New York State Department of Transportation

Intelligent Transportation System (ITS) Study for the Buffalo and Niagara Falls Metropolitan Area
Erie and Niagara Counties, New York

SYSTEM ARCHITECTURE
Working Paper # 5

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1.0 INTRODUCTION AND SCOPE

This document has been prepared as part of the New York State Department of Transportation (NYSDOT) Buffalo and Niagara Falls Intelligent Transportation System Study. Working Paper #5 defines the conceptual system architecture that applies to the regional ITS program. The paper follows the work that has been developed to date (previous working papers), which identified the user services, market packages and functional requirements that are pertinent to the Buffalo/Niagara Falls region.

The conceptual system architecture is limited to the functional requirements and their inter-relationships which follow the National Systems Architecture ITS program framework. More importantly, the system architecture identified in this working paper reflects the national Intelligent Transportation Infrastructure (ITI) components that have been identified as the building blocks of any ITS program within a metropolitan area. The concept developed in this system architecture working paper will be the cornerstone of the implementation program of ITI for the Buffalo/Niagara Falls region ITS program.

The scope of this working paper is limited to identifying the basic functional components of the Buffalo/Niagara Falls regional ITS Architecture and relationships with respect to data and control sources. Users of the system are identified as external entities.

A preliminary set of alternative architectures is presented and evaluated in this document. While the overall analysis is kept at a conceptual level, a logical and structured evaluation is carried out to identify the most probable candidate architecture that would satisfy all of the current functional requirements as well as future requirements for the Buffalo/Niagara Falls region.

A structured design methodology is utilized in developing the system architecture with generic Data Flow Diagrams (DFD) with data and control sources being identified as the key elements of the architecture. A transformation of the logical architecture to physical architecture components is presented in Chapter 3 which follows the framework of the National Architecture Program.

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2.0 NATIONAL SYSTEM ARCHITECTURE PERSPECTIVE & RELATION TO BUFFALO/NIAGARA FALLS AREA

2.1 INTELLIGENT TRANSPORTATION INFRASTRUCTURE (ITI)

This section discusses what the ITI is all about and what ITI components do. The descriptions that follow are from the FHWA guide, "Building the ITI," April 1996. Later in this report the integration of the ITI with the architecture is addressed.

The ITI refers to those portions of ITS-related hardware, software and services that today, and increasingly in the future, will support the transportation-related activities. The ITI is comprised of nine (9) integrated components. The ITI is not just a group of components, but instead, it is an integrated system. The system consists of the following components:
- Traffic Signal Control
- Freeway Management
- Transit Management
- Incident Management
- Electronic Fare Payment
- Electronic Toll Collection
- Railroad Grade Crossings
- Emergency Management Services
- Regional Multi-Modal Traveler Information.

The deployment objectives for each of the national ITI components are listed below.

Traffic Signal Control
- Deploy signaling systems that react quickly to changing traffic conditions.
- Collect and process real-time traffic information to provide up-to-date status of the transportation system.
- Install automated tools which take all traffic data into account and provide the traffic manager with a clearer picture of the status of the transportation system.
- Deploy modular systems that facilitate future upgrades and allow addition of new capabilities as they become available.
- Provide flexible signal timing to transit and emergency response vehicles.

Freeway Management
- Provide critical information to travelers through infrastructure-based dissemination methods, such as variable message signs and highway advisory radio.
- Monitor traffic and other environmental conditions on the freeway system.
- Identify recurring and non-recurring flow impediments so that short-term and long-term actions can be taken to alleviate congestion.
- Implement various control and management strategies (such as ramp metering and / or lane control, or traffic diversion).
- use probe vehicles as an additional sensor for collecting real-time traffic information.

Transit Management
- Provide real-time, accurate transit information to travelers and operators.
- Monitor the locations of transit equipment so as to provide more timely information on arrival times.
- Optimize travel times for transit vehicles.
- Support flexible routing of transit vehicles.
- Support automated maintenance monitoring of transit vehicles.

Incident Management
- Coordinate incident management across regional boundaries to ensure efficient and sufficient response.
- Use traffic management capabilities to improve response times.
- Use onboard moving map route guidance equipment to assist incident response vehicles (e.g., ambulances and tow trucks).
- Reduce traveler delays due to incidents.

Electronic Fare Payment
- Provide a single medium for paying travel-related fares and parking fees.
- Reduce the necessity for travelers and public agencies to handle money.

Electronic Toll Collection
- Reduce delay at toll collection plazas.
- Reduce costs incurred by toll operating agency.
- Use common toll readers and tags to promote interoperability and reduce cost to the traveling public.
- Reduce handling and processing of money.

Railroad Grade Crossing
- Improve and automate warnings at highway rail crossings.
- Provide travelers with advanced warning of crossing closures.
- Coordinate rail movements with the traffic signal control system.

Emergency Management Services
- Use traffic management capabilities to improve response times.
- Use onboard moving map route guidance equipment to assist emergency vehicle operators.
- Improve response to HAZMAT incidents by providing emergency personnel with timely, accurate information.

Regional Multimodal Traveler Information
- Promote regional coordination in collecting, processing and presenting traveler information.
- Collect and maintain comprehensive transportation data for all potential users on a timely basis.
- Format/package this data such that it will be meaningful to the traveler and operator.

- Provide travel information to the public via a range of communication devices (broadcast radio, cellular telephone, the Internet, cable TV) for presentation on a range of devices (home/office computers, television, kiosks, radio).

2.2 ITS NATIONAL SYSTEM ARCHITECTURE

The National ITS Architecture defines a framework for the design of Intelligent Transportation Systems. This major effort was recently completed by the U.S. Department of Transportation and Federal Highways Administration. The framework allows for multiple design approaches which can be developed for specific environments and tailored to meet the individual needs of the user. The architecture defines the ITS functions that must be performed to implement a given user service, the physical entities or subsystems where these functions reside, the interfaces/information flows between the physical subsystems, and the communication requirements for the information flows. ITS technologies have been encapsulated in a collection of inter-related user services for the application to the national surface transportation problems. To date, 29 user services have been defined nationally. These were reviewed in Working Paper #4.

In addition, the national architecture identifies and specifies the requirements for the standards needed to support national and regional interoperability.

The national architecture, its goals, objectives, definition, evaluation and deployment are documented in extensive volumes. The specific documents that are directly related to this project are the architecture definition documents which consist of:

- The Logical Architecture: This represents a functional review of the ITS user services. It defines the functions or process specifications that are required to perform the ITS user services, and the information or data flows that need to be exchanged between these functions.

- The Physical Architecture: This partitions the functions defined by the logical architecture into systems, and at the lower level, subsystems, based on functional similarities of the process specifications and the location where the functions are to be performed.

- Implementation Strategy: This defines a series of steps to encourage efficient deployment of architecture compatible ITS systems.

2.3 BUFFALO ITI

For development of the Buffalo ITS, the national ITI components were used as a base in developing the Buffalo ITI. In some cases the national ITI components were combined to form a single Buffalo ITI component. New components were also added to best reflect the needs of Buffalo/Niagara Falls. A mapping of the national ITI components to the Buffalo ITI components is shown below. The International Border Crossing functions and commercial vehicle operations functions relevant to this region may be the only extension to the national ITI components needed.

National ITI Components	Buffalo ITI Components
Traffic Signal Control	Traffic Control System
Freeway Management	Traffic Control System
Transit Management	Transit Systems
Incident Management	Traffic Control System
Electronic Fare Payment	Electronic Payment Services
Electronic Toll Collection	Electronic Toll System
Railroad Grade Crossings	N/A
Emergency Management Services	Emergency Management Services
Regional Multimodal Traveler Information	Driver & Traveler Services
N/A	Border Crossing Functions
Future	Commercial Vehicle Operations

Deployment of ITI components within the Buffalo and Niagara Falls region will permit efficient operation and management of the roadway and transit resources through the integration and use of currently available technologies, combined with strengthened institutional ties and inter-jurisdictional/inter-agency co-ordination. Additionally, in the Buffalo/Niagara Falls region, the transborder agencies need to be coordinated efficiently in order to provide a seamless ITS environment throughout the region.

FIGURE 2-1 BUFFALO ITS ARCHITECTURE INTERFACES

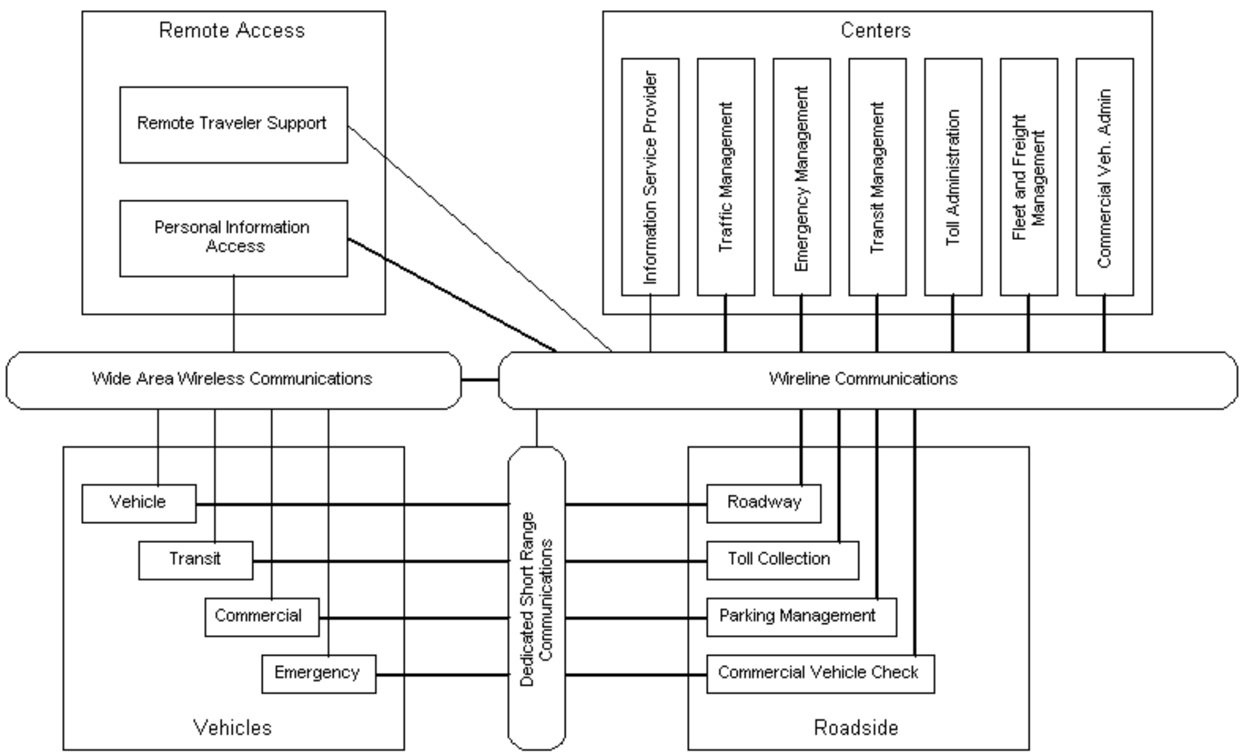

Figure 2-1, the Interface Diagram, is adapted from the national ITS architecture "sausage" diagram. The term sausage diagram comes from the shape of the communication linkages. As shown here, the subsystems are distributed into 4 groups. These groups being Remote Access, Centers, Vehicles, and Roadside. The basic communication channels between these subsystems are shown. All 17 of these subsystems directly support the Buffalo ITI.

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3.0 SYSTEM ARCHITECTURE FOR BUFFALO

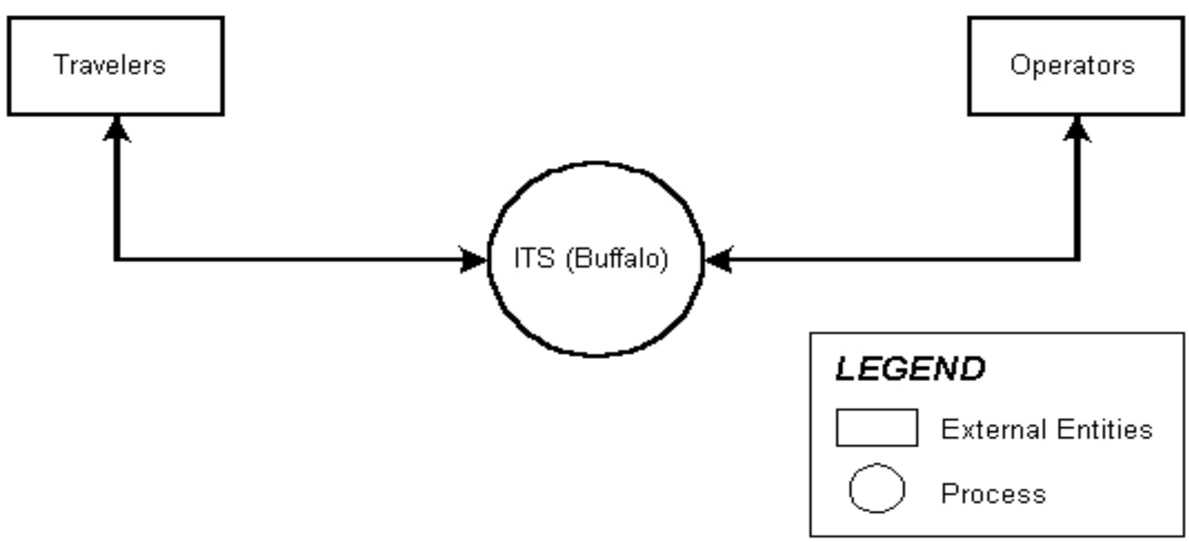
The basic approach to deployment of the architecture in Buffalo should follow these steps:

1. define user services;
2. define functions/interface;
3. develop logical architecture;
4. develop physical architecture option; and
5. identify standards.

The user services (step 1) were defined in Working Paper # 3 and discussed in the User Services Workshop. Functionality was defined in Working Paper # 4 (step 2). The next steps (through 4) are addressed in this working paper starting with defining the necessary interfaces and developing the logical and physical architectures. The following sections proceed with these steps. Identifying standards will be an on-going process, most of which will occur on a national level. Some standards will be presented in the ITS Strategic Plan.

A context diagram is used to represent the Buffalo ITS System Architecture. It defines the boundaries between the overall architecture and two major terminators. These are "travelers" (user terminators) and "operators" (user terminators). The context diagram, shown in Figure 3-1, reflects the Buffalo ITS logical architecture.

FIGURE 3-1 CONTEXT DIAGRAM FOR BUFFALO ITS



The data flowing from the various travelers as well as operators represents queries and requests for ITS services. The flows to the travelers/operators represent responses to the requests and unsolicited notification of ITS status.

3.1 TRAVELERS

Travelers are key users of the Intelligent Transportation System for the Buffalo/Niagara Falls area. Travelers are individuals who use transportation services. Travelers require pre-trip planning information and en-route information. Their use of transportation services includes not only trip related information but requests for assistance in an emergency. Travelers may be vehicle drivers, passengers, transit users, or pedestrians. This section identifies the key types of travelers and their requirements related to the ITS Architecture Design.

3.1.1 Travelers In Private Vehicles

Travelers of this category are the majority of users of Intelligent Transportation Systems. Accuracy, timeliness and relevance of real-time traffic and traveler information is critical to this segment of travelers. Any individual who operates a licensed vehicle on the roadway can be classified into this group. This would include operators of private, commercial and emergency vehicles where the data being sent or received is not particular to the type of vehicle.

Data can be sent out as broadcast or specific. For specific data transfers, vehicle and driver identification is needed which are unique. Data requests by travelers in private vehicles may contain driving and routing information as well as incident/accident information and other travel related information.

3.1.2 Travelers At Home

Travelers of this nature essentially require information from Intelligent Transportation Systems to manage pre-trip planning functions. These pre-trip planning functions may include autonomous or centralized route selection and route guidance as well as travel time information on roadways as well as transit, transit schedules and availability as well as weather information. Other types of information requested by travelers at home would include Yellow Page service information such as gas, food, lodging, vehicle repair, points of interest and recreational information. This information needs to be up to date in order to have an impact on the overall travel functions.

3.1.3 Travelers In Transit Vehicles

Some common requirements from this category would include route, schedule and cost. These travelers use public transit vehicles, specialized and private transit vehicles and need the ability to request and receive information on traffic and traveler information. This category of travelers in transit vehicles would also include drivers of transit vehicles. Drivers of transit vehicles may require demand responsive information regarding transit operations, autonomous route information, flexible fixed route information as well as fixed schedules, run times and passenger loading. Flexible fixed routes are now being considered by transit agencies in the U.S. to meet ADA requirements. The fixed route could be deviated from to capture those trips that are now provided for with prescription or dial-in type services for the disabled.

3.1.4 Travelers In Transit Stations

This category of travelers essentially requires schedules and travel times on a real-time basis. The data demands placed by such travelers on the Buffalo/Niagara Falls Intelligent Transportation System would include real-time information on multi-modal transit schedules as well as border crossing related information. They would also require information on costs and payment options for transit trips within individual cities as well as cross border trips.

3.1.5 Pedestrians

This category of travelers include those who remain pedestrians throughout their trip and those who switch to another mode. Pre-trip planning is important to both groups as it influences whether a trip is made and the mode it is made on. En-route pedestrians may need to know transit vehicle arrival times, transit schedules, etc.

3.2 OPERATORS

Operators are the second external entity that has been identified in the context diagram of the system architecture plan developed for the Buffalo/Niagara Falls region. Operators are key users of the ITS System and they require proper analysis with respect to their requirements and needs. The conceptual design is based on these uses of the ITS architecture. Operators will request and receive information that will be used in a variety of ways to facilitate efficient transportation throughout the region. Operators range from traffic and road information system providers to transit information system providers as well as, independent service providers who will supply enhanced features and functions to the traveling public. Operators also have command functions to perform. Operators control special event traffic plans, road closures, etc.

The communication architecture that integrates these functional capabilities is key to enhancing/expanding the operator's capabilities. Therefore, it is important to identify the specific communication architecture related to operators of the ITS system for this region.

3.2.1 Traffic Operations Center Operators

The Traffic Operations Center (TOC) operators are key personnel who manage urban and freeway traffic control systems related traffic management centers. They require and obtain real-time traffic data from sensors on the roadway through the traffic control systems functions. They may also obtain live/digitized video from the field to confirm and manage traffic conditions. Other information TOC operators use are:

- incident and accident information;

- route guidance information;
- device status information;
- incident management response plan generation information;
- congestion information as well as specific event information.

The TOC operators handle a complete range of statistical information from raw data to pre-processed, processed and evaluated information for traffic management applications.

3.2.2 Incident/Emergency Management HAZMAT Response Operators

Incident management (IM), emergency management (EM) and hazardous material management response operators need real-time information in order to efficiently dispatch response teams to affected areas. The information needs to be accurate, timely and precise. They also provide real-time information to the police, hospitals and other emergency/rescue operations personnel. These operators need to be closely coupled to the real-time traffic control and communication systems deployed, in order to provide the most efficient, reliable responses to emergency situations.

3.2.3 Border Crossing & CVO Electronic Clearance Operators

A unique requirement for the Buffalo\Niagara Falls region are the Border Crossing/CVO operators who provide real-time information to the Immigration and Customs personnel on goods and people transported by commercial vehicles which cross the International border. The real-time information may consist of driver ID's, vehicle ID, trip ID's and cargo/load information. A typical example would be the North American Trade Automation Prototype (NATAP) that is being developed for cross border applications between U.S., Canada and Mexico.

There is also information that is driver specific as well as vehicle specific at any given instant. In order to facilitate efficient traffic flow across the border points, this information is obtained by the relevant authorities, prior to the vehicles arriving at the border. Preclearance for commercial vehicles using trip ID and cargo/load ID will have a tremendous impact on the overall throughput across the border.

3.2.4 Toll System Operators

New York State contains a variety of electronic toll facilities from Thruway facilities to bridge facilities. Toll system operators require real-time information on vehicle data such as type, load, number of axles, and weight. The toll is calculated based on this information and is electronically entered into the transponders via Dedicated Short Range Communication technology (DSRC). The toll system operators also need to interface with financial institutions to manage debits and credits of prepaid clients.

3.2.5 Multimodal Traveler Information System Operators

These operators are typically independent service providers who obtain raw traffic and traveler information data from the public sector Traffic Operations Centers and enhance the data and provide it as a service to the traveling public. This is typically a fee paying service which includes route guidance, Yellow Page information, and traffic congestion information, as and when required. The typical independent service provider would also provide broadcast information which would be deployed using a variety of dissemination methods such as TV, on-line bulletin boards, and the Internet.

3.2.6 Transit System Operators

Transit system operators in the Buffalo/Niagara Falls region provide information such as transit schedules, fares and timetables to the traveling public. They would also obtain real-time information on congestion and accident information and schedule their transit operations accordingly. The real-time operation requirements from the transit system operators on the ITS system are as demanding as the other types of operators who would request data from the ITS system.

3.2.7 Automated Highway System Operators

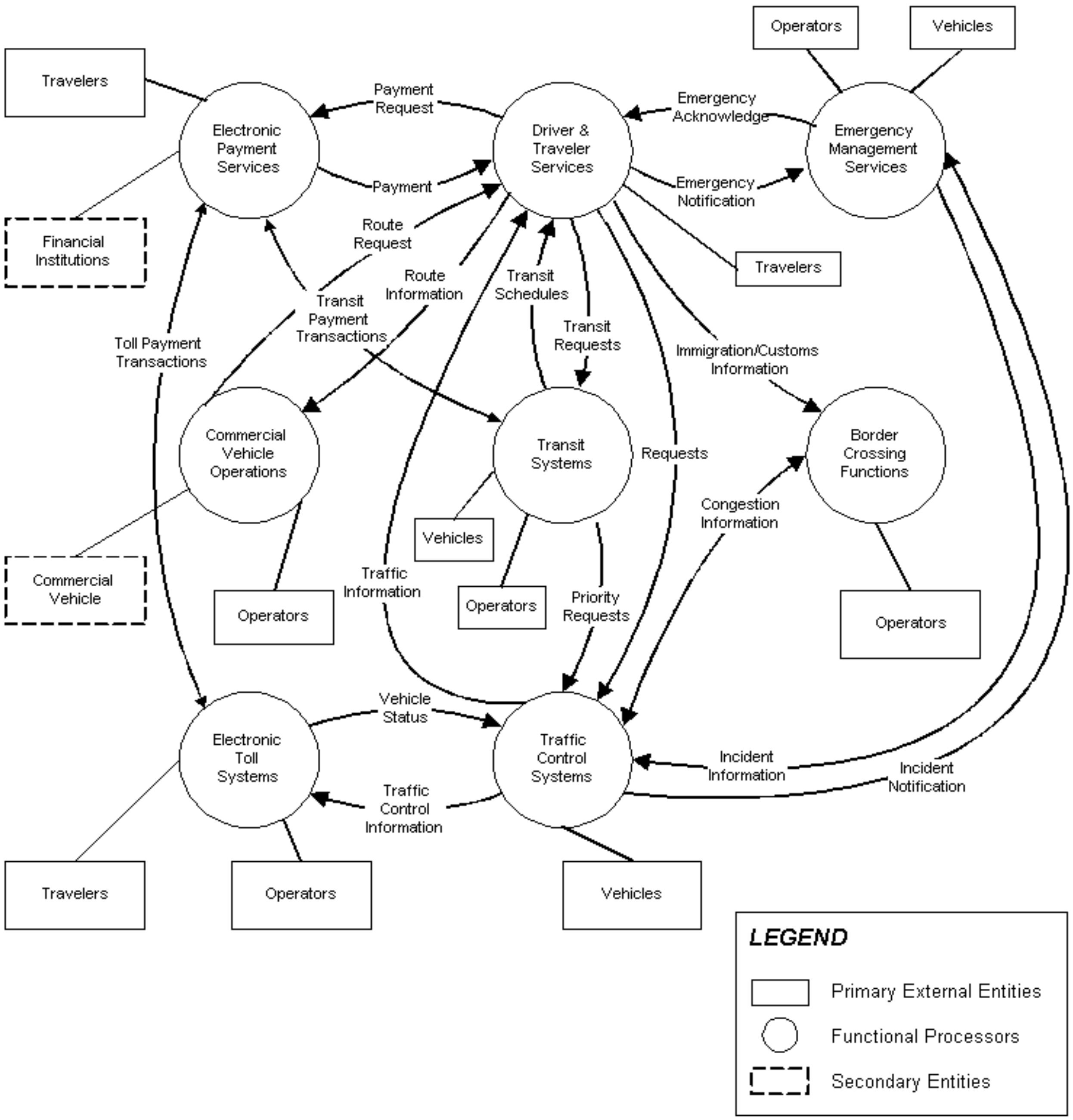
The Advanced Highway System (AHS) operators are a future concept where AHS would provide real-time information on platooning, auto pilot, crash avoidance and enhanced travel functions that would not be available through the public system. On-board changeable message sign information, as well as road conditions would be typical information that AHS would provide to the drivers and other traveling public.

3.3 LOGICAL ARCHITECTURE FOR ITS BUFFALO

Subsequent to a detailed review of the relevant user services and the associated functional requirements that have been identified in previous working papers for the Buffalo/Niagara Falls ITS Study a set of major functions were identified. These are transformed in this conceptual design to develop the logical architecture for the Buffalo/Niagara Falls ITS. The basic functional process entities identified are preliminary candidates for deployment and as shown in Section 2.1, maps fairly closely to the National Intelligent Transportation Infrastructure (ITI) components.

A conceptual design of the system architecture for the Buffalo/Niagara Falls regional ITS system and the overall data flow diagram which represents a logical architecture is presented in Figure 3-2. The Buffalo ITI components are inter-linked with logical data flows to provide the communications and control functions needed to enable seamless integration of the ITI functions within the region.

FIGURE 3-2 LOGICAL ARCHITECTURE OF THE BUFFALO/NIAGARA FALLS ITS



3.3.1 Traffic Control Systems

This functional process contains all the functionality needed for the management of traffic in arterial and freeway networks. Included are traffic surveillance, traffic control, incident management and demand management functions plus all associated capabilities. The traffic surveillance, traffic control and incident management facilities work closely together to detect incidents from traffic data and minimize their impact on the flow of traffic by developing appropriate responses. These responses include informing emergency services for appropriate action.

3.3.2 Transit Systems

This functional process performs the management functions related to fixed and flexible route transit services. Interface with traffic control systems provides support for priority at signalized roadway intersections and freeway ramps. Transit systems provide overall co-ordination between transit and traffic management services. Scheduled information is provided to the transit driver and transit traveler directly via these functions. They provide transit schedules and cost related information to traveler services. Interaction with electronic payment services enable advanced payment of transit fares.

3.3.3 Driver and Traveler Services

This functional process provides the multi-modal trip planning, route guidance and advisory functions for travelers of all types. The multi-modal trip planning function enables trips to include private car and regular transit mode, plus ridesharing and demand responsive transit and other modes. Links are also provided to multi-modal transportation service providers so that travelers may use modes such as heavy rail and airlines as part of their trips. Both centralized, dynamic and autonomous modes of on-line guidance is supported for drivers and travelers. The driver and traveler services function contains pre-trip traveler information, en-route driver information, route guidance, ride matching and reservations, travel services information, emergency notification and personal security.

3.3.4 Electronic Payment Services

This functional process is responsible for the collection and management of toll payments, parking and other road pricing components as well as Yellow Page services. This process interfaces with financial institutions for prepayment for services.

3.3.5 Commercial Vehicle Operations

This function encompasses all types of commercial vehicles from goods vehicles to hazardous material vehicles and is responsible for providing facilities for management of commercial vehicle operation. Typical commercial vehicle operations that would be pertinent to the Buffalo/Niagara Falls region include:

- management of commercial vehicle fleet operations;
- management of commercial vehicle driver operations;
- provision of commercial vehicle-to-roadside facilities;
- provision of commercial vehicle data collection;
- administration of commercial vehicles;
- provision of commercial vehicles onboard data;
- management of cargo.

3.3.6 Border Crossing Functions

The Border Crossing functions are unique to the Buffalo and Niagara Falls region. The U.S. Canadian Border is a major transportation facility which includes bridges and other routes. The Border Crossing functions provide commercial vehicle clearance screening facilities and management of commercial vehicles. These processes enable roadside facilities to pull in approaching vehicles whose credentials have not been precleared. The major components of this process would include preclearance of commercial vehicles based on identity, size, load, cargo and other related information which is critical to immigration and customs personnel. Typical subprocesses that would be included in this function would be:

- to administer commercial vehicle credentials databases;
- to validate immigration and customs for cargo, personnel, and vehicles;
- process screening transactions of cargo.

3.3.7 Emergency Management Services

This functional process provides services related to emergencies that occur on the roadway. The function is responsible for the management of services responding to incidents and ensuring communications with the law enforcement agencies. Key components of this function are emergency service identification and provision of an operator interface for emergency data. This process will automatically call out the appropriate emergency services to an incident. It will also manage confirmation of response action provided by an emergency service operator. Emergency services will also co-ordinate responses from other emergency management systems and provide access to law enforcement agencies for action on violations.

3.3.8 Electronic Toll System

This process is responsible for electronic toll payment functions throughout the region. These include electronic payments for tolls for single transactions and advanced payments for frequent travelers. The processing of electronic toll payments requires obtaining vehicle type and vehicle identity and status (if the toll has not already been paid), it requests payment through the payment instrument. Communications with the financial institutions is a subfunction that may be activated concurrently to facilitate the requirement. Another capacity is to provide toll transaction data at frequent intervals to develop travel time between toll plazas, which may be input to traffic control centers.

3.4 DATA SOURCES

Traffic information gathering, processing and disseminating are basic functions of the ITS architecture. In defining the information flows, the data sources and the destinations are also defined, both to and from the ITS architecture. This section deals essentially with the data sources that the system architecture will embrace both internally and externally through the terminators as reflected in the context diagram in Section 3. Overall, all data sources can be grouped into two major categories. They are as follows:

3.4.1 Fixed Data Sources

The fixed data sources range from field traffic and traveler information gathered by instrumentation as well as information provided by other TOC's and related control and management centers.

Roadside Data Sources: The roadside data sources consist of detector loops embedded in the pavement, video imaging systems which provide logical loop information, overhead detectors using radar, microwave, infrared and acoustic techniques. Other technologies that can be deployed in the Buffalo/Niagara Falls region would also include satellite-based tracking methods to obtain traffic conditions within the region as well as roadside readers for electronic toll systems.

Typical data that is gathered from the roadway would include:

- volume, speed, occupancy and vehicle length at specific locations;
- incident/accident information using algorithm techniques;
- vehicle and license plate information;
- vehicle ID and other information using transponder technology;
- vehicle ID's used for toll applications;
- vehicle classification and weight.

Another major source of data from the field is device status and roadway condition status, which is critical to the operation of ITS systems within the region.

- External Fixed Data Sources: These data sources would include TOC to TOC communications as well as data from external sources such as radio stations, bridge operators and other facility operators which could provide traffic and traveler related information to and from the ITS system.

3.4.2 Mobile Data Sources

The mobile data sources would include probes, certain electronic toll and traffic management (ETTM) equipped vehicles or other automatic vehicle identification (AVI) transit vehicles, etc. The type of information that would flow from these mobile data sources would include:

- travel time information;
- passenger loading information;
- scheduling information;
- routing information;
- emergency notification information;
- police related information;
- hazardous material related information;
- commercial vehicle operations information.

Typical communications architecture required to provide this type of mobile data to the ITS system would include wireless communications of various types such as:

- two-way wide area wireless technology:

    - global system for mobile communications (GSM);
    - special mobile radio (SMR);
    - enhanced special mobile radio (ESMR);
    - personal communications systems (PCS);
    - ARDIS, RAM, Geotech 220 MHZ, two-way paging, or cellular digital packet data (CDPD);

- satellite communication technologies such as ORBCOMM, MSAT, VSAT, IRIDIUM, etc.;
- one-way broadcast communication technologies such as:

    - highway advisory radio (HAR);
    - FM subcarrier systems;
    - subcarrier traffic information channel (STIC);
    - Seiko’s high speed FM subcarrier (HSDS) and other such technologies;

- dedicated short range communication (DSRC technology) which is the primary means of communications used in transponder tag technology.

The various types of vehicles which would carry and require mobile data would include, as a minimum:

- emergency vehicles (police, fire, ambulance);
- commercial vehicles;

- transit vehicles (bus and LRV);
- private vehicles (in future applications).

3.5 PHYSICAL ARCHITECTURE

According to FHWA's "Architecture Reference Model" White Paper, June 1995, the architecture provides a framework through which stakeholders can efficiently implement ITS services which are interoperable. This framework is based on a collection of diagrams which represent different aspects of the architecture. In support of standards activities, there are four diagrams which are collectively referred to as the Reference Model. Two of these diagrams are used to present the reference model for the Buffalo/Niagara Falls ITS. These are the:

- Architecture Flow Diagram (AFD) - This captures the physical architecture subsystems and terminators, and the aggregated dataflows connecting them. The dataflows are directional and are labeled mnemonically to indicate the type of data that is contained in the dataflow. It is an abstract representation in that it does not provide any information about the underlying communications layer required to support the architecture.

- Architecture Interconnect Diagram (AID) - This is similar to the AFD diagram in that it shows the subsystems, terminators and their connectivity. It differs in that the flows are now labeled to indicate the type of interconnect "technology" that is suitable for that link.

For the Buffalo/Niagara Falls ITS plan the overall AFD and AID are as shown in Figures 3-3 and 3-4.

FIGURE 3-3 ARCHITECTURAL FLOW DIAGRAM (AFD)

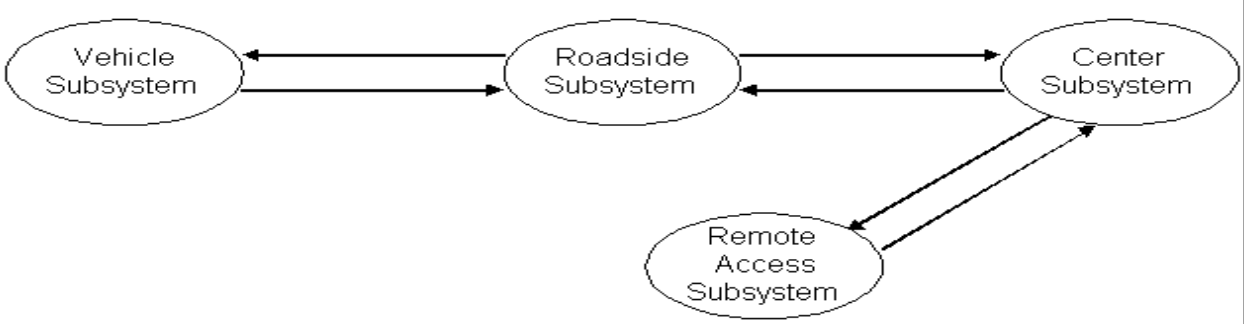
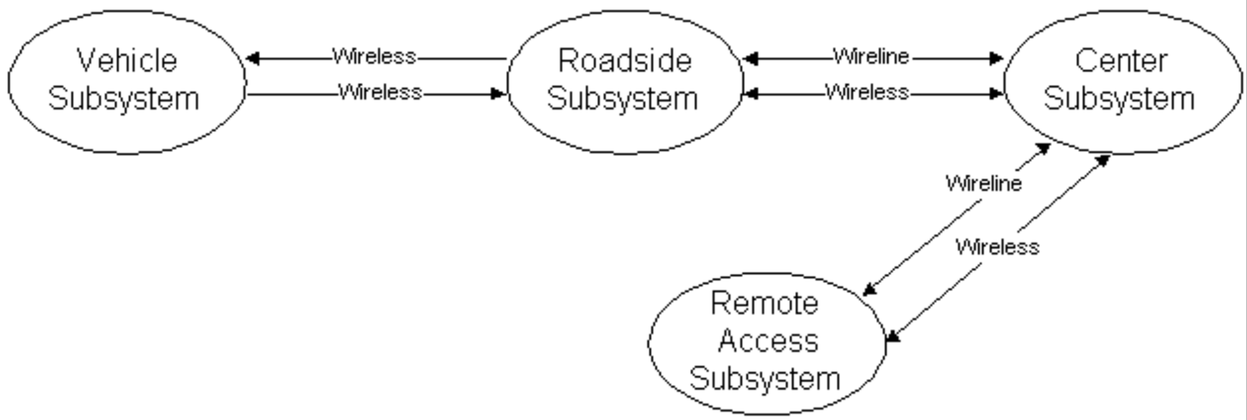


FIGURE 3-4 ARCHITECTURAL INTERCONNECT DIAGRAM



Mapping of the logical architecture functional components to the physical architecture leads to a top level decomposition of four groups of subsystems. These subsystem groups were first introduced in the" sausage diagram" in Figure 2-1. These are:

- center subsystems;
- vehicle subsystems;
- roadside subsystems;
- remote access subsystems.

These groups of subsystems are integrated with the communications subsystem. The communications subsystem enables all of these ITS hardware/software components to be integrated in a seamless fashion.

3.5.1 Center Subsystems

The Center Subsystems are a collection of major subsystems which would provide management, administration and support functions for the overall Buffalo/Niagara Falls ITS system. The subsystems enable co-ordination between modes and across jurisdictions within a region.

The center subsystems that are relevant to the Buffalo ITS plan would include, as a minimum, the following:

- commercial vehicle administration subsystem;
- emergency management subsystem;
- fleet & freight management subsystem;

- information service provider subsystem;
- traffic management subsystem;
- toll administration subsystem;
- transit management subsystem.

Depending on the architecture definition options identified in Section 4, some or all of these subsystems can reside physically and/or logically in a single transportation management center. Conversely, a single subsystem may be replicated in many different physical centers to facilitate existing operations.

- Commercial Vehicle Administration Subsystem: A Commercial Vehicle Administration Subsystem for the Buffalo ITS region will operate at one or more fixed locations within the area. This subsystem will perform administrative functions supporting credentials, tax, and safety regulations. It would be able to issue credentials, collect fees and taxes and support enforcement of credential requirements. This subsystem could also receive applications for, and issue special over sized/over weight permits in co-ordination with other authorities. The subsystem would exhibit communications capabilities with other subsystems such as fleet and freight management subsystems and vehicle check subsystems at the roadside to enable credential checking and safety information collection.

- Emergency Management Subsystem: It will operate in various emergency centers supporting public safety involving police and fire stations within the Buffalo/Niagara Falls area, as well as medical emergency response teams. This subsystem will interface with other emergency management subsystems to support coordinated emergency response involving multiple agencies. This subsystem will create, store and utilize emergency response plans to facilitate coordinated response. It will track and manage emergency vehicle fleets. An interface with the transit management subsystem will allow coordinated management of transit emergencies.

- Fleet and Freight Management Subsystem: The Fleet and Freight Management Subsystem for the Buffalo/Niagara Falls ITS region will manage fleets of commercial vehicles and may be a private trucking firm or a public agency with a fleet of vehicles. The subsystem will provide the capability for dispatchers to receive real-time routing information and access a database containing vehicle and cargo locations as well as carrier, vehicle, cargo and driver information. Specifically, in the Buffalo/Niagara Falls region, the International Border Crossing functions could be managed by a fleet and freight management subsystem. It will provide efficient purchase of the electronic credentials through automated interface with clearing houses and agencies. Specific Border Crossing functions will be managed by the subsystem which will operate from the border bridge areas such as the Peace Bridge. These management centers will communicate across the border with the Canadian authorities as well as other regional centers providing similar information.

- Information Service Provider Subsystem: This subsystem will provide capabilities to collect, process, store and disseminate traveler information to subscribers and the public at large. Traveler information that would be provided in the Buffalo/Niagara Falls region would include basic advisories, real-time traffic conditions and transit schedule information. It could also include Yellow Pages information, ride matching information, parking information and support mayday systems. The subsystem would also provide the capability to provide specific directions to travelers by receiving origin and destination from travelers, generating route plans and returning with calculated plans for the users, i.e., centralized route guidance environments.

- Traffic Management Subsystem: The Traffic Management Subsystem for the Buffalo/Niagara Falls ITS will operate within the Traffic Operations Centers and will communicate with the roadway subsystem to monitor and manage traffic flow. Incidents will be detected and verified and incident information will be provided to the emergency management center, to travelers and to third-party providers. As identified in the functional requirements in Working Paper #3, the subsystem will support HOV lane management and co-ordination. The subsystem will also monitor and manage maintenance work and disseminate maintenance work schedules and road closures. The Traffic Management Subsystem will communicate with other similar subsystems to co-ordinate traffic information and control strategies in all related jurisdictions.

- Toll Administration Subsystem: A Toll Administration Subsystem for the Buffalo/Niagara Falls ITS environment will provide general payment and administration capabilities which will support cross border functions. It will support electronic assessment of tolls and other transportation user fees. The subsystem will be capable of supporting traveler enrollment and collection of both prepayment and post-payment transportation fees in co-ordination with existing, and evolving financial infrastructure supporting electronic payment transactions.

- Transit Management Subsystem: A regional Transit Management Subsystem for the Buffalo/Niagara Falls area provides the capability to determine accurate ridership levels and implement corresponding fare structures. Interface with the Traffic Management Subsystem will provide the operators an environment in which to deploy management functions. The Transit Management Subsystem will also provide a capability for automated planning and scheduling of public transit operations. A subsystem of this nature will also provide the ability to furnish travelers with real-time traveler information, continuously updated schedules, schedule adherence information, transfer options and transit routes and fares.

3.5.2 Roadside Subsystems

The roadside subsystems provide direct interface to vehicles traveling on the roadway and include functions that must be located on or near the roadway to support direct surveillance control functions, execution and information provision. The roadside systems could include drivers and other travelers on the roadway network as well as short range interfaces to vehicle subsystems.

Typical roadside subsystems that are relevant to the ITS system for the Buffalo/Niagara Falls region.

- Commercial Vehicle Check Subsystem: This type of subsystem will support automated vehicle identification at mainline speeds for credential checking, roadside safety inspections and weigh-in-motion using two-way data exchange. Dedicated short range communications (DSRC) technology will be used to communicate to the vehicles. The capabilities include providing schedules to the commercial vehicles, providing toll information, providing safety information which would allow authorities access to examine historical safety data and automatically decide whether to allow the vehicle to pass or to direct them for examination. These subsystems could also provide supplementary inspection services to current capabilities by supporting expedited brake inspections, the user of operator handheld devices, on-board safety database access, and enrollment of vehicles and carriers in the preclearance program, specifically in the border crossing environment.

- Roadway Subsystem: A roadway subsystem for the Buffalo/Niagara Falls region ITS program would include equipment distributed on and along the roadway which monitors and controls traffic. CCTV cameras, variable message signs, cellular callboxes, highway advisory radio and video image processing systems for incident detection and verification, vehicle detector signals and freeway ramp metering systems are the typical field equipment associated with this environment. HOV lane management as well as potential demand lane management functions are also features of these subsystems.

- Toll Collection Subsystem: The Toll Collection Subsystem is very relevant to the Buffalo/Niagara Falls region, due to the prevalent toll roads as well as bridges that populate the New York State. These systems would provide the capability to travel toll roads without stopping vehicles by using onboard devices. These subsystems exhibit the capability to implement various variable road pricing policies.

3.5.3 Vehicle Subsystems

Vehicle subsystems as identified in the National Architecture Program include all vehicle-based general driver information, vehicle navigation and advanced safety systems functions. The general vehicle category contains fleet vehicle subsystems as defined below.

The subsystem provides information to the driver regarding current travel conditions, availability of services along the route and at the destination. It includes processing, detection, storage and communication functions necessary to support efficient accurate information management. Autonomous and centralized route guidance functions are typical capabilities that are identified in vehicle subsystems. Also included as part of the subsystem is the whole area of automated control and highway systems which include auto pilot and crash avoidance systems. These are not currently envisioned for the Buffalo/Niagara Falls region ITS program plan in the near to medium term. The relevant components of this subsystem are:

- Commercial Vehicle Subsystems: These provide sensory, processing, storage and communication functions necessary to facilitate safe and efficient freight movement. These subsystems also provide emergency response teams with timely and accurate cargo contents and other information after a vehicle incident via two-way communication capability. These subsystems also provide the capability to collect and process vehicle, cargo and driver safety data.

- Emergency Vehicle Subsystems: These systems provide similar information as commercial vehicles subsystem but, also provide specific information related to emergencies. It will provide two-way communication to support coordinated response to emergencies in accordance with an associated emergency management subsystem. Typical emergency vehicles will be equipped with automated vehicle locating capabilities such as GPS linked to vehicle tracking and fleet management functions in the emergency management subsystem.

- Transit Vehicle Subsystems: These subsystems reside in transit vehicles and provide the processing, storage and detection as well as communication functions necessary to support safe and efficient movement of passengers using the transit system. The transit vehicle subsystems will also provide travelers with real-time traveler information, continuously updated schedules, transfer options, routes and fares.

3.5.4 Remote Access Subsystems

These subsystems include equipment that is used by the traveler to gather information and access services prior to a trip and while en-route. These subsystems interface to the information provided by traveler information. Range of service options and levels of equipment complexity are supported by the subsystems. Major components of the subsystem are:

- Personal Information Access Subsystems: These subsystems access traveler information at home, at work and other locations frequented by a traveler using personal, fixed and portable communication devices. Radios, televisions, personal computers, personal digital assistants, telephones and any other communications capable consumer products can be used to supply information to the traveler. These systems are all included in the Personal Information Access Subsystems, and will be prevalent in the Buffalo/Niagara Falls region in the future. Therefore, it is important to develop a plan that will facilitate such subsystems.

- Remote Traveler Support Subsystems: Provide support information based on requests supplied by the traveler. In addition to the traveler information provision, these subsystem will support safety monitoring using CCTV cameras or other surveillance equipment and provide emergency notification within public areas as well as mayday support.

3.5.5 Communications Subsystem

The communications subsystem is integral to the overall capabilities of the ITS architecture since it provides the interface capability between all functional subsystems as well as physical centers.

ITS implementations in the Buffalo/Niagara Falls region require complex communication services. Specifically, some of the ITS User Services will be best served by leveraging off existing commercial telecommunication infrastructures. Others will require specialized, dedicated communication subsystems. Alternate architectures identified in Chapter 4 reflect some generic concepts for different communication architectures which have costs and performance implications.

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4.0 ALTERNATIVE ARCHITECTURES

This chapter presents several options for the conceptual system architecture for the Buffalo/Niagara Falls ITS System. The primary rationale for developing alternate architectures is to evaluate the pros and cons of the different options with respect to a set of variables which have a major impact on the overall implementation of ITS/ITI components in a metropolitan environment such as the Buffalo/Niagara Falls region.

The intent of this exercise in evaluating alternative architectures at a conceptual level is to identify the extreme architecture options which should be discarded due to their extensive cost, or complexity in deployment and/or institutional barriers. Using a series of systematic evaluation procedures, a viable candidate can be arrived at for the ITS architecture for the Buffalo/Niagara Falls region which would facilitate the inception of an implementation design in the future.

Three alternatives have been presented for evaluation and analysis to obtain the best possible candidate architecture for the conceptual design of the ITS system and its integral components for the Buffalo/Niagara Falls region.

The architecture alternatives presented here are physical representations with specific interfaces and interconnections which reflect possible deployment configurations. The logical groupings reflect physical/functional groupings. The dashed lines reflect the physical groupings.

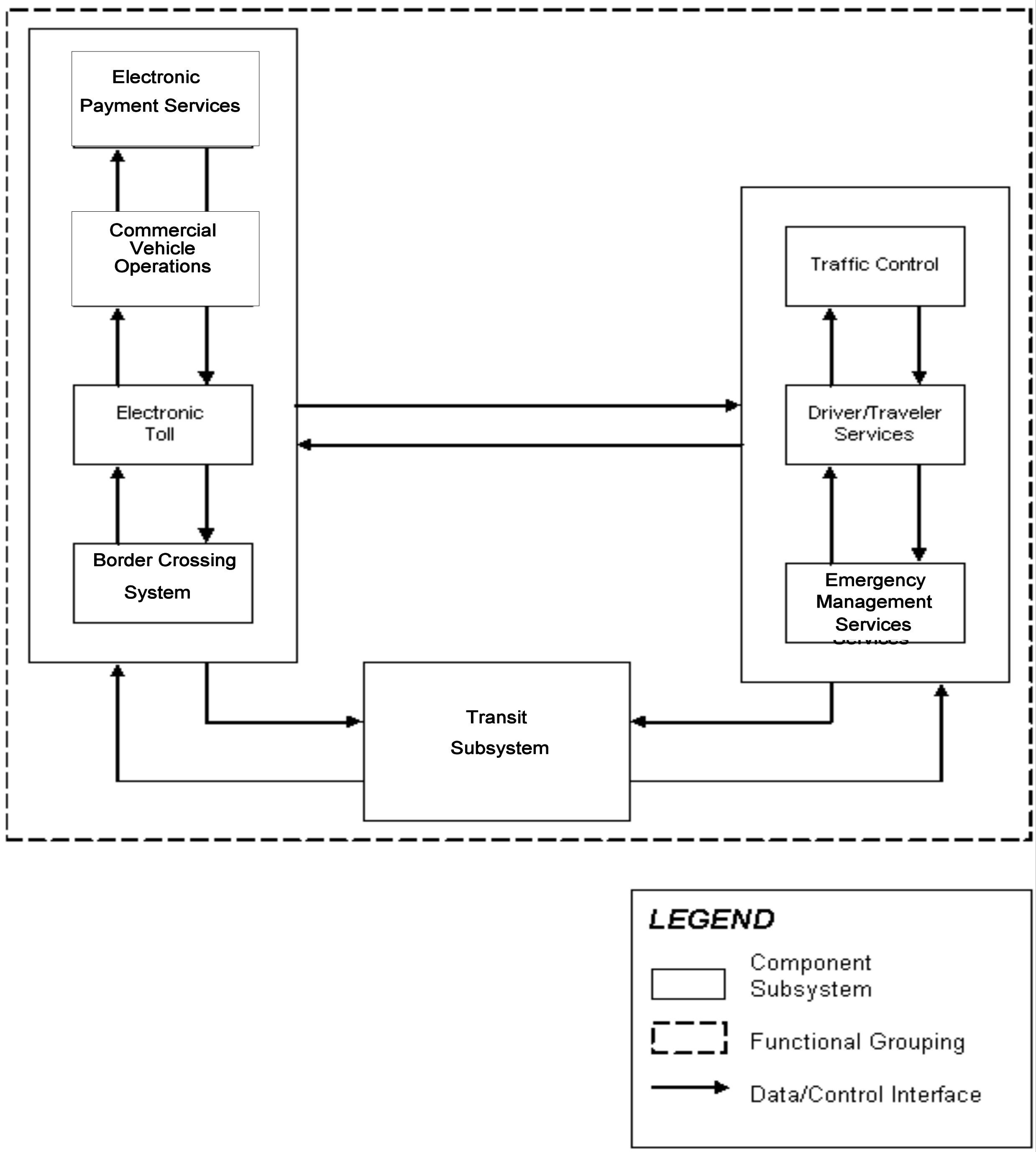
4.1 CENTRALIZED ARCHITECTURE

The architecture shown in Figure 4-1 is based on a centralized concept where the functional/operational components are grouped together to provide overall ITI implementation with centralized operations and information dissemination capabilities. Although the figure reflects all subsystems in one central location, the centralized architecture is also applied to systems that are in a very limited number of different physical locations.

This approach has advantages in central management of various functions such as emergency management as well as traffic control, traffic management and toll collection which leads to efficient operations that minimize overhead with respect to duplication of staff and effort.

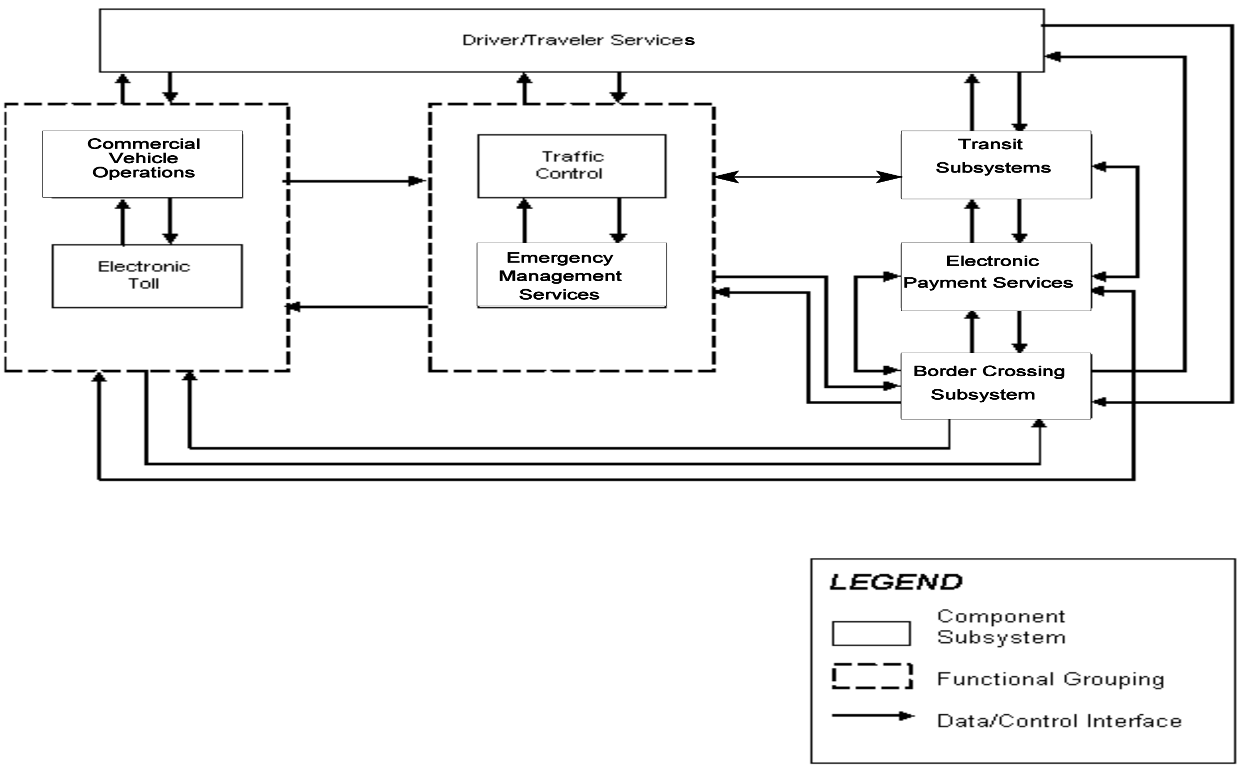
One of the disadvantages of this approach is that there is very little redundancy. Additionally, the systems are tightly coupled which leads to less flexibility in both expansion and adaptation to new technology. The centralized architecture also exhibits generic constraints with respect to interface standards and portability.

FIGURE 4-1 CENTRALIZED OPTION



4.2 PARTIALLY DECENTRALIZED OPTION

FIGURE 4-2 PARTIALLY DECENTRALIZED OPTION



This architecture concept is based on a semi-distributed environment with related logical functions being grouped physically together to provide efficiencies providing the flexibility and enhanceability for the future. The grouping of electronic toll and commercial vehicle operations is one functional entity. Traffic control and emergency services is another functional entity. Transit systems, electronic payments systems and border crossing systems are separately interfaced with the driver/traveler services. This reflects an efficient architecture.

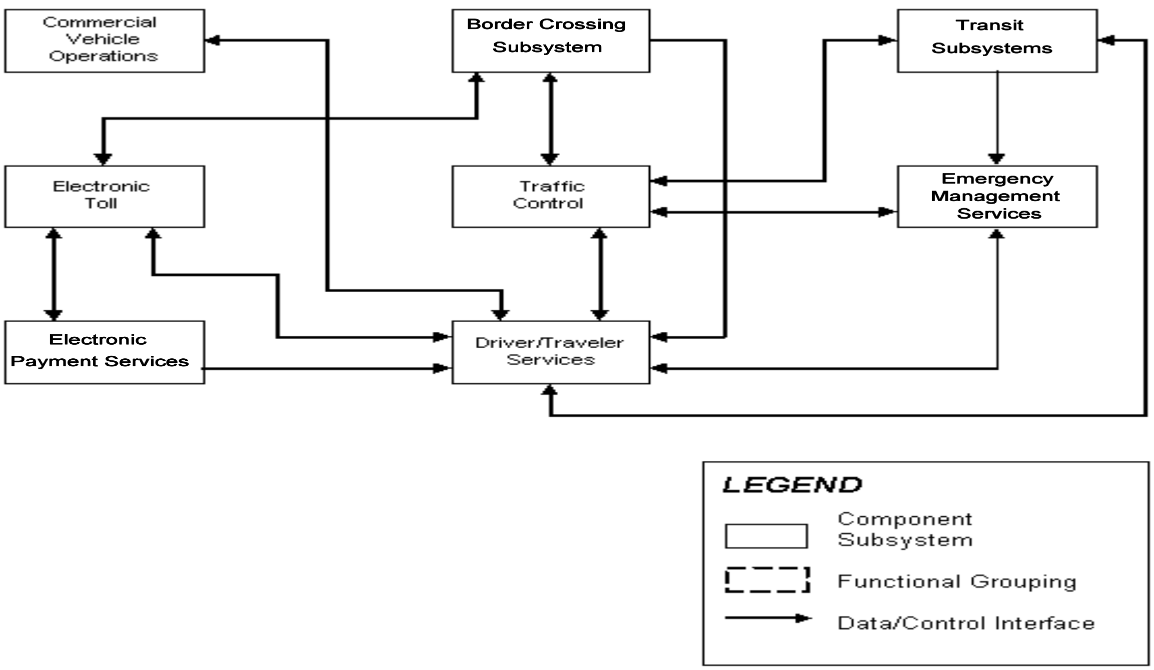
All data flows to and from driver/traveler services. The advantage of this architecture, as reflected in Figure 4-2, is the fact that simultaneous information can be received and provided to the driver/traveler services which is the main external interface to the ITS system. This is specifically true with respect to the traveling public who would be the main users of the ITS system.

The key feature of the partially decentralized architecture is that all ITS elements in the region will be controlled by the NITTEC ROC during the core hours of 6:00am to 7:00pm, while not precluding dual control by the physical subsystem operators such as the New York State Thruway Authority and the Niagara Frontier Transportation Authority. Each operating agency would be linked to the Regional Operations Center. In this way dual control is allowed during the hours of 6:00am to 7:00pm and could extend beyond these hours in the case of a total system emergency.

The apparent disadvantage of this architecture is the reliance on driver/traveler services to provide all of the interfaces to the traveling public which, in some ways, lends itself to independent service providers (ISP) (i.e., the private sector) benefiting greatly from such regional systems. ISP could be controlled with standards and accountability with respect to enhanced information that would be provided to the general traveling public.

4.3 DISTRIBUTED OPTION

FIGURE 4-3 DISTRIBUTED OPTION



As seen in Figure 4-3, this architecture represents a fully distributed autonomous architecture with data and control interfaces between all of the major functional components. While this architecture has total flexibility, it also lacks collective, efficient operations, due to its fully distributed nature.

The main advantage of this architecture is that it represents total flexibility and adaptability to future technologies and future systems with standard data and control interfaces between the functional components.

The major disadvantage of this architecture is due to the autonomous nature which requires well defined communications and data interfaces. Developing and adapting these standards has proven to be very challenging. Also, this architecture does not set any framework in place for future expansion.

4.4 COMPARISON CRITERIA

The fundamental evaluation criteria that would be required to assess the viability of the most appropriate conceptual system architecture for the Buffalo/Niagara Falls region ITS system require technology evaluation as well as user needs. As a minimum, the following evaluation criteria were used:

- Ability To Meet User Needs: The technology as well as the functional components should meet the end user needs for ITS functions. For example, does it provide real-time incident/condition summaries and provide traveler advisories including variable speed limits and road conditions. Does the architecture exhibit the ability to meet the user needs, such as the provision for real-time route specific traffic and transit information in a timely, accurate, reliable manner?

- Accessibility: How readily available is the technology for the end user so that the ITS architecture/system is usable and efficient? The information and capabilities should be readily accessible to the external entities such as travelers and independent service providers/operators. Since technology changes over time, system interfaces to some currently less prevalent devices may not be required initially. Over time, these devices may demand acceptance.

- Interactivity: What capabilities does the ITS functions/technologies have which would support users requesting specific information? For example, an onboard system may be capable of interacting with users to support route specific information, while a commercial radio broadcast is not. These are all parts of driver/traveler information system.

- Interoperability: These are very critical requirements which would allow the similar systems to operate together with common data sets and information content. Overall ITI components should be developed with standards that support extensive interoperability.

- Information Sharing Among Agencies: The system should be capable of sharing common information among different agencies within the ITS architecture. Information sharing is an absolute requirement. The limitations on this capability should only be reflected in terms of future systems. The current technology should allow for all existing agencies/control centers to share information as seamlessly as possible.

- Addressing Of Local Needs and Regional Needs: This criterion is a hot issue among multiple agencies and inter-regional groups. The ITS architecture should exhibit flexibility to provide these capabilities.

- Minimization of Communications Costs: This criterion is very pertinent to all new and existing ITS infrastructure development. Communication costs are directly related to the advanced techniques being used currently.

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5.0 COMPREHENSIVE EVALUATION AND RECOMMENDATION

In evaluating the three architecture options, as identified in Chapter 4, the criteria described previously were used to obtain relative strengths and weaknesses of each architecture. Table 5-1 summarizes the evaluation results which are discussed below.

Table 5-1 Architecture Evaluation

	Relative Ranking		
	Centralized	Partially Decentralized	Distributed
Criteria	***Option 1***	***Option 2***	***Option 3***
Ability to meet user needs	Medium	High	High
Accessibility	Low	High	Medium
Interactivity	Medium	Medium	Medium
Interoperability	Low	Medium	Medium
Information Sharing	Low	High	High
Local Needs	Medium	Medium	Medium
Minimizing Communication Cost	Medium	Medium	Low

In reviewing the *ability to meet user needs* for each of the architecture options defined, the partially decentralized and the distributed options exhibit a high capability as opposed to the centralized option. This is based on flexibility and extensibility demonstrated by generic decentralized and fully distributed architectures which allow for new and expanded functions, subsystems and components to be added with minimal overhead to the existing system.

Accessibility was another criterion that was used to evaluate the different architecture options. This qualitative analysis reflects a highly accessible feature for the partially decentralized option. The distributed option reflected a medium accessibility level with the centralized options reflecting the lowest accessibility level due to strict limitations on technology upgrades.

The next criterion that was evaluated was *interactivity* and all architecture option exhibited approximately similar levels of capability (Medium) with respect to interactivity.

The *interoperability* criterion reflected a medium to high capability level for the partially decentralized and distributed options, while reflecting a low capability level for the centralized option.

The remaining criteria such as *information sharing*, *local needs* and *minimizing communication costs* all reflected a high to medium level of response from the partially decentralized architecture option with distributed architecture reflecting a similar level.

Table 5-2 represents an additional qualitative evaluation of the three architectures.

Table 5-2 Alternative Architectures Advantages/Disadvantages

Alternative	Pros	Cons
Centralized	□ Facilitates regional coordination □ Single communications channel to/from central facility □ Efficiency and cost of staffing □ Single interface to support □ Consistent user interfaces	□ Autonomy sacrificed □ Local TOCs become obsolete □ Susceptible to failure □ Consensus building most difficult □ Difficult to adapt to changing technologies
Partially Decentralized	□ Limited additional facilities to operate or maintain □ Almost full autonomy maintained □ Partially fault tolerant	□ Regional coordination more difficult □ Some duplicate data processing and display equipment □ Added complexity □ Additional manpower supporting distributed operations
Distributed	□ Full autonomy maintained □ Inherently fault tolerant □ Flexibility to expand and add areas/jurisdictions/user services and new technologies	□ Extensive duplicate data processing and display equipment □ Very complex to integrate □ Significant additional manpower supporting distributed operations □ Does not easily support regional operation

Overall aggregation of the evaluation results leads to the partially decentralized architecture option as being the most promising architecture that would satisfy all of the functional requirements identified in the Buffalo ITS program.

6.0 IMPLEMENTATION APPROACH

The architecture defined in this document for the Buffalo/Niagara Falls Region should be implemented to achieve the benefits identified in three principal ways:

- development of and agreement on standards for transportation products based on the functional requirements and the corresponding architecture (including adaption of NTCIP);
- adaptation of the National Architecture to the regional requirements for an integrated regional ITS solution;
- facilitation of an incremental deployment of systems compatible with the architecture.

The implementation approach for the Buffalo/Niagara Falls ITS Region would follow a series of steps that encourage efficient deployment of architecture compatible systems. These are:

- identification of basic building blocks that apply to most ITS deployments;
- focus on near term problems and early deployments best suited to addressing these problems through the Buffalo/Niagara Falls ITI components;
- collectively encourage private sector participation in the ITS deployment;
- facilitate rapid system integration of ITS services in relation to technology advancement.

Each of these steps will be used to inform the public sector of progress within the framework of the U.S. DOT recommendations.

6.1 BUFFALO/NIAGARA FALLS ITS BUILDING BLOCKS

The basic building blocks would provide service options considered by ITS implementors and requires a set of market packages. The market packages are tailored to fit separately or in combination to solve transportation problems and meet the needs of the Buffalo/Niagara Falls Region. The approach would be structured around a few key packages that illustrate the range of incremental deployment options that may apply to different scenarios and timeframes within the Buffalo/Niagara Falls Region. These market packages address specific services that will be required by Buffalo/Niagara Falls Region traffic managers, transit operators, travelers and other ITS stakeholders.

6.2 SELECT EARLY WINNERS/EARLY DEPLOYMENT

The strategy would be to select early deployments that are not dependent on technology advances or institutional changes and that leave room for a competitive environment on which to advance transportation technologies. A finite set of early market packages will need to be selected to provide the following:

- development of public and private markets;
- low risk implementation characteristics; and
- identifiable user benefits.

The elements identified in the Buffalo/Niagara Falls Region ITI lead to a set of market packages. These early market packages are oriented towards public infrastructure support for major metropolitan areas such as Buffalo. Early deployment of such market packages will need to be initiated in the Buffalo Region.

6.3 ENCOURAGEMENT OF PRIVATE SECTOR PARTNERSHIP

The Buffalo/Niagara Falls ITI initiative represents a tangible commitment to deploy key public infrastructure that should promote further deployment of ITS services. The implementation strategy reflects a shift in funding from public agencies to private users. This shift can be accomplished through emphasis on individual user fees for services and other incentives that would enhance the potential for profitability and encourage capital investments by private industry.

6.4 SERVICE INTEGRATION AND INTEROPERABILITY

The approach here would be to strongly persuade all ITS operation developers/entities to comply to interoperability standards in order for the overall system to be flexible, extensible and expandable in the future. A proprietary system should be discouraged for any ITS implementations. Adoption of existing standards and development of new ITS standards should be encouraged to link existing nonproprietary systems. Adoption of NTCIP interface standards is recommended.

The Buffalo/Niagara Falls ITS architecture will provide a framework that would be adapted to support an interoperable regional transportation system design. This architecture should reflect major services, technology and interface choices which are most appropriate for the implementation region of Buffalo/Niagara Falls.

7.0 SUMMARY

This working paper provided a brief explanation of the National ITS Architecture and its impact on the Buffalo/Niagara Falls Architecture. A viable ITS architecture for the Buffalo/Niagara was presented. The chosen architecture is considered partially decentralized in that most day-to-day operations are distributed among the respective physical subsystem operators. All subsystem operators are interconnected with the communications system and central control could be performed in extreme situations.

An implementation approach was laid out which focuses the next steps on deploying ITS projects that create the building blocks of the regional ITS System. These first projects will focus on improving existing infrastructure, complying with standards and the architecture, and providing immediate benefits to the users.

The next working paper, Alternative Technologies, will examine various implementation components and recommend technologies.