agencies were already sharing microwave towers, although the shared towers were planned and built by a single agency for its needs only.)

More recently, Lopez (1999) described the Virginia Department of Transportation (DOT) public-private arrangements to share the installation of 1,500 miles (2,413 km) of fiber optic facilities and associated electronics within Virginia's interstate RoW. The agreements grant the private sector exclusive access to interstate and primary road RoW to deploy a commercial fiber optic network, in exchange for providing Virginia DOT fiber optic telecommunications infrastructure and services necessary to support ITS on a statewide basis. The paper details Virginia DOT's pending public-private fiber optic resource sharing program; evaluates practices and strategies used in the design, operation, and maintenance of the proposed telecommunications network; and chronicles project initiation, forming of relationships, design, and operations and maintenance concerns. It also looks at the various nontechnical issues encountered and how their negative impacts were minimized in crafting a successful partnering agreement. (An outline of the Virginia DOT view of the private and public sector roles in Intelligent Transportation Systems can be found in a 1998 paper by Bard and Barron.)

In a 1998 paper, Saucedo and Li discuss strategic requirements, including front-end planning/system design considerations, key issues of systems integration, cost considerations, and equipment selection criteria of the Houston Computerized Traffic Management System (CTMS). The CTMS includes a common fiber-optic backbone that is shared by the Texas DOT, the Metropolitan Transit Authority, the City of Houston, and Harris County; it is used for transmitting voice, video, and computer data for monitoring and controlling of traffic flow. Information carried on the network includes CCTV; computer data for motorist information shown on VMS; traffic data, such as speed and occupancy; and voice telecommunications along freeways and between major highway trunks and the TMC. The agencies use the system to monitor traffic conditions enabling them to make appropriate decisions for traffic control and incident management.

In a similar way, Fowler (2000) focused on the Kansas DOT intelligent transportation systems. Specifically, the author describes the benefits that were realized as a consequence of the partnerships created to share resources (i.e., the fiber optic infrastructure) to meet current and future ITS objectives.

Several case studies illustrating government-based partnerships that have resulted in the development of fiber systems are presented in Pietrzyk (1999). The paper provided a general discussion of fiber and fiber-optics systems and fiber network development within Miami-Dade County, Florida, including a summary of communication needs assessment of the Florida DOT and Miami-Dade County transportation-related agencies. The Pietrzyk outlined and compared wireless options for ITS infrastructure communication applications, as well as identified barriers to fiber-optic network deployment. The paper also discussed cost-sharing opportunities for fiber system expansion and the major steps needed to develop a fiber-optic communications system serving ITS infrastructure.

2.2.2 Other Infrastructure

All the studies discussed above concentrated in highway RoW/fiber-optics infrastructure sharing. There have been, however, other successful private-public partnerships involving different types of telecommunications infrastructure. For example, Jenq (1997) describes a successful development of information distribution using cable television. The paper documents the Atlanta Traveler Information Showcase, a Federal initiative aimed at demonstrating the benefits of ITS technology by implementing an integrated ATIS. The study describes the development and integration of five state-of-the-art traveler information technologies: (i) a fully automatic cable television programming and production system, (ii) an interactive television system, (iii) a real-time traffic World-Wide-Web home page, (iv) two personal communication devices, and (v) an in-vehicle navigation system. The cable television system (known by local residents as Georgia Traveler Information Television) was the component that was judged most useful by viewers, program distributors (county governments and participating cable companies), and the Georgia DOT. Jenq describes the challenges (i.e., product concept development; television programming system hardware and software development; presentation design; communications with ATMSs and integration with other ATIS subsystems; negotiation and establishment of distribution system; design of operation procedure; and institutional coordination) in developing the Atlanta Traffic Channel.

Another example of shared telecommunications resources is the Southern California ITS Showcase (Federal Highway Administration and Federal Transit Administration, 2000B, pp. 22-23). This architecture includes 17 projects distributed over four California Department of Transportation (Caltrans) Districts. Over a dozen systems share resources. Each system communicates with its peers through a "seed" which also connects to a "kernel," which provides regional routing and other management services. Kernels are also connected. Although each Caltrans District controls its own sensors, displays, and other traffic management field devices, there is an overall network topology that allows sharing and inteaction.

2.3 SHARED COMMUNICATION BANDWIDTH AND FREQUENCY

This section contains literature references to interoperability capability (e.g., police, fire, and bus drivers sharing a bandwidth or frequency). This section does not include the equipment or infrastructure.

Many of the ITS applications that are intended to enhance the safety of the individual traveler are available to both personally owned vehicles, as well as vehicles owned and operated by traditional public safety agencies. This creates an environment where spectrum use may be shared between public-safety-related and non-public-safety-related functions. Kain (1997) discusses some of the problems that this might create, including operational, interoperability, and spectrum requirements issues, as well as issues raised by the public safety community concerning technology and interoperability with ITS.

2.4 SHARED INFORMATION

This section on shared information includes data and software, as well as "information." Shared data can be raw or processed. Shared software might include, for example, a geographic information system (GIS), which could be shared among several regional agencies. Shared information also includes sharing media, such as a web page or spots on public media such as television, radio, newsprint, or other advertisement venues.

When data systems are shared, interfaces or translations must exist at several junctures. Hardware, network protocols, data elements, and application programs must be compatible in order to share or exchange data (Federal Highway Administration and Federal Transit Administration, 2000B, p. 27).

Neudorff (1997) documented the I-95 Corridor Coalition (a partnership of the major public and private transportation agencies from Virginia to Maine) development and deployment of an Information Exchange Network (IEN), aimed at enhancing mobility, safety, and efficiency across all modes and transportation facilities that serve the Corridor. The paper describes the IEN; it discusses the various IEN applications (including incident tracking, construction activities, VMS/HAR, traffic/transit link conditions, and historical data); and it also describes the IEN architecture and components (including workstations, user interface, servers, and communications network). This study also discusses the data interfaces, which connect and extract information from an agency's ITS-based system, process and convert the data to the appropriate format, and transmit the data to a server for subsequent aggregation and distribution to IEN workstations throughout the corridor.

Another example of ITS information sharing and multi-agency utilization of information is presented in Mondul (1997). The author describes the capabilities and operational use of the Virginia Operational Information System (VOIS) which exchanges information among Virginia DOT, state police, Department of Emergency Services, and other state agencies. Mondul also presents an example of the usage of the VOIS system during Virginia's response to Hurricane Frances in early September 1996. On that occasion, the system was used to communicate and exchange real-time emergency information within Virginia DOT and with other state agency subscribers.

In a 1997 study, Gangisetty describes the design of an ATMS for Interstate 476 (I-476) in Delaware and Montgomery Counties, Pennsylvania. The system combines real-time data for graphic displays with an open architecture for network and communications services. The paper includes a discussion of the design challenges encountered (e.g., developing systems, incorporating hybrid communications with standard interfaces, designing an infrastructure system able to facilitate future expansion, applying teleconferencing and telecommunication equipment for traffic monitoring, and interfacing I-476 ATMS elements with existing central communications and control equipment) and also the client-server architecture that provides shared access to the system database and controls for control center personnel and other outside agencies.

ITS in rural areas has several applications, one of which is roadway operations and maintenance. In Michigan, a snow and ice removal program (Anderson, 1998) incorporated weather information, data from snowplows, and a route optimization application. A central maintenance center then coordinated snowplow routes for reducing the number of vehicles required to service a particular area. This study noted that plans included extending the project to adjoining counties.

In 1995, the Minnesota DOT (Rockvam and Wikelius, 1998) began work on a system to allow Minnesota DOT district employees to electronically report (1) pavement conditions, (2) weather conditions, (3) permit status information, and, eventually (4) maintenance-related information. The data would be available to DOTs across the state. This system would be integrated with other weather information to provide travelers with comprehensive information about Minnesota roads. Challenges included obtaining reliable road condition data from the field and devising a comprehensive system that met the needs of operational personnel as well as travelers.

Individual agencies in Minnesota will be networked together to share information among small/medium urban areas with significant surrounding rural areas (Federal Highway Administration and Federal Transit Administration, 2000B, p. 25). Each "virtual transportation operations center" maintains control of its own equipment. A typical example of the information that could be shared would be "the interconnection of the traffic signal computer(s) at the city DOT and the county department of public works, with pavement and road weather sensor information at the state DOT district office, and video signals from shared CCTV cameras on major routes and at common trouble zones. A logical extension of this concept would be … output from any local 'smart work zone' … [and] transit information as well" (Federal Highway Administration and Federal Transit Administration, 2000B, p. 25).

An ATIS provides travelers information for making decisions. There are two categories of information: (1) real-time network facts, which could concern either traffic or transit operations, and (2) traveler guidance (Lappin, 2000). Most ATISs aggregate data from other sources and provide it in new formats for the traveler. ATISs have several outlets for their information – publicly available kiosks, hotels/motels, internet web sites, television, etc. Most recently, 511 telephone systems have become a standard interface for traveler information.

The FleetOnline system, which provides highway information in Arizona, with greater detail on the Phoenix metropolitan area, is an example of an ATIS with principal emphasis on commercial vehicle carriers and drivers (Li and Hunt, 1999). FleetOnline uses two types of highway databases: one containing freeway and expressway data for which real-time traffic information can be updated via the internet, the other containing arterials with historical (not real-time) data. Speed predictions are provided using a traffic forecasting system. Several information sources are accessed to obtain the data: regional traffic information centers, state motor carrier administration agencies, DOTs of participating cities and municipalities, weather data from the National Weather Service, and participating motor carriers. Under a public-private agreement with AZTech, FleetOnline uses data stored in the AZTech database server. The AZTech raw data is fused, processed, and value-added before being entered to the FleetOnline database. This arrangement of sharing and reusing data facilitates commercial vehicle traffic and benefits the entire region's transportation situation.

In the November 1997 Memorandum of Understanding between DOT and the Department of the Interior (DOI), there was a call for an operational test in a national park using ITS technologies to improve transportation in and around the park. Acadia National Park was selected as the ITS test site (National Park Service, 2000). Acadia National Park, located primarily on Mount Desert Island in northeastern Maine, encompasses 35,000 acres. The plan for ITS applications for Acadia centered on an ATIS, which was designed to provide travelers with information via radio, internet, and signs. Acadia's ATIS would build upon the initial success of the Island Explorer transit system, which was launched in June 1999. Objectives of the ATIS were to reduce demand for parking, improve safety by eliminating illegal/unsafe overflow parking along state and local roadways, reduce traffic congestion, and improve economic development opportunities in the local communities. The primary users of the information would be tourists who access and benefit from the ATIS. Additional users who would be expected to share the data include the ITS Joint Program Office, National Park System, Downeast Transportation Inc. (the operators of the Island Explorer), Regional Planning Authority, and the state of Maine.

Branson, Missouri, located in the heart of the Ozark Mountains, has become a major tourist vacation center. Because Branson is accessible only by rural routes and almost everyone who visits comes by private automobile or motor coach, FHWA selected Branson as an operational test site to evaluate and showcase another ATIS. The Branson Travel and Recreational Information Program (TRIP) provides tourists with comprehensive information on local attractions, as well as current weather, traffic, and road construction information. With a purpose of providing pre-trip, en-route, and on-site information, dissemination is accomplished via two VMS, commercial radio and television, HAR, Interactive Voice Response (IVR), 31 interactive information kiosks, and the Internet (Garrett, 1998). It should be noted that the TRIP system was designed and developed using public and private partnerships. These partners included federal, state, and local levels of government, tourism agencies, chambers of commerce, law enforcement and emergency response organizations, radio and TV stations, and commercial developers (Stone, 1998). Data from all sources are managed in a centralized database by the Branson Police Department using a graphical user interface. The Missouri DOT and the City of Branson share ownership of the data (Bennett, 2001). After conversion, the data are shared with any requestor. There is no public transit in Branson. Tour buses use the TRIP system. Buses are contracted for special events (e.g., conferences) to provide transportation from hotels to shows and other venues.

2.5 SHARED TECHNOLOGIES

Some of the more widely used ITS technologies include automatic passenger counts, automatic vehicle location (AVL) capabilities, real-time travel information, fare cards (or other electronic payment systems), GISs, emergency alarms and Mayday systems, mobile data terminals, traffic signal preferential treatment, digital communications, automatic destination signs, and stop annunciators.

The New York City Transit in New York is one of the largest and most complex public transportation systems in the world, and has been in operation since 1904. The bus and subway services operate 24 hours a day throughout the city. Currently, an average of over 6 million riders use the New York transit system daily. The New York City Subway has an automated fare collection (AFC) system using fare cards. These MetroCards can be used on either the subway or the bus system. MetroCards are individually identifiable by a serial number. Data are collected on card usage every time the card is inserted into a fare reader (Berry, 2001).

There are many opportunities for shared data using transit technologies. For example, buses equipped with AVL could be used to obtain congestion or traffic speed data, which could be shared with TMCs, paratransit operators, emergency operations centers, or other highway traffic managers (e.g., King County Metro Transit AVL System, see Dailey and Cathey, 2002). Two other potential applications for sharing technologies include the use of temporal-spatial data in traveler information systems and the integration of multi-agency/multi-mode/multi-jurisdictional electronic payment systems (e.g., King County Metro and the Puget Sound area; see Federal Highway Administration and Federal Transit Administration, 2000A, pp. 12-13).

The Ventura County, California, introduction of a multi-agency smart card payment system in 1996 is an example of shared communication project that did not work as expected (Federal Highway Administration and Federal Transit Administration, 2001). The plan was to install and integrate smart card technology on several (initially eight) transit systems in the Ventura County area to increase operational efficiency. The system would integrate Automated Passenger Count (APC), AVL, and GPS technologies. Because of operational and data processing problems, the system was discontinued in 1999.

In a 2001 report, Nalevanko et al. present another illustration of shared technology involving the Austin, TX Capital Area Rural Transportation System (CARTS). The agency had problems in ensuring vehicle communications over its very large service area. A utility company operating in the same area installed a state of the art radio communications system, and purposely added excess capacity to encourage other governmental agencies to share this unique resource. CARTS was the first agency to join the system, and as a result the agency experienced increased communication capacity and radio coverage throughout its service area. The cost was approximately the same as the previous radio system, but this new system offered better capabilities.

3. EXAMPLES OF AGENCIES THAT SHARE COMMUNICATION

The first section of this report provided examples of communication sharing by resource type. This section discusses the various agencies and/or organizations that could benefit by sharing communication resources. Some of these agencies include the following:

- Transit, Rail, Maritime Administration (MARAD), Commercial Vehicle Operations, etc.,
- Health and Human Services Departments, Paratransit, etc.,
- Traffic Management Centers (Freeway Traffic Management Systems, etc.),
- Incident management personnel (police, fire, Emergency Management Centers, etc.), and
- Public and private organizations with interests in transportation issues (e.g., universities, environmental advocates, etc.).

3.1 SPECIFIC EXAMPLES

Southeast Michigan undertook a project to link several partners, including cities, counties, the suburban bus system, government councils, and the Michigan DOT. To expand and integrate ITS programs required increased cooperation among regional jurisdictions. This type of cooperation and interagency communication was critical to improve traffic conditions and mitigate congestion (Bair, 2002).

One of the most difficult tasks for any inter-jurisdictional implementation is to achieve consensus among the shareholders. This problem also exists when it comes to sharing communication resources. One example of a successful cross-organizational sharing effort is that of the King County Department of Transportation Metro Transit Division, commonly called the King County Metro (KCM). KCM operates in a 2,128 square mile area, which includes Seattle, Washington (KCM, various websites). KCM and other transportation agencies work together to the extent possible to provide efficient transportation options to the public. For example, KCM feeds data to Smart Trek, a real-time traffic information on-line service for the Puget Sound region. In addition, KCM provides options for internet users to view congestion, construction, and road condition information. In 1999, KCM began collaboration with six other transportation agencies, including transit, ferries, and rail, to implement a regional Smart Card system. Under this system, the seven agencies provide riders with the option to use one fare card in four Puget Sound counties. Fare collection is done using the Smart Card to allow linked trips between the different agencies. KCM is currently working with traffic engineers in partner cities (e.g., Seattle, Shoreline) to test Transit Signal Priority (TSP) to increase the efficiency of the buses and to provide a smoother ride for the transit passengers. Real-time AVL data are used to provide arrival/departure times at two transit stops. In general, the KCM data are shared with anyone who makes a request. However, it was decided early on that the raw data will generally not be shared. Computer programs were developed so that appropriate data could be extracted for sharing (Friedman, 2001).

McNeilly and Kuciemba (1996), discuss the technical and policy concerns associated with resource sharing in the state of Maryland. Those issues include the consensus building efforts necessary to instill interest in public agency resources, development of procurement documents and negotiations necessary to successfully realize shared resourcing projects, and the understanding of both public and private sector concerns to realize benefits for both concerns. (Update: as of July 2002, Fiber Optics lines have been installed on most Interstates RoW in central MD – approximately 370 total miles; regarding wireless communications, several towers were installed along controlled access facilities that accommodate multiple providers – as many as five providers per structure. See Resource Sharing: State-by-State Status Report, FHWA, 2002.)

Melcher (1997) describes the advantages of developing multi-agency telecommunications networks to serve both ITS wireline telecommunications applications and other state government applications, including economic benefits that may be realized by aggregating telecommunications procurement activities to obtain economies of scale and scope and technical benefits that facilitate efficient information sharing. The paper also identifies and addresses impediments to multi-agency utilization of ITS wireline telecommunications infrastructure. The Federal Highway Administration Report No. FHWA-SA-97-054 (1997A) also presents a discussion of the benefits of these partnerships.

The Southern California Priority Corridor (Federal Highway Administration and Federal Transit Administration, 1999) provides an illustration of how agencies can apply the National ITS Architecture and Standards to achieve regional ITS coordination among numerous traffic and transit management and traveler information centers. The report discusses collaboration by multiple Metropolitan Planning Organizations and state and local transportation agencies in a complex, multi-jurisdictional setting; integration of extensive "legacy" ITS infrastructure using an open architecture and interface standards to enable unprecedented levels of data and control sharing among traffic management centers; the participation of "highlighted" stakeholders, including the California Highway Patrol, South Coast Air Quality Management District, California Trucking Association, border crossing agencies, and Mexico; and opportunities for private sector information service providers to acquire and provide value-added regional traveler information.

Edelstein, et al., in a 2000 paper present the lessons learned in planning the Broward County, Florida, TMC. The Broward County ITS Operations facility, which includes interstate dynamic message sign system, intra-coastal waterway dynamic message sign system, Broward County Advanced Traffic Management System, ATIS services, and additional communication linkages, combines different agencies with different goals, objectives, and personalities. The paper presents the lessons learned in the following areas:

- **Partnering**
  Significant cost savings can be realized by combining the functions of the ITS Operations Facility with the county's need for a replacement building to house their traffic engineering staff (i.e., having one building in lieu of two buildings).
- **System Architecture**
  Metropolitan areas planning a similar TMC project to that of Broward County are

advised to prepare an ITS Strategic Plan/System Architecture prior to the TMC Master Plan phase to provide the needed rational structure for the integration of the TMC.

- **Memorandums of Understanding (MoU)**
  Edelstein, et al. (2000) recommend that the preparation of MoUs begin as early as possible, so that interagency agreements may be developed in parallel with the conceptual design.
- **3-D Computer Animation System**
  The 3-D Computer model was particularly useful for policy, managerial and technical staff, permitting them to play a more significant role during the TMC design process.
- **Flexibility**
  All the facilities were designed to accommodate planned growth in terms of the number of operators, other stakeholders, and additional partners; as well as communications requirements of both initial ITS needs and future needs of ITS infrastructure growth.

Davis (1999) discusses issues related to institutional barriers to shared control and operation of traffic signals within the Metropolitan Transportation Commission (MTC) representing the nine-county area surrounding the San Francisco Bay. The MTC and the Arterial Operations Improvement Advisory Committee created an interagency traffic Signal Task Force to develop procedures and policies recommendations to simplify and expedite the implementation of projects that entail shared control and operation of traffic signal systems and equipment. Nine institutional barriers to shared control and operation of traffic signal systems were identified and prioritized (based upon both their importance and the likelihood of advancing a solution to each issue) by the Task Force. Three prioritization levels were established with three main issues within each level:

- High Priority
  1. Different Operating Philosophies
  2. Trust/Communication
  3. Hierarchy of Control/Operation
- Medium Priority
  1. Liability
  2. Operations vs. Maintenance
  3. Level of Responsiveness
- Low Priority
  1. Leadership
  2. Access to Funding
  3. Cost of Cooperation

The paper also addresses technical barriers, including compatibility problems with communications between equipment from different vendors, as well as the institutional barriers to interagency control and operation of traffic signal systems and equipment.

A similar discussion, but for the various agencies and partners participating in the Minnesota Transportation Operation Communication Center is presented by Nookala and Maddern (2000). The goal of the project was to establish an integrated statewide transportation network serving rural and smaller urban areas in Minnesota. In trying to achieve this goal, several problems were identified including duplication and insufficient use of infrastructure and resources by the different participating agencies (which up to the start of the project thought of themselves as stand-alone agencies), outdated communication centers, lack of ITS integration between adjoining systems, and lack of adequate financial resources. In response to these problems and to guide future ITS investments, MnDOT and the Department of Public Safety-State Patrol formed the Statewide ITS Leadership to provide advice for the development of eight new Traffic Operation and Communication Centers and several ITS subsystems. These share communication centers would ensure consistency and interoperability between agencies and regions.

3.2 STATISTICS FROM THE 1999 ITS DEPLOYMENT TRACKING SURVEY

This section presents statistics obtained from the 1999 ITS Deployment Tracking Survey (for more information, see http://itsdeployment2.ed.ornl.gov/its2000/default.asp). The survey is distributed to and information is collected from a selected group of transportation agencies including Arterial Management Agencies, Freeway Management Agencies, and Public Transit Agencies in 78 of the largest metropolitan areas in the United States.

3.2.1 Infrastructure and Information Sharing Among Agencies

Of the total number of arterial and freeway management agencies responding the survey (i.e., 488), 29.7% (145 agencies) indicated that their activities were housed in a building shared with other agencies or activities. Of those, 69 stated that their facilities were electronically linked to other transportation management facilities.

The total number of agencies with communications infrastructure already in place (or that were planning to deploy it in the near future) was 270, or 55.4%. Of those, 63% (170 agencies) indicated that they were using fiber-optic cable as the type of communication infrastructure (Note: 95.6% of the Freeway Management Agencies that have some kind of communications infrastructure used fiber-optic cable.); 28.9% of the agencies used wireless communications; and 15.2% had leased lines.

Out of 381 agencies, 205, or 53.8%, stated that they coordinated information with other agencies; while 86, or 22.6%, indicated that they turned over the control of some of their infrastructure to other agencies during some time (e.g., night, weekends, special events). Table 1 shows distributions of coordinated information with other agencies and turned-over-control to other agencies.

***Table 1.* Distributions of Coordinated Information and Turned-Over-Control**

Agencies that	One Other Agency		Two Other Agencies		Three Other Agencies		Four or More Agencies	
Coordinate information with	134	35.8%	36	9.5%	21	5.5%	14	3.6%
Turn over control of some infrastructure to	66	17.3%	9	2.4%	5	1.3%	6	1.6%

Coordination of operations with other agencies indicates some sharing of infrastructure (e.g., communications infrastructure, information distribution infrastructure). Out of 488 agencies, 132 agencies indicated that they coordinated operations with other agencies, and 107 (21.9%) specifically stated that they shared some infrastructure. Similarly to Table 1, Table 2 shows distributions of coordinated operations and infrastructure sharing by the agencies interviewed.

***Table 2.* Distributions of Coordinated Operations and Infrastructure Sharing**

Agencies that	One Other Agency		Two Other Agencies		Three Other Agencies		Four or More Agencies	
Coordinate operations with	28	21.2%	33	25%	17	12.9%	54	40.9%
Share some type of infrastructure with	27	25.2%	17	15.9%	17	15.9%	47	43.9%

The ITS Deployment Tracking Survey also asked the participating agencies what methods of communication were used on-site at an incident (or while responding to an incident) to communicate with state or local DOT, police, fire/rescue, and towing services. From this type of data it is possible to infer information such as sharing of frequencies and other communications media.

Table 3 shows a summary of the responses. Consider, for example, communications with police. Out of the 132 agencies that indicated having communication with police while responding to an incident, 98 (74.24%) used two-way radios to communicate, 59.1 % communicated through cellular phones, and 48.4 % used 800 MHz trunked radios. Hand-held devices, automated data systems, and other means of communications were used in 42.7%, 35.6%, and 6.1%, respectively. (Note: the percentages do not add to 100% since an agency may be using more than one method of communications.)

Table 3. **Communications Between Agencies**

Communication Infrastructure	Police		Fire		DOT		Towing Co	
Two-way radio	98	74.24%	83	70.34%	94	79.66%	71	60.17%
Cellular telephone	78	59.09%	58	49.15%	93	78.81%	73	61.86%
800 MHz trunked radio	64	48.48%	52	44.07%	39	33.05%	20	16.95%
Hand-held (i.e., walkie-talkie)	55	41.67%	46	38.98%	35	29.66%	22	18.64%
Automated data systems	47	35.61%	32	27.12%	15	12.71%	10	8.47%
Other	8	6.06%	8	6.78%	9	7.63%	4	3.39%
Agencies responding	132		118		119		86	

In all the cases (i.e., communications with police, fire, DOT, and towing companies), the most widely used method of communication was radio communications (i.e., two-way radio and 800 MHz trunked radio). This clearly indicates a sharing of frequencies among the different agencies dealing with incident response. Cell phone was the next most used mean of communication.

This information is presented in some more detail in Table 4. For two-way radio communications, for example, this table indicates that out of the 129 agencies that have this type of technology, 75 use it to communicate with police and fire; 61 for communications with emergency management agencies and DOT; and 45 use two-way radio to communicate with police, fire, DOT and towing companies.

Table 4. **Most Used Communications Infrastructure**

Communication with	Two-way Radio		Cellular Telephone		800 MHz Trunked Radio	
Police, Fire, DOT, Towing Co	45	34.88%	38	30.16%	5	6.25%
Police, Fire, DOT	61	47.29%	44	34.92%	23	28.75%
Police, Fire	75	58.14%	54	42.86%	49	61.25%
Total Number of Agencies*	129		126		80	

*Using the communications technology indicated at the header of each column

3.2.2 Public Transit Agencies

The 1999 ITS Deployment Tracking Survey contacted 199 Public Transit Agencies. Out of these 199 agencies, 35 (17.6%) coordinated, or were planning to start coordinating, travel request and vehicle dispatching for multiple agencies.

Regarding electronic payment, 105 agencies (52.8%), had (or were planning to have) a fully operational Electronic Fare Payment System (other than registering fare boxes); 42 (21.1%) were using the same electronic payment system as other operators in the region; and 2 (1.0%) indicated that they accepted electronic payment of transit fares through the use of electronic toll collection media.

In addition, 20 public transit agencies (10.1%) had agreements in place with other agencies or jurisdictions to use similar hardware and software to aid maintenance and interoperability. Of the 199 agencies, 91 (45.7%) had, or were planning to have, an AVL system, which could provide valuable information not only to the public transit agency, but also to other transportation agencies, such a freeway and arterial management. Of the 199 responding agencies, 51 agencies were already providing traffic incident reports to emergency management agencies.

4. ISSUES CONCERNING SHARED COMMUNICATION

Some implementation challenges to sharing data have been documented (Federal Highway Administration and Federal Transit Administration, 2000A, pp. 10-11). A partial list includes the following (1) institutional relationships may be difficult, (2) departments sharing data may need to adapt to a standard format, (3) implementation may be delayed to meet functionality requirements (software customization).

Emerging paradigm shifts in surface transportation organizations are evident within the United States (TCRP, 2001, pp. 21-22). With respect to sharing communication resources, these shifts include the following: (1) decision-making authority exists on multiple levels, from the local service level to the strategic level and (2) services may be provided using shared facilities, equipment, and information. Two specific examples are as follows:

- TRANSCOM, which involves 15 cooperating transportation and traffic agencies in New York, New Jersey, and Connecticut, and
- E-ZPass, which involves multiple agencies in multiple states, to reduce waiting times at bridges and tunnels. E-ZPass's regional consortium comprises five transportation agencies representing Delaware, New Jersey, and New York. The larger Interagency Group is an association of 16 northern toll agencies in seven states (New York, New Jersey, Delaware, Pennsylvania, Maryland, Massachusetts, and West Virginia). This organization will ultimately share resources for the world's largest seamless electronic toll collection network (E-ZPass, 1999).

Based on the lessons learned in the Ventura County, California, smart card project (Federal Highway Administration and Federal Transit Administration, 2001), the following issues must be addressed:

Institutional issues

- There must be a champion to lead the integration and enforce management controls,
- There must be sufficient staff resources, with appropriate skills and knowledge,
- Regular, open communication must occur among all stakeholders,
- The systems integrator/vendor must be responsive,
- There must be a competitive pricing structure so that the new technology is attractive to users, and
- Training for participants is mandatory (e.g., if transit drivers are required to enter data, they must understand their role).

Technical issues

- System performance, data collection, and reporting requirements must be established early and monitored for all participants, and
- A method for financial reconciliation and distribution of revenues must be established based on a fair market share formula.

Customer acceptance issues

- An effective marketing strategy using broadcast and print media, must be developed,

- Incentives for trying the new system will encourage first-time customers, and
- User surveys can assess satisfaction and identify areas for improvements.

Many studies have been conducted to identify and address relevant issues arising from public-private partnerships in which private telecommunications providers are granted access to roadway RoW for their own telecommunications infrastructure (mainly fiber optics conduits and cable) in exchange for providing telecommunications infrastructure to the public sector.

Jakubiak, Brady, and Relin (1996); Jakubiak, Hardison, and Relin (1996); and Jakubiak and Needham (1997); identified nontechnical (i.e., legal and institutional) issues related to sharing the public resource of highway RoW and the private resource of telecommunications expertise. The three papers focus on threshold legal and political issues, financial issues, and project structure and contract issues, while different forms of shared resource projects and methods of valuation are presented in Horan and Jakubiak (1996).

Jakubiak and Relin (1996) and a Federal Highway Administration report (1996) present a more detailed discussion of these issues. The report identified and explored 20 institutional and non-technical issues associated with implementation of shared resource projects and described various options for dealing with these issues. Those 20 issues were divided into 4 categories: Threshold Legal and Political Issues (issues that are to be resolved upfront otherwise they can slowdown progress), Financial Issues (which involve valuation and taxation issues), Project Structure Issues (dealing with project implementation), and Contact Issues (issues related to the allocation of responsibilities among the participating public and private organizations). Threshold Legal and Political Issues included "Public sector authority to receive and/or earmark compensation", "Authority to use public right-of-way for telecommunications", "Authority to participate in public-private partnerships", "Political opposition from private sector competitors", "Inter-agency and political coordination", and "Lack of private sector interest in shared resources". Among Financial Issues, Jakubiak and Relin identify as relevant issues the "Valuation of public resources", "Tax implications of shared resource projects", "Valuation of private resources", and "public sector support costs". Project Structure Issues included "Exclusivity", "Form of real property right", "Type of consideration", and "geographic scope". Finally, "Relocation", "liability", "Procurement issues", "System modification", "Social –political issues", and "Intellectual property" were identified as Contract Issues.

The report also included five case studies —involving the State of Maryland, the Ohio Turnpike Commission, the State of Missouri, the Bay Area Rapid Transit System, and the City of Leesburg in Florida—to illustrate the types of arrangements that had been implemented up to the time the research was conducted. Other case histories, interviews with leading experts from the federal government and the private sector, and procedural tools to take into account when developing options, as well as a section containing "real" language drawn from actual request for proposal (RFP) documents used to develop a shared resource approach, can be found in Gilroy and Roberts (1997). Also, Kessler and Jakubiak (1998) discuss completed, under negotiation, or in consideration wireline projects in which

RoW is made available to carriers in exchange for telecommunications or intelligent transportation systems, services, money, or a combination of these. An example of an owner of a right of way that retains ownership and earns a return in the form of annual payments would be the New York State Thruway Authority, which collects a percentage of "user fees" generated by the length of fiber-optic cable installed.

In a 1997 presentation of the AASHTO Telecommunications Task Force *Guidance on Sharing Freeway and Highway Rights of Ways for Telecommunications*, Pickering identifies and describes activities and issues involved in the joint use of public freeway and highway RoW, in which cash or in-kind compensation may be generated to reduce the net cost of public sector ITS and transportation communications. Pickering also provides some "maxims" which include keeping the process moving, strive for administrative efficiency, and seek a judicious balance between conflicting objectives.

The AASHTO Guidance classifies resource sharing projects as those that (1) are a public private partnership, (2) offer private access to public property (roadways in the case of the transportation officials) for telecommunications facilities, and (3) provide compensation (cash or in-kind payments) to the rights-of-way owner that exceeds the administrative costs of the project. It also acknowledges that partnering opportunities could be short lived because two main forces: market conditions that drive vendor interest and the value of the resource being shared which is directly related to the potential revenue available to the private firm. In his presentation,

Kitchener (2000) describes the process and the lessons learned, with emphasis on the importance of cooperative agency effort, for Idaho. The author discusses institutional issues faced by ITS planning and how these issues can be tempered by demonstrating the benefits of information sharing through systems integration.

Specifically addressing the public transit arena, Giuliano et al. (2001) in a paper presented at the TRB 80th Annual meeting describe the results of the San Gabriel Valley Smart Shuttle (SGVSS) Field Operational Test (FOT) in California. The main objective of the three-year FTO was to integrate a regional fixed route operator and three local municipal public transit operators using wide area network computer-assisted dispatching, automated vehicle location, and mobile data terminals. The focus of the paper is on the issues that impeded the system to be fully integrated, including definition of the project by decision makers from outside the participating organizations; time and budget constraints; lack of clear project goals and objectives; limited commitment on the part of some project participants; contracting and management problems; and technical problems with software and hardware. The authors provide many insights on the challenges of service integration, as well as lessons learned. Among the latter, the authors identify:

- "Goals and objectives should be clear, appropriate, understood by all parties, and agreed upon by all parties, especially those charged with carrying out the FOT;"
- "Institutional arrangements should be formal, clearly specified, and should allocate responsibility and risk appropriately;"

- “Any FOT should pass a basic test of reasonableness before it is allowed to go forward;”
- “The technology should fit with the problem being solved;”
- “Delays are inevitable in FOTs and should be built into the schedule;”
- “New technology tests should be as simple and incremental as possible; and”
- “Basic technical knowledge and computer literacy of participants cannot be assumed.”
-

The Institute for Transportation Research and Education (2001) of North Carolina State University, in association with KFH Group and TransCore, produced a guide for determining how far transit should go to implement new technologies in rural and small urban areas. One purpose was to determine how these transit systems benefit from cooperative arrangements. Common themes to illustrate successful implementations include working in partnerships with governmental agencies, transit and human service providers, and private interests.

5. CONCLUSIONS AND RECOMMENDATIONS

This paper has presented examples of successful communication resources sharing. It has also included some examples where the sharing plan did not entirely succeed. A table that lists the specific examples of shared resources presented in this report is provided in Appendix B. As can be seen in this table, most sharing of communication resources is a sharing of data or information. Some organizations share raw, real-time data; others do not share raw data, but they will share the information after it has been aggregated or otherwise formatted. Technologies and telecommunications infrastructure are the next most frequently shared resource.

A tabular listing of agencies that have successfully integrated their operations to achieve agency goals is given in Appendix C. Agencies that have successfully integrated communications resources to reach multi-agency goals have included traffic and/or transportation agencies (including weather-related road conditions), traveler information services, welfare-to-work agencies, transit agencies, and toll facilities.

The issues surrounding sharing communication resources were briefly examined. Technology-related issues include standardization, system performance and reliability, and implementation issues that surround customization for differing needs of different agencies. The primary issues seem to be more institutional-related than technology-related. Non-technical issues include legal and political issues, financial issues, and project structure and contract issues.

5.1 REASONS FOR SHARING OR NOT SHARING COMMUNICATION RESOURCES

Overall, there are many reasons to share communication resources. Rationale includes the practical implementation considerations. In rural areas, sharing is especially important because of the limited resources available to provide ITS deployment.

Reasons for not sharing communication, such as security concerns and service availability, can mostly be resolved with technology-based solutions. However, the main implementation barriers for not sharing resources often lie within institutional barriers. In addition, the inherent physical separations among various jurisdictions hinder an effective decision-making process. However, separation based on “distances” can be overcome, as was proven by E-ZPass, which will involve seven states and 16 toll agencies. Education (e.g., learning about successful sharing ventures), planning, and community involvement foster effective resource sharing.

5.2 RECOMMENDATIONS

To be able to share ITS technologies (Federal Highway Administration and Federal Transit Administration, 2000A, p. 14), the following recommendations for development and implementation are useful:

- Requirements Development
  1. Get input from all departments regarding what the system should do,
  2. Ensure that the requirements are realistic and fit the budget, and
  3. Use existing, rather than customized, software products, whenever possible.

- Specification Development
  1. Use an open architecture,
  2. Ensure that standards are followed, and
  3. Specify desired reporting functions.

- Technology
  1. Investigate the technology,
  2. Buy the most perfected hardware and technology available, and
  3. Ensure that data quality is constantly monitored and maintained.

The Intelligent Transportation Society of America (ITS America) has proposed the creation of a "National Transportation Information Network," to link urban and rural transportation systems into an integrated, but distributed, data network (Bair, 2002). This comprehensive "infostructure" will be capable of collecting and sharing transportation system condition and performance information covering entire freeway and arterial networks in metropolitan areas (including freeway and arterials). Such a communication network could become an integral and vital part of a homeland security infrastructure, available in times of national emergency for evacuation and mobilization purposes.

The second phase of this project will document some of the best practices, physically interview successful operating agencies, and illustrate the recommended development process. A particular model, process, or flowchart will be developed to illustrate the best practices, and evaluation criteria will be designed.

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APPENDIX A
ACRONYMS

AFC	Automated Fare Collection
APC	Automated Passenger Counts
APTA	American Public Transit Association
APTS	Advanced Public Transportation System
ARTS	Advanced Rural Transportation System
ATIS	Advanced Traveler Information System
ATMS	Advanced Transportation Management System
AVCSS	Advanced Vehicle Control and Safety System
AVL	Automatic Vehicle Location
CALTRANS	California Department of Transportation
CCTV	Closed Circuit Television
CTD	Commission for the Transportation Disadvantaged
CTMS	Computerized Traffic Management System
CVO	Commercial Vehicle Operations
DOI	Department of Interior
DOT	Department of Transportation
FHWA	Federal Highway Administration
FTA	Federal Transit Administration
GIS	Geographic Information System
HAR	Highway Advisory Radio
IEN	Information Exchange Network
ITMS	Integrated Transportation Management Symposium
ITS	Intelligent Transportation System
IVR	Interactive Voice Response
KCM	King Count Metro
LAN	Local Area Network
MARAD	Maritime Administration
MDI	Model Deployment Initiative
MPO	Metropolitan Planning Commission
ORNL	Oak Ridge National Laboratory
RFP	Request for Proposal
RoW	Right of Way
TCRP	Transit Cooperative Research Program
TMC	Traffic Management Center
TRB	Transportation Research Board
TRIP	Travel and Recreational Information Program
TSP	Transit Signal Priority
VMS	Variable Message Sign
VOIS	Virginia Operational Information System

APPENDIX B
TABULAR LISTING OF SHARED RESOURCES, BY SITE, AS DOCUMENTED IN THE REPORT

Site	Shared Resource					
	Facilities	Telecom. Infra.	Bandwidth/ Frequency	Information	Technologies	Personnel
Alabama, Birmingham			X[3]			
Arkansas, Little Rock, North Little Rock	X[1]	X[2](F)				
Arizona		X[2](W)				
Arizona, Phoenix	X[1]			X, X[4](EPS, ETC)		
Arizona, Maricopa County (Aztech)						X
Arizona, Tucson	X[1]		X[3]			
California, Los Angeles, Anaheim, Riverside	X[1]		X[3]	X[4](EPS)		
California, San Diego	X[1]		X[3]			
California, Southern Priority Corridor				X		
California, ITS Showcase		X		X	X	
California, San Francisco Bay	X[1]		X[3]	X, X[4](EPS)		
California, Ventura County				X	X	
California, Sacramento	X[1]		X[3]			
Colorado		X[2](F)				
Colorado, Denver, Boulder	X[1]		X[3]			
Connecticut, New Haven, Meriden				X[4](EPS)		
Connecticut, Hartford, New Britain, Middletown	X[1]		X[3]	X[4](EPS)		
District of Columbia	X[1]		X[3]	X[4](EPS)		
Florida, Miami-Dade County		X	X[3]			
Florida, Broward County					X	
Florida, Comm. Trans. Disadvantaged				X	X	
Florida, Jacksonville	X[1]		X[3]			
Florida, Tampa, St. Petersburg, Clearwater	X[1]		X[3]	X[4](EPS)		
Florida, Orlando	X[1]		X[3]			
Florida, Sarasota, Bradenton	X[1]		X[3]			

Site	Shared Resource					
	Facilities	**Telecom. Infra.**	**Bandwidth/ Frequency**	**Information**	**Technologies**	**Personnel**
Florida, West Palm Beach, Boca Raton, Delray	**X[1]**					
Georgia, Atlanta	**X[1]**		**X[3]**	**X, X[4](EPS)**		
Idaho				**X**		
Illinois-Indiana: Chicago, IL; Lake County, IL; Gary, IN	**X[1]**		**X[3]**	**X[4](EPS)**		
Indiana, Indianapolis	**X[1]**		**X[3]**			
Kansas		**X**		**X**		
Kansas, Wichita			**X[3]**			
Kentucky, Louisville			**X[3]**			
Louisiana, Baton Rouge	**X[1]**		**X[3]**			
Louisiana, New Orleans	**X[1]**		**X[3]**			
Maine, Acadia National Park				**X**		
Maryland		**X[2](F,W)**	**X[3]**		**X**	
Massachusetts		**X[2](F,W)**				
Massachusetts, Boston, Lawrence, Salem	**X[1]**					
Massachusetts, Springfield			**X[3]**	**X[4](EPS)**		
Michigan		**X[2](F)**				
Michigan, Detroit, Ann Arbor	**X[1]**		**X[3]**			
Michigan DOT (weather-related)				**X**		
Michigan, Grand Rapids	**X[1]**			**X[4](EPS)**		
Minnesota (weather-related)				**X**		
Minnesota (small urban/rural)				**X**		
Minnesota, Minneapolis, St. Paul	**X[1]**		**X[3]**	**X[4](EPS)**		
Missouri		**X[2](F)**				
Missouri, Branson				**X**		
Missouri, Kansas City	**X[1]**		**X[3]**			
Missouri, St. Louis	**X[1]**		**X[3]**			
Nebraska, Omaha	**X[1]**		**X[3]**			
Nevada, Las Vegas			**X[3]**			

Site	Shared Resource					
	Facilities	Telecom. Infra.	Bandwidth/ Frequency	Information	Technologies	Personnel
New Jersey		X		X	X	
New Mexico, Albuquerque	X[1]		X[3]			
New York		X[2](W)				
New York, Albany, Schenectady, Troy	X[1]		X[3]			
New York, Buffalo, Niagara Falls	X[1]		X[3]			
New York, Rochester	X[1]		X[3]			
New York, Syracuse			X[3]			
New York, New York City				X	X	
New York-New Jersey: New York, NY; Long Island, NY; Northern NJ	X[1]		X[3]	X[4](EPS)		
North Carolina, Raleigh-Durham				X[4](EPS)		
North Carolina, Greensboro, Winston-Salem, High Point	X[1]		X[3]			
North Carolina-South Carolina: Charlotte, NC; Gastonia, NC; Rock Hill, SC			X[3]	X[4](ETC)		
Ohio, Cleveland, Akron, Lorain	X[1]		X[3]			
Ohio, Cincinnati, Hamilton			X[3]			
Ohio, Columbus			X[3]			
Ohio, Dayton, Springfield	X[1]		X[3]			
Ohio, Toledo			X[3]			
Ohio, Youngstown, Warren			X[3]			
Oklahoma, Oklahoma City	X[1]					
Oregon, Portland	X[1]		X[3]			
Pennsylvania, Allentown, Bethlehem, Easton			X[3]			
Pennsylvania, Harrisburg, Lebanon, Carlisle			X[3]			
Pennsylvania, Pittsburgh, Beaver Valley			X[3]			
Pennsylvania, Scranton, Wilkes-Barre			X[3]			
Pennsylvania, Delaware and Montgomery Counties				X		

Site	Shared Resource					
	Facilities	Telecom. Infra.	Bandwidth/ Frequency	Information	Technologies	Personnel
Pennsylvania-Delaware-New Jersey: Philadelphia, PA; Wilmington, DE; Trenton, NJ	X[1]		X[3]			
Rhode Island, Providence	X	X		X[4](EPS)		X
South Carolina, Sumter				X		
South Carolina, Charleston			X[3]			
South Carolina, Greenville, Spartanburg	X[1]		X[3]			
Tennessee, Knoxville	X[1]		X[3]			
Tennessee, Nashville			X[3]			
Texas, Houston		X	X[3]			
Texas, Austin			X[3]			
Texas, Dallas, Fort. Worth	X[1]		X[3]	X[4](EPS)		
Texas, El Paso	X[1]		X[3]			
Texas, San Antonio			X[3]			
Utah, Salt Lake City, Ogden	X[1]		X[3]			
Virginia				X		
Virginia, Norfolk, Virginia Beach, Newport News			X[3]			
Virginia, Hampton Roads	X[1]		X[3]			
Virginia, Richmond, St. Petersburg	X[1]		X[3]			
Washington, Seattle	X[1]		X[3]	X, X[4](EPS)	X	
Wisconsin, Milwaukee, Racine	X[1]		X[3]	X[4](EPS)		
Wyoming		X[2](F)				
I-95 Corridor (Virginia to Maine)		X		X		

[1] Source: 1999 ITS Deployment Tracking Survey
[2] Source: FHWA, RESOURCE SHARING: STATE- BY- STATE STATUS REPORT, December 2001 Update (http://www.fhwa.dot.gov/realestate/utilsr.htm). F: Fiber-optics; W: Wireless.
[3] Source: 1999 ITS Deployment Tracking Survey. Information about shared frequencies and bandwidth inferred from hardware usage (two-way radios and 800 MHz trunked radio).
[4] Source: 1999 ITS Deployment Tracking Survey. EPS: transit agencies share electronic payment system; ETC: transit agencies accept electronic toll collection media as payment.

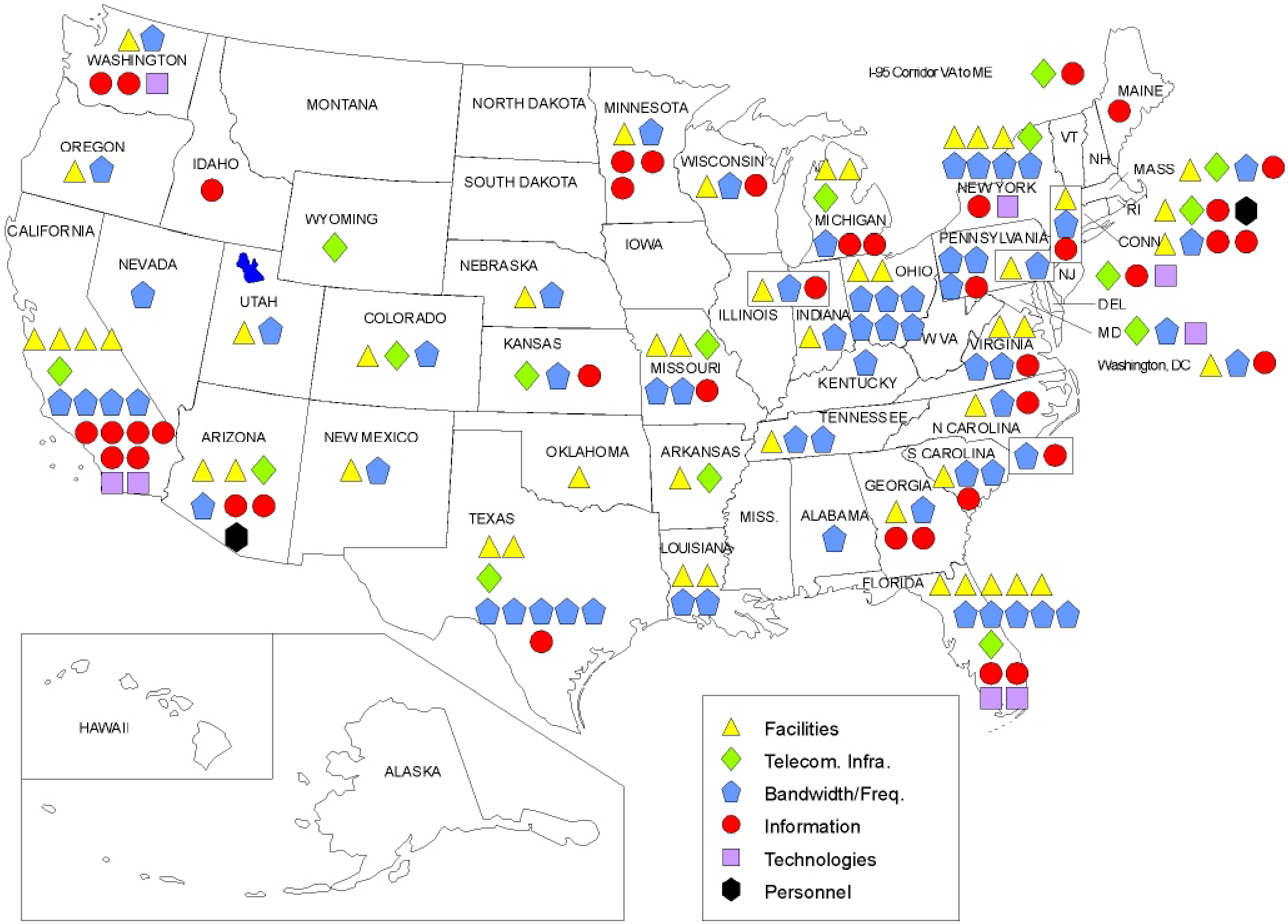

FIGURE 1. DISTRIBUTION OF SHARED RESOURCES BY STATE

APPENDIX C
EXAMPLES OF AGENCIES SHARING RESOURCES

Site	Magnitude
California, Southern Cal. Priority Corridor	Traffic, transit, and traveler information centers; state and local transportation agencies
California, San Francisco Bay	Agencies in nine-county area
California, San Diego	Transit agencies; welfare-to-work agencies
Florida, Broward County	Various agencies
Florida, Comm. Trans. Disadvantaged	All 67 counties; federal, state, and local agencies; public transit agencies; funding agencies
Maryland	Public agencies, private sector
New Jersey	Transit agencies; welfare-to-work objectives
New York, New Jersey, Connecticut (TRANSCOM)	Fifteen transportation and traffic agencies
New York, New Jersey, Delaware, Pennsylvania, Maryland, Massachusetts, West Virginia	Seven states, 16 northern toll agencies
Michigan, Southeast	Cities, counties, bus system, government councils, Michigan DOT
South Carolina, Sumter	Public and private agencies, local governments, general public, transit agencies
Washington, King County	Cities, four counties, transit and other transportation systems, public and private requestors