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REVIEW OF ITS ARCHITECTURE WITHIN THE CANADIAN CONTEXT

Prepared for

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by

D. Sims, T. De Silva, and K. Bebenek
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May 1999

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16. Abstract

This document outlines Canadian institutional responsibilities, industrial capabilities, system deployment, and standards development related to intelligent transportation systems (ITS). It also assesses the U.S. National ITS Architecture from a Canadian perspective and provides a basis for Transport Canada to determine its role in the development and implementation of the most effective ITS architecture for Canada.

The report identifies key issues for consideration in the development of a Canadian ITS architecture, based on an analysis of the following factors:

- the development of the existing U.S. National ITS Architecture
- the Canadian environmental and industrial context
- current U.S. and Canadian standards
- current U.S. and Canadian initiatives
- Canadian ITS products and services

The report recommends that Canadian ITS architecture largely reflect U.S. programs, to ensure cross-border compatibility. Consistency with international programs is also recommended, to maximize Canada’s competitiveness in the international marketplace. However, Canada’s special characteristics, such as population dispersion, language requirements, and environmental extremes, should be taken into account. Variances in U.S. and Canadian communications infrastructures and organizational frameworks are also important considerations. The report includes an action plan for development of a Canadian ITS architecture.

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16. Résumé

Ce document examine l'état de la situation des systèmes de transports intelligents (STI) au Canada, en ce qui a trait aux responsabilités institutionnelles, aux capacités industrielles, à la mise en œuvre des systèmes et à l'élaboration de normes. Il évalue également, d'un point de vue canadien, l'architecture nationale STI mise au point aux États-Unis, et définit le cadre d'intervention de Transports Canada dans la mise au point et l'instauration de l'architecture STI la plus efficace qui soit pour le Canada.

Après une analyse de la question, les chercheurs cernent les grands enjeux à prendre en compte dans la mise au point d'une architecture STI pour le Canada. Voici les thèmes sur lesquels porte leur analyse :

- cadre de développement de l'architecture nationale STI adoptée aux États-Unis;
- contexte environnemental et industriel canadien;
- normes canadiennes et américaines en vigueur;
- initiatives en cours au Canada et aux États-Unis;
- produits et services STI canadiens.

Le rapport recommande de fonder largement l'architecture STI canadienne sur les programmes américains, de façon à garantir l'interopérabilité des systèmes. Il recommande en outre une harmonisation des programmes à l'échelle internationale, afin de maximiser la compétitivité du Canada sur le marché mondial. Il souligne toutefois la nécessité de tenir compte des caractéristiques qui font du Canada un cas singulier, soit la dispersion de sa population, les exigences linguistiques et les conditions climatiques extrêmes. La dissemblance entre les infrastructures de communications et les cadres organisationnels du Canada et des États-Unis sont également des facteurs à considérer. Le rapport comporte un plan d'action pour la mise au point d'une architecture STI canadienne.

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EXECUTIVE SUMMARY

Intelligent Transportation Systems (ITS) use advanced technologies to optimize the safety and efficiency of the surface transportation network. To ensure compatibility among ITS technologies, a system architecture is required to establish a framework for integration and co-ordinated deployment by public and private sector organizations. The system architecture defines the functionality and information flows among the various ITS components to achieve total system goals.

The Federal Highway Administration (FHWA) in the United States has developed the U.S. National ITS Architecture, which includes:

- the logical architecture, which defines the functional processes and information flow needed to support the ITS user services;
- the physical architecture, which defines the various subsystems for the major entities, including the traveller, control centre, roadside, and vehicle;
- a series of implementation market packages;
- a series of standards currently under development.

At present, there is no Canadian equivalent to the U.S. National ITS Architecture. A variety of operating Canadian ITS applications exist under all user service bundles, with a particular emphasis on travel and transportation management. The Canadian ITS industry is very active in the worldwide arena, with particular strengths in key technology areas, including geographic information systems, displays, sensors, system integration and software, and navigation technologies. Canadians actively participate in a wide range of international ITS standards efforts. It is important for Canada to establish a Canadian national architecture to promote ITS deployment and a sustained ITS industry in Canada.

The Canadian architecture should largely reflect the U.S. program, taken within the context of the Canadian environment to ensure that the compatibility and interconnection of ITS initiatives in Canada are guided by our national interest. The Canadian architecture should reflect the goals and objectives of the federal government in establishing a seamless transportation network across Canada and along north-south corridors and border crossings. Canada's national ITS architecture should be largely consistent with U.S. and international programs to maximize Canada's competitiveness in the international marketplace.

A number of distinguishing features in the Canadian transportation environment will affect the adoption of the U.S. National ITS Architecture in Canada:

- **geographic considerations**, including population dispersion, bilingual language requirements, environmental extremes, and varying legislation;
- **compliance of existing ITS infrastructure**, such as freeway management programs in the Toronto and Montreal urban areas;
- **communications infrastructure considerations**, such as variances between radio frequency spectrum allocation in the U.S. and Canada;
- **institutional/organizational framework considerations**, to address variances in the roles and relationships among government and transportation agencies in the U.S. and Canada;
- **funding considerations**, acknowledging the U.S. federal government's significant role and contributions in the development and deployment of ITS in that country.

The action plan for the development of a Canadian ITS architecture should include:

- development of a vision statement of ITS deployment in Canada;
- confirmation of applicable national ITS architecture definitions;
- investigation of issues developed;
- development of alternative solutions to issues;
- analysis of solutions;
- recommendation of regional variations;
- development of regional ITS architectures for Canada;
- definition of roles and responsibilities;
- development of implementation and funding plans.

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GLOSSARY

AASHTO	American Association of State Highway and Transportation Officials
AHS	Automated Highway Systems
APTS	Advanced Public Transportation Systems
ASC	Activated Signal Control
ASTM	American Society for Testing and Materials
ATIS	Advanced Traveller Information System
ATMS	Advanced Traffic Management Systems
AVL	Automatic Vehicle Locationing
BSP	Base Standards and Protocols
C-2-C	Centre-to-Centre Profiles
CAC	Canadian Advisory Committee (for ITS Standards)
CCC	Canadian Career Consortium
CCTV	Closed Circuit TV
CDMA	Code Division Multiple Access
CEMA	Consumer Electronics Manufacturers Association
CEN	European Committee for Normalisation
CIDA	Canadian International Development Agency
CMS	Changeable Message Signs
COMPASS	large, integrated FTMS
CRAD	Chief Research and Development (DND)
CRC	Communications Research Centre
CRC	Cyclic Redundancy Code
CRTC	Canadian Radio-television and Telecommunications Commission
CSCE	Canadian Society for Civil Engineering
CTA	Canada Transportation Act
CUTA	Canadian Urban Transit Association
CVISN	Commercial Vehicle Information Systems and Networks
CVO	Commercial Vehicle Operations
DAB	Digital Audio Broadcasting
DARC	Data Radio Channel
DCM	Data Collection and Monitoring
DDE	Data Dictionary Entry
DFAIT	Department of Foreign Affairs and International Trade
DOT	Department of Transportation (United States)
DSRC	Dedicated Short-Range Communications
EDAC	Error Detection and Correction
ETC	Electronic Toll Collection
ETR	Express Toll Route
FCC	Federal Communications Commission
FHWA	Federal Highway Administration (United States)
FTA	Federal Transit Administration (United States)
FTMS	Freeway Traffic Management System
GIS	Geographical Information System
GPS	Global Positioning System

HELP	Heavy Vehicle Electronic Licence Plate
HOV	High Occupancy Vehicle
IBOC	In-Band On-Channel
IEEE	Institute of Electrical and Electronics Engineers (United States)
IP	Internet Protocol
IRAP	Industrial Research Assistance Program
ISO	International Organization for Standardization
ISTEA	Intermodal Surface Transportation Efficiency Act
ITE	Institute of Transportation Engineers (United States)
ITIIS	International Travel Information Interchange Standards
ITS	Intelligent Transportation Systems
IVHS	Intelligent Vehicle-Highway Systems
JSO	Japanese Standard Organisation
LRT	Light Rail Transit
NAFTA	North American Free Trade Agreement
NEMA	National Electrical Manufacturers Association
NHSTA	National Highway Traffic Safety Administration (United States)
NPP	National (ITS) Program Plan
NRC	National Research Council Canada
NSERC	Natural Sciences and Engineering Research Council
NTCIP	National Transportation Communications for ITS Protocol
OSI	Open Systems Interconnection
RDS	Radio Data Service
SAE	Society of Automotive Engineers
SCC	Standards Co-ordinating Committee
SCOOT	Adaptive traffic signal control system
SDO	Standards Development Organization
SNA	(IBM) Systems Network Architecture
SONET	Synchronous Optical Network
TAC	Transportation Association of Canada
TC	Transport Canada
TCF	Technical Co-ordination Forum
TDC	Transportation Development Centre (Transport Canada)
TDD	Time-Division Duplex
TDMA	Time Division Multiple Access
TEA	Transportation Equity Act
TICS	Technical Committee on Transportation Information and Control Systems
TMC	Traffic Message Channel
TOC	Traffic Operations Centre
TPC	Technology Partnerships Canada
VMS	Variable Message Signs

1 OVERVIEW OF U.S. NATIONAL ITS ARCHITECTURE

1.1 INTRODUCTION

Intelligent transportation systems (ITS) are the application of computer, electronic, communication, and safety systems by transportation providers, such as governments, transit agencies, and commercial vehicle operators to better manage, and improve delivery of, transport services to the public. To ensure interoperability and compatibility of technologies and components within the ITS umbrella, the Federal Highway Administration (FHWA) in the United States commissioned and developed a framework in the form of a national ITS architecture.

The U.S. National ITS Architecture was reviewed to establish a preliminary assessment of its suitability and the issues surrounding its adoption in the Canadian context. The project team assembled a substantial collection of reference material for this review, building on IBI's library, the FHWA, other public documentation, and Transport Canada studies and reports. The list of reference material is provided in Appendix A.

1.2 DEFINING ITS SYSTEM ARCHITECTURE

To gain an understanding of the national ITS systems architecture and its role in the deployment of ITS programs, it is essential to clearly define the meaning behind the term "system architecture". In the context of the U.S National ITS Architecture, **the system architecture provides a unified framework for integration to guide the co-ordinated deployment of ITS programs by public agencies and private organizations**. Its main goal is to offer a starting point from which stakeholders can work together to achieve compatibility among intelligent technologies to ensure unified ITS deployment for a region.

The architecture describes interaction among physical components of the transportation system, such as the travellers, vehicles, roadside devices, and control centres. It also describes the information and communication system requirements, how data should be shared and used, and the standards required to facilitate information sharing for ITS deployment. Overall, the system architecture defines the functions of ITS components and the information that flows among ITS elements to achieve total system goals.

The architecture is not a particular ITS program design, nor does it specify how the ITS system is to be deployed. It offers a set of options that should be taken into account when considering any ITS deployment. It acts as a deployment guide to allow individual agencies and organizations to use their own discretion in determining the most appropriate technologies and institutional arrangements for their particular deployment. It is a tool that can help stakeholders identify potential ITS applications, deployment opportunities, integration with other systems, institutional linkages and information exchange, and activities co-ordination that can improve efficiency and performance.

1.3 DEVELOPMENT OF THE U.S. NATIONAL ITS ARCHITECTURE

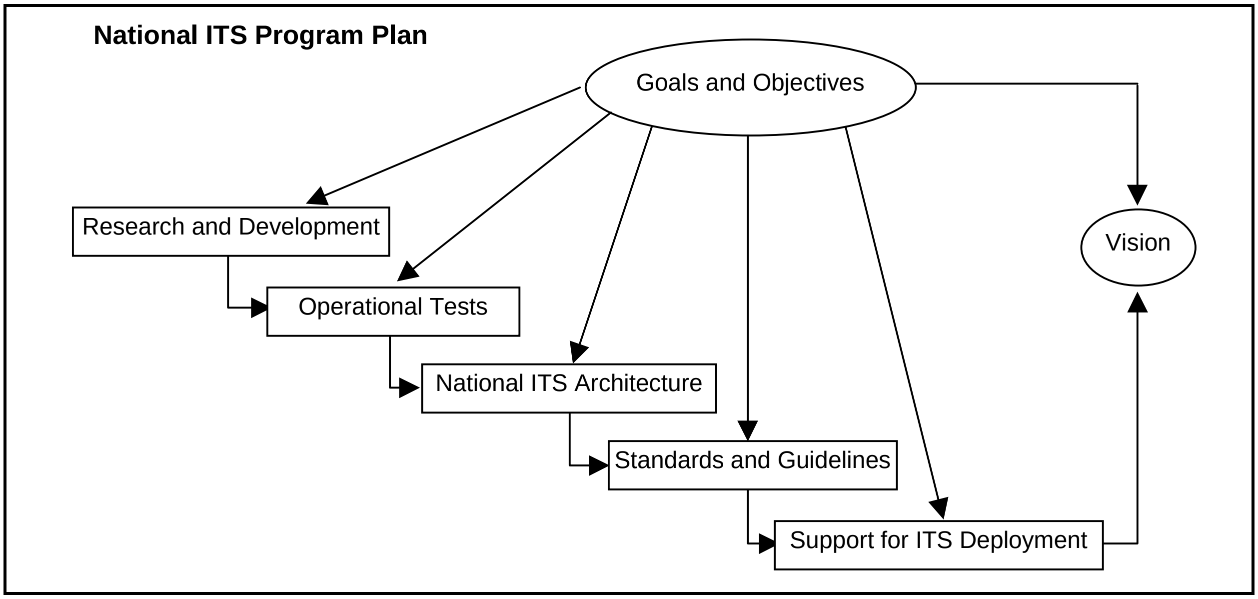
The U.S. National ITS Architecture was developed with the recognition that the development of a comprehensive system approach to design of integrated ITS at the national level will reduce the resource-intensive requirement expected from individual stand-alone systems. Its development was a part of initiatives called for by the National (ITS) Program Plan (NPP), which identified and documented the comprehensive top-down guidelines for deployment of ITS within the United States. The NPP (reference 8, Appendix A) comprised five types of initiatives, including research and development, operational tests, definition of a national ITS architecture, initiatives for standards and guidelines, and support for ITS deployment.

The goals and objectives of the NPP are to enhance surface transportation through:

- improved safety;
- increased capacity and operational efficiency;
- reduced energy and environmental cost associated with traffic congestion;
- enhanced present and future productivity of individuals, organizations, and the economy as a whole;
- enhanced personal mobility;
- creation of an environment in which the development and deployment of ITS can flourish.

Figure 1-1 outlines the role of the National ITS Architecture within the overall NPP and illustrates how the goals and objectives for the program provide direction in each of the component areas and in establishing and delivering the vision.

Figure 1-1: National ITS Architecture Context



The development of the U.S. National ITS Architecture is reflected by the following milestone events:

1991	U.S. Congress legislates ITS program;
1992	Development of the U.S. National ITS Architecture sponsored by the U.S. DOT begins;
1993-1995	Phase 1, ITS Architecture Development (four teams led by Hughes Aircraft, Loral, Rockwell International, and Westinghouse Electric);
1995-1996	Phase 2, ITS Architecture Development – Consolidation (joint effort by Loral and Rockwell International);
1996	Version 1 of U.S. National ITS Architecture containing a set of 16 documents is completed;

1997	The 30th user service is added to complete the seven user service bundles and thirty user services;
1998	September, Version 2 of U.S. National ITS Architecture, containing updates to the logical architecture, physical architecture, and several other key architecture definition documents is completed. October, the FHWA publishes the "TEA21: Interim Guidance on Conformity with National Architecture and Standards", to ensure that ITS projects carried out using funds made available by the Highway Trust Fund conform to the National Architecture. The current interim guidance is effective for approximately one year from the publishing date. A final policy is expected within the same time frame.
1998	December, the FHWA publishes the "Proposed Criteria and Draft List of Critical ITS Standards", as part of its ongoing effort to ensure national interoperability in the implementation of ITS technologies. A final report outlining the critical standards will be presented to the U.S. Congress by June 1, 1999.

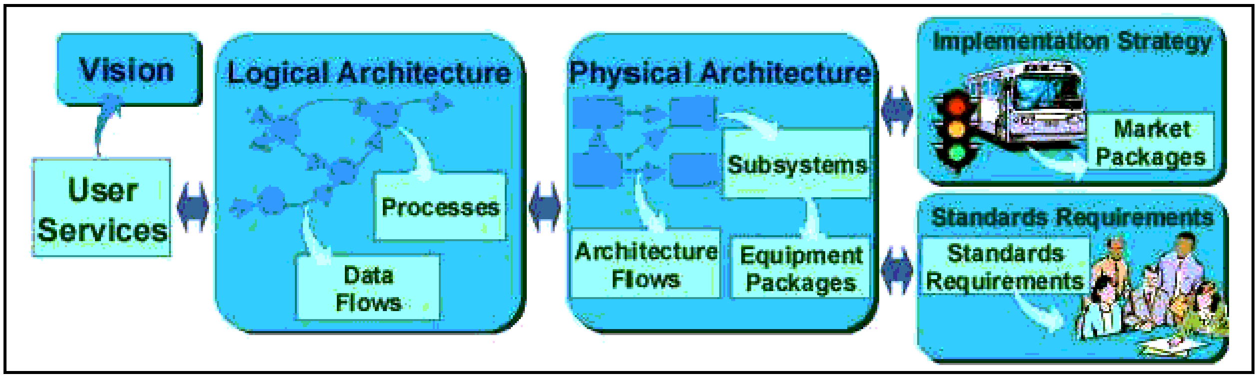
The U.S. Department of Transportation (DOT) Architecture Team composed of representatives from U.S. DOT's FHWA, the Federal Transit Administration (FTA), the National Highway Traffic Safety Administration (NHTSA), and the MITRE Corporation led the management of the architecture development program.

Four methods were used to provide a forum for information dissemination and feedback:

- ITS Architecture Consensus Task Force – consisting of ITS stakeholders, primarily associations/societies and interest groups;
- The regional architecture forums – involved public meetings that resulted in local feedback of the current status for architecture alternatives;
- ITS America – provided feedback through technical committees, and a task force;
- Focus groups – provided feedback on key issues and views of the principal stakeholders.

The U.S. Architecture categorizes ITS applications into seven user bundles and thirty user services. User bundles include travel and transportation management, electronic payment, public transportation operations, commercial vehicle operations (CVO), travel demand management, emergency management, and advanced vehicle control and safety system. Using the user services as a guide, the architecture defines the key transportation infrastructure subsystems that work together to support the user services, the communication links between the subsystems, and the organizational roles of key stakeholders. An overview of the National ITS Architecture is provided in Figure 1-2 (reference 3, Appendix A).

Figure 1-2: National ITS Architecture Overview

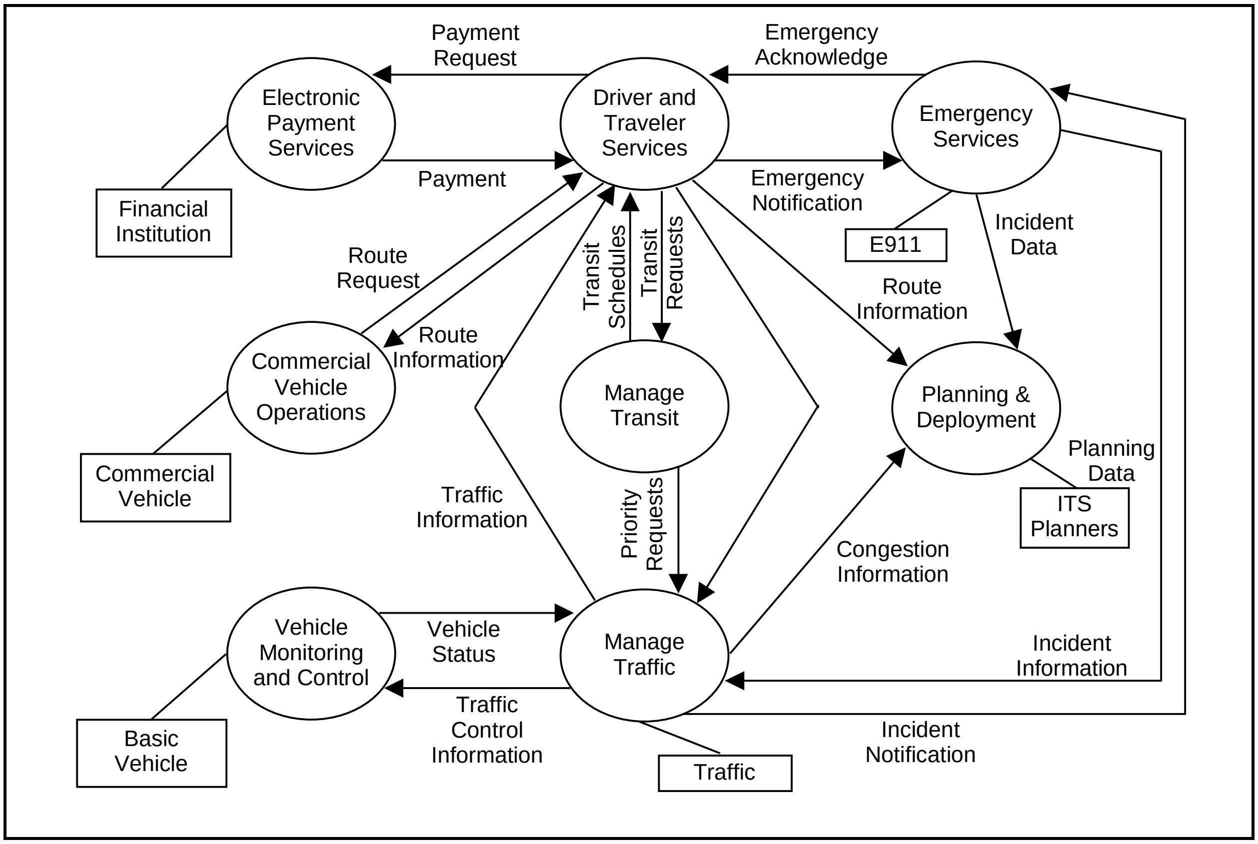


The **user services are defined as the services provided through ITS from the user's perspective**. The essential architecture elements to provide the user services are contained in the logical architecture and physical architecture. Information about the equipment and market packages is given to ensure that common definitions are provided to enhance understanding in the deployment of the ITS services. The U.S. National ITS Architecture documents are divided into five categories, including executive summary, architecture definition, evaluation, implementation strategy, and standards, as detailed in Appendix B.

1.4 LOGICAL ARCHITECTURE

The logical architecture defines the functional processes and information flow (data flow) of a system required to support the ITS user services. The logical architecture provides the description, data flow requirements, functional requirements, user services requirements, and data flow diagrams for each of the functional processes. Functional processes describe the system capabilities for each of the basic tasks, e.g. the Manage Traffic functional process describes the data processing and transfer that are required to perform the variety of tasks, such as incident detection, which constitutes traffic management. The user services requirements provide functional statements of what must be done to support the user services. Figure 1-3 (reference 3, Appendix A) is a data flow diagram that shows how processes and data flows can be grouped. Circles identify the processes and arrows represent the data flows.

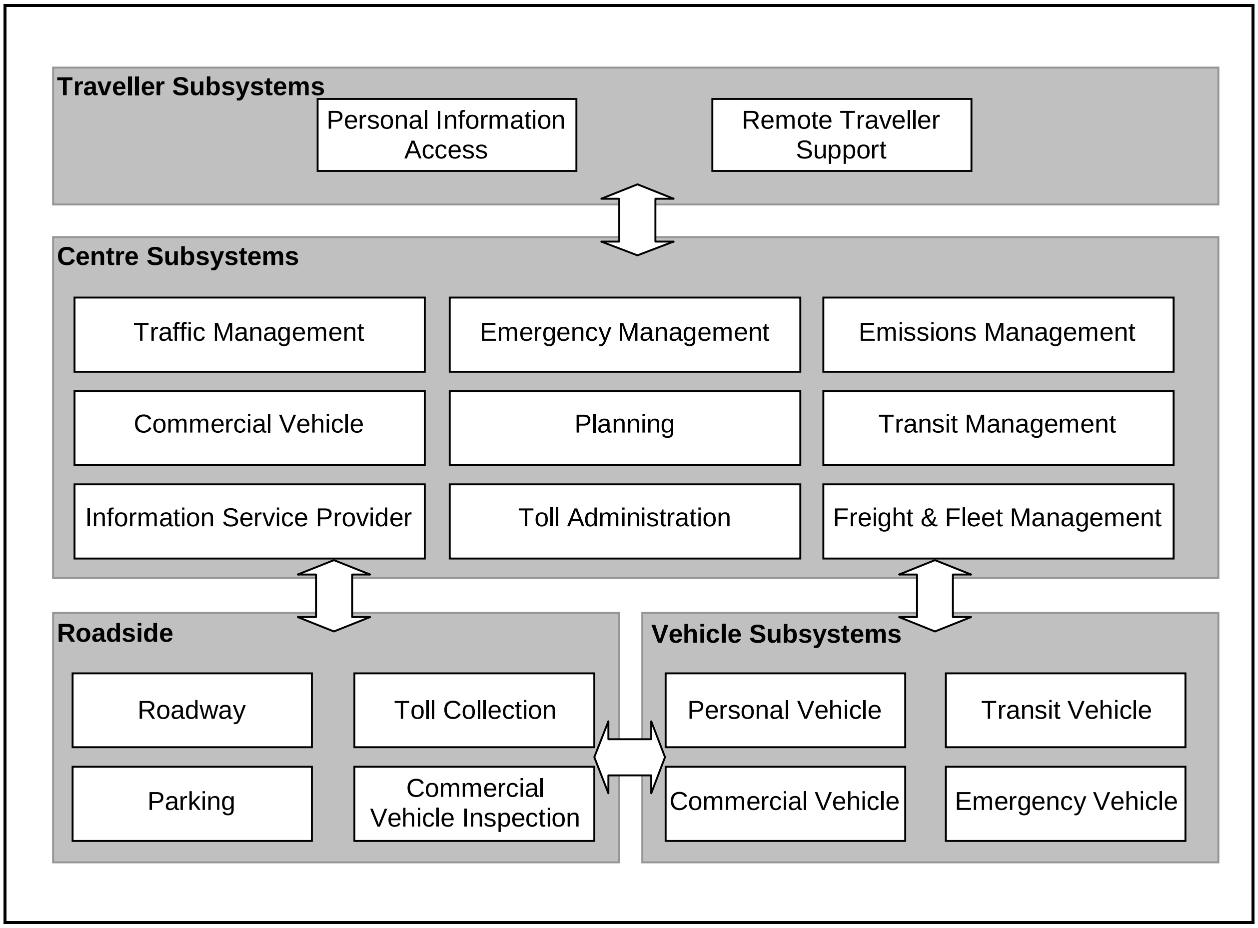
Figure 1-3: National ITS Architecture – Simplified Top Level Logical Architecture



1.5 PHYSICAL ARCHITECTURE

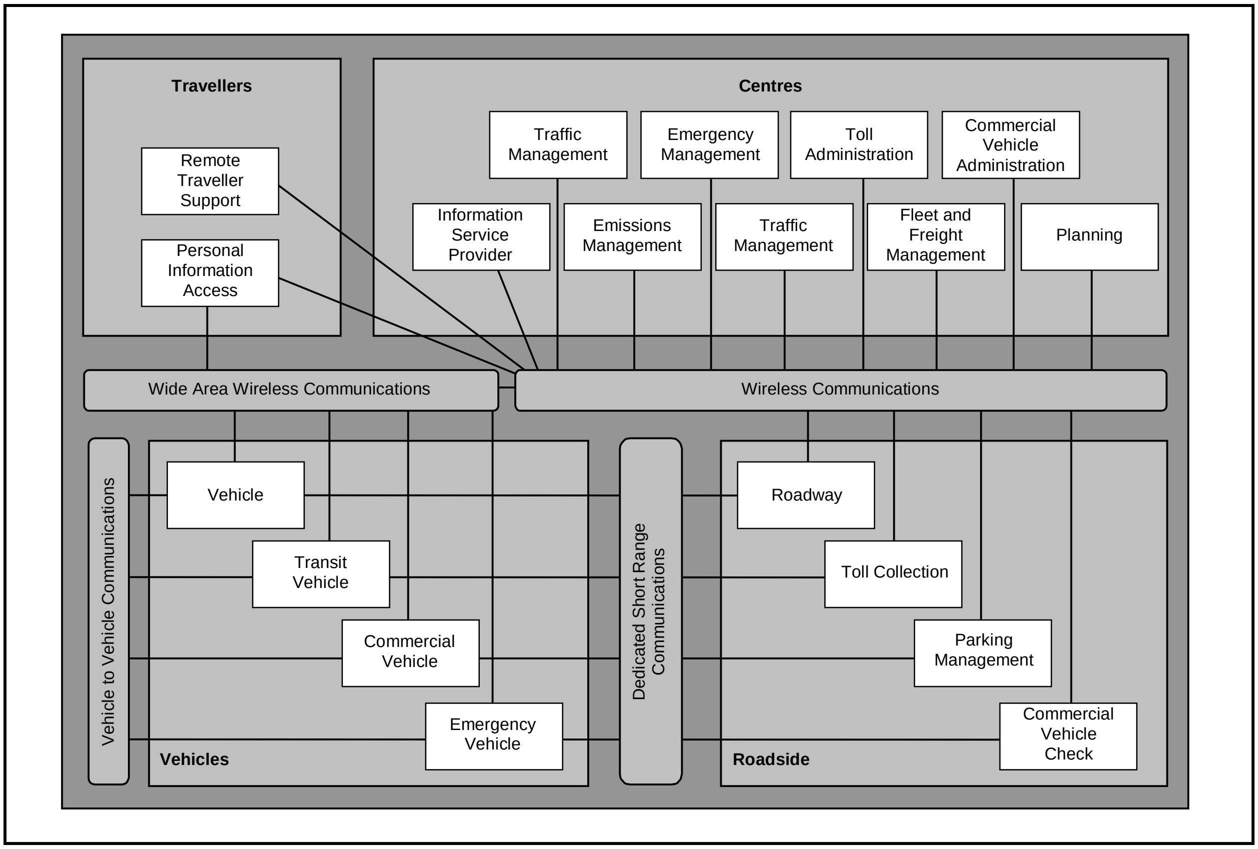
The national architecture initiative also defined a physical architecture. The physical architecture, set out in Figure 1-4 (reference 3, Appendix A), includes four physical components or entities, including the traveller, control centre, roadside, and vehicle. Various subsystems were identified for each of the four physical entities. Each subsystem is assigned the appropriate functional processes defined by the logical architecture. For example, the interaction between the transit management centre, the transit vehicle, the roadway, and the personal information access and remote traveller support subsystems would be described under the manage transit process from the logical architecture. The relationships among the transportation management related subsystems are described by the transportation layer of the physical architecture.

Figure 1-4: National ITS Architecture – Physical Architecture



The flow of information and data transfer for the transportation layer components are defined by the communications layer of the physical architecture. The data flow components (defined by the logical architecture) that originate from one subsystem and end at another are grouped into (physical) architecture flows. By defining the communications requirements, the communications industry and communications service providers can more effectively and efficiently position their products and services to commercially address the needs of ITS deployment. Figure 1-5 (reference 3, Appendix A) provides an overview of the communications requirements between the physical entities.

Figure 1-5: National ITS Architecture – Communications Overview

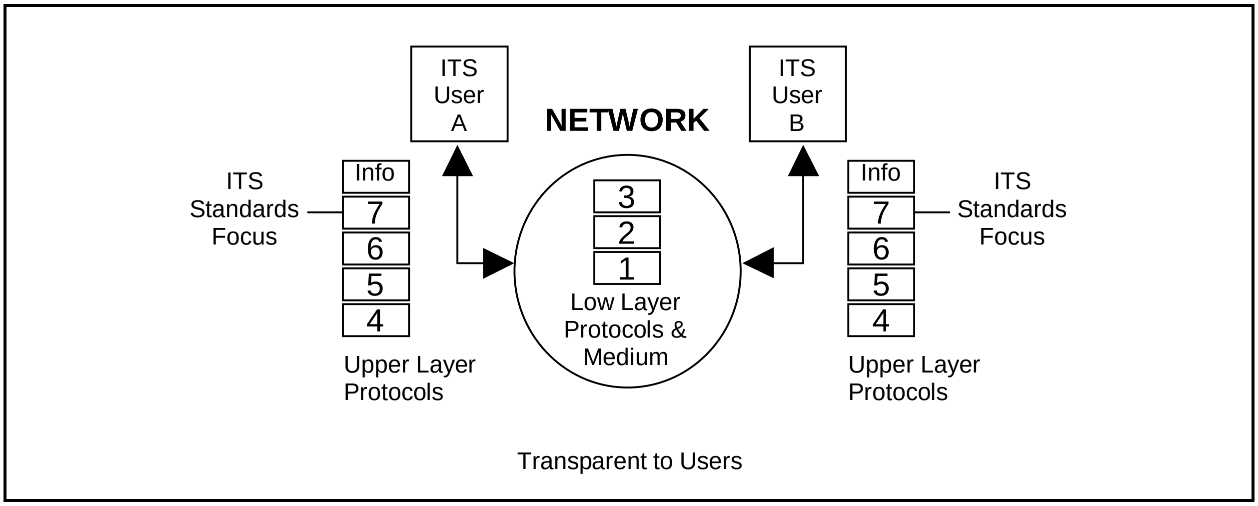


In general, the communications architecture for ITS has two components: one wireless and one wireline. One, or both, of these components support all transportation layer entities requiring information transfer. In many cases, the communication layer appears to the ITS user (on the transportation layer) as “communication plumbing”, many details of which can, and should, remain transparent. Nevertheless, the basic telecommunication media types have critical architectural importance.

1.5.1 Open System Concept

The generic hierarchical communication model, as shown in Figure 1-6, follows the open systems interconnection (OSI) model, which organizes the communication network in a highly structured format to reduce its overall design complexity. This model is structured as a series of layers, each providing certain services to the layer above and capable of conversing with the corresponding layer at the other end of the link. Thus, the high level layers (e.g. ITS application) are shielded from the actual implementation details of the communication services. Different networks can use layers different from the OSI model, such as the IBM Systems Network Architecture (SNA). When different protocols are used in different networks, an interworking function must provide the conversion between the protocols at the various levels.

Figure 1-6: Generic Hierarchical Communication Model



Layer 1 is the lowest layer in the OSI model and is referred to as the physical layer, which provides the transmission of bits over wires or radio links. The different manifestations of the physical layer are the greatest concern to the ITS user and service provider because, as of today, they affect the hardware that must be carried or installed in the vehicle. In the future, wireless equipment is expected to become more flexible so that multiple physical layer variants could be implemented within a single piece of equipment and would therefore remove one of the constraints to the implementation of the ITS communications architecture.

Layer 2 is the data link layer, which is concerned with making the link appear to the receiver as bit error-free as possible by implementing error detection and correction (EDAC) coding schemes in the transceiver. One example of this is the use of a cyclic redundancy code (CRC) to a block or frame of the data. When the data passes the CRC check at the receiver, the returned acknowledgement indicates whether re-transmission is needed. Layer 2 and the other higher layers can be implemented by the software installed within a general purpose processor and allow the ITS user greater flexibility to implement different versions without affecting the equipment that must be carried or installed in a vehicle.

Layer 3 is the network layer, which controls the operation of the network. Here, the key issue is routing packets, which are also used to generate billing information for the communications service provider (billing is tied to Internet Protocol (IP) addresses).

Layer 4 is the transport layer, which mediates between the session layer and the network layer, providing end-to-end accounting (sequencing, non-duplication, etc.) for all the data at the receiving end. It also isolates the top layers from the changing physical technologies.

Layer 5 is the session layer, which allows users on different machines to establish communications, or sessions, between them. This involves ordinary data transport, but with enhanced services, such as remote log-in or file transfer.

Layer 6, the presentation layer, performs syntax and semantic operations on the information transmitted between the users, such as encoding data in a standard way, or compressing or encrypting the data.

Layer 7 is the application layer, which provides commonly used protocols for tasks such as terminal emulation, file transfer, electronic mail, and remote job entry. (Note that for many ITS applications, layers 5 and 6 are absorbed into the application layer, layer 7.)

1.5.2 Wireline

The wireline portion of the network can be manifested in many different ways – most are implementation dependent. The physical layer of the wireline component is really not an issue, since most wireline technologies can support all ITS requirements. The higher layers can also be very flexible, as for the most part translators will be available and will permit interfacing between different systems at well defined gateways. Translators are found as embedded features in devices such as modems, switches, and coders. They allow the devices to handle multiple protocols. Translators are important because the OSI defines the functionalities and not protocol at each layer.

1.5.3 Wireless

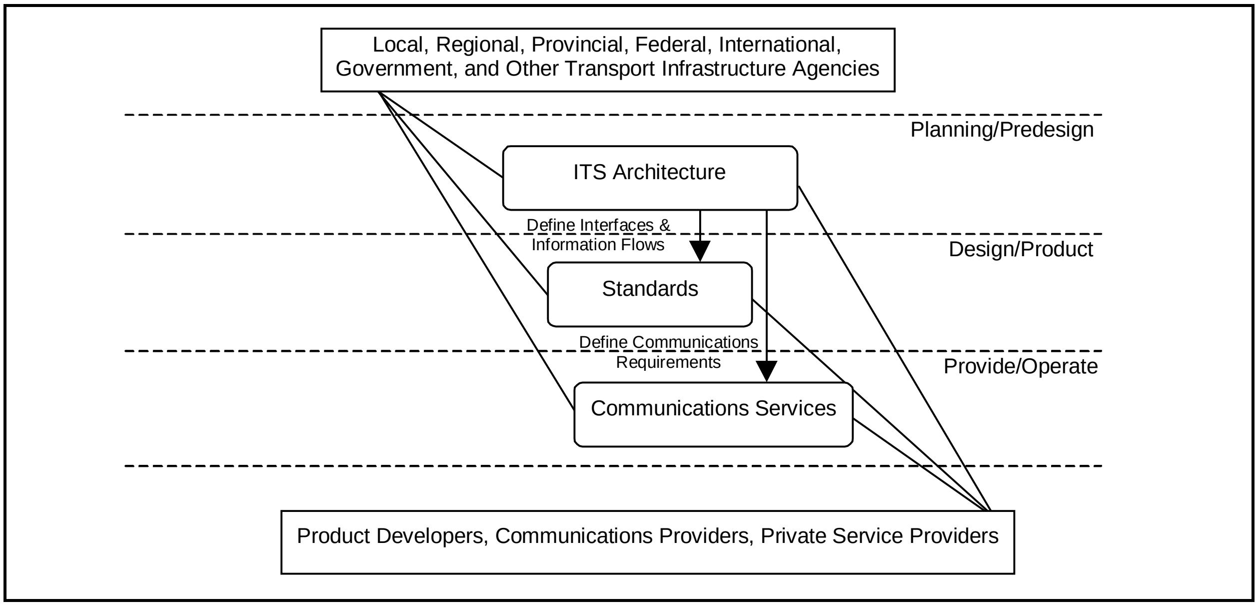
The wireless portion is configured in three basic, different ways:

- Wide-area wireless infrastructure supports wide-area information transfer (many data flows). For example, existing and emerging mobile wireless systems can be used directly by ITS subsystems in the transfer of data. The ES–3 wireless interface to this infrastructure is referred to as “**u1**”. It denotes a wide area wireless air link, with one set of base stations providing connections to mobile or untethered users. It is typified by the current cellular telephone and data networks or the larger cells of Specialized Mobile Radio for two-way communication, as well as paging and broadcast systems for one-way communications.
- Short-range wireless infrastructure for short-range information transfer (also many data flows, but limited to specific applications). The wireless interface to this infrastructure is referred to as “**u2**”, denoting a short-range air link used for close-proximity (typically less than 50–100 ft.) transmissions between a mobile user and a base station. Within the ITS community this is commonly referred to as dedicated short range-communications (DSRC) and is typified by transfers of vehicle identification numbers at toll booths. Unlike the wide area infrastructure component that is shared with many user applications, the National Architecture envisages that this infrastructure component would typically be dedicated to ITS applications. Recent technology developments, such as Bluetooth, which support multi-application, warrant further investigation. A short description of Bluetooth is attached in Appendix E.
- Dedicated wireless systems could handle high data rates, have low probability of error, and would deliver service over a fairly short range. These systems are appropriate for automated highway systems related (AHS-related) data flows, such as vehicle to vehicle transceiver radio systems. This wireless interface is denoted by “**u3**”. Systems in this area are still in the early research phase.

1.6 STANDARDS

Standards help ensure that national interoperability of ITS services can be achieved. The architecture flow and communication requirements define the interface between the subsystems of the physical architecture. By defining the interfaces and information flows, efforts to undertake the development and implementation of industry standards can proceed. Figure 1-7 illustrates how ITS architecture applies to the development of standards and communications services.

Figure 1-7: National ITS Architecture Application



Current non-North American standard setting efforts revolve around three key organizations, the International Organization for Standardization (ISO), the European Committee for Normalisation (CEN), and the Japanese Standard Organisation (JSO). Work in ISO is done through its Technical Committee on Transportation Information and Control Systems (TICS). Work in CEN is done through the Technical Committee CEN/TC278. The duplication of CEN and the Japanese standards occurs because in Europe and in Japan respectively, CEN and JSO standards are obligatory, but conformance to ISO standards is not. Table 1-1 outlines the ITS standards working groups for the ISO/TC204. It also shows equivalent CEN working groups for reference. Japanese equivalent committees are not as easily identifiable. The standards provided through these ISO working groups form the basis for standardization of information, communication, and control systems in the surface transportation, public transport, commercial transport, and control systems (TICS) field.

Table 1-1: ISO/TC204 Working Groups

Working Group (WG)	Lead	Co-operating WG
Architecture	ISO	CEN WG12, 13
Quality and reliability requirement	ISO	
TICS database technology	ISO	CEN WG7
Fee and toll collection	CEN WG1	
General fleet management	ISO	CEN WG2
Commercial/freight	ISO	CEN WG2
Public transportation/emergency	ISO	CEN WG2, 3
Integrated transportation information, management and control	ISO	CEN WG5
Traveller information systems	CEN WG4	
Route guidance and navigation systems	ISO	CEN WG4
Vehicle/roadway warning and control system	ISO	ISO/TC22/SC13/WG8
DSRC for TICS application	CEN WG9	
Wide area communication/protocols and interfaces	ISO	CEN WG11

1.7 CURRENT U.S. INITIATIVES

1.7.1 Critical Standards

To ensure that industry-driven standard development can proceed rapidly to support the rapid deployment of U.S. ITS services, the U.S. Congress directed the U.S. DOT to identify a list of critical standards required to ensure national interoperability that are "critical to the development of other standards, specifying the status of the development of each standard identified" as part of Section 5206(b) of the *Transportation Equity Act for the 21st Century (TEA-21)*. In response to this request, the U.S. DOT has developed a discussion paper called the *TEA-21 Critical Standards: Proposed Criteria and List of Critical Standards* based on preliminary discussions between member of the standards community and ITS America. The U.S. ITS industry has until January 2001 to develop and agree on the TEA-21 critical standards shown in Table 1-2. Otherwise, the U.S. Congress would require that the U.S. DOT set the standards for the industry. This list is currently considered as work in progress. The final list will be submitted to the U.S. Congress for June 1, 1999.

Table 1-2: National ITS Architecture – Proposed List of Critical Standards

No.	Title	Lead SDO	Type of Criticality	Status
1	Advanced Traveller Information System (ATIS) data dictionary [SAE J2353]	SAE	National	In ballot
2	Advanced Traveller Information System (ATIS) message set [SAE J2354]	SAE	National	In ballot
3	ATIS message structure for high-speed FM subcarrier [SAE J2369]	SAE	National	In ballot
4	ATMS data dictionary (TMDD) – sections 1 & 2 (links/nodes/events) [TM 1.01]	ITE	Foundation	In ballot
5	ATMS data dictionary (TMDD) – sections 3 & 4 (DMS/video/control/etc.) [TM 1.02]	ITE	Foundation	In ballot
6	Information service provider – vehicle location referencing standard [SAE J1746]	SAE	National, foundation	In ballot
7	Message sets for DSRC, electronic toll and traffic management, and commercial vehicle operations [IEEE P1455]	IEEE	National	In ballot
8	Message sets for incident management: emergency management system to traffic management system and emergency telephone system (or 911) [IEEE P1512]	IEEE	National	Draft
9	On-board land vehicle mayday reporting interface [SAE J2313]	SAE	National	In ballot
10	Standard for data dictionaries for intelligent transportation systems [IEEE P1489]	IEEE	Foundation	In ballot
11	Standard specification on DSRC data link layer [ASTM2]	ASTM	National	In ballot
12	DSRC physical layer – 902-928 MHz [ASTM1]	ASTM	National	In ballot
13	Standard specification on dedicated short-range communications (DSRC) at 5.8 GHz – physical layer	To be determined	National	To be determined
14	Template for ITS message sets [IEEE P1488]	IEEE	Foundation	Draft

Not all ITS services require standardization at the national level. The focus of the standardization for various ITS systems and interfaces to ensure national interoperability has been on the hardware and software of mobile systems that cannot easily be adapted to communicate with different fixed systems as the mobile travels. The key elements for standardization have been the communication interface between the vehicle and the infrastructure, such as DSRC and the high-speed subcarriers. The standards that support the development of others are referred to as the **foundation standards**. Foundation standards include the development of a data dictionary template and location referencing standards.

1.7.2 Guideline for Conformity

Effective October 2, 1998, ITS projects using funds from the Highway Trust Fund (including the mass transit accounts) are subject to the *TEA-21: Interim Guidance on Conformity with the National Intelligent Transportation Systems (ITS) Architecture and Standards*. The interim guidance report includes sections on definition, questions and answers, and statutory language, and is intended to foster the integration of ITS into current and future transportation planning processes and focus on near-term ITS projects that have the greatest potential for affecting regional integration. Questions regarding applicability and scope, ITS projects, ITS considerations within transportation planning, federal roles, and ITS standards are addressed in the report. This report is expected to be finalized by October 1999, and will form the basis for the enforcement of section 5206(e) of the TEA-21 for ITS project conformity with the U.S. National ITS Architecture and standards when using the Highway Trust Fund (including the mass transit accounts).

1.7.3 Regional Architecture

Interpretations of the U.S. National ITS Architecture at a regional level are currently being suggested for deployment in the U.S. in response to regional variation of ITS deployments. The “regional” architecture provides a regional interpretation of the National ITS Architecture for a seamless ITS environment throughout the region. It provides a mechanism for co-ordination among different agencies in different jurisdictions to apply ITS services and strategies to meet local needs. A portion of the ITS Deployment Program funding provided by the U.S. DOT is used to develop the regional architecture.

2 REVIEW OF ITS IN THE CANADIAN ENVIRONMENT

2.1 INTRODUCTION

The Canadian ITS industry is growing rapidly in response to an international market with a projected cumulative market base between 1996 and 2011 of over U.S. $434 billion (reference 4, Appendix A). The role of ITS in our future transportation network must be identified and a viable ITS architecture reflecting the needs of Canada must be developed to ensure the best use of our resources.

2.2 TRANSPORTATION SERVICE PROVIDERS

The public sector organizations responsible for the provision of transportation services in Canada can be grouped into four broad categories:

- Federal government through various departments, such as Transport Canada;
- Provincial governments through transportation ministries, such as the Ministry of Transportation of Ontario;
- Municipal governments, such as the City of Toronto;
- Transit agencies.

Table 2-1 presents a summary of the role and responsibility of each of the four categories of transportation service providers.

Table 2-1: Role and Responsibility of Each Category of Transportation Service Provider

Public Sector Transport Organizations	Role and Responsibility
Transport Canada	• Develop up-to-date relevant transportation policies and legislation to maintain highest level of safety and security possible. • Responsible for maritime, rail, and airline sectors.
Provincial ministries of transportation	• Plan, design, procure construction of, and operate Canadian highways. • Responsible for highway design standards, vehicle registration, vehicle inspection, driver licensing, and policing and enforcement. • Regulate trucking industry.
Municipal transportation departments	• Responsible for highways and local roads within their boundaries. • Administer traffic control systems.
Transit agencies	• Responsible for providing transit services.

2.3 EXISTING ITS INITIATIVES

An inventory of ITS initiatives in Canada was developed by initiating telephone contact with the provincial transport ministries, undertaking website searches, and performing an inventory scan from various reports. This list of ITS initiatives provides an indication of the ITS activities taking place in Canada. The initiatives are categorized according to the current user service bundle definitions defined within the U.S. National ITS Architecture. Other definition groupings, such as SRI Consulting's breakdown of ITS technology into four ITS sectors, and 15 ITS applications (reference 4, Appendix A) should also be noted to reflect the potential for a regrouping of the ITS user service bundles and User Services (see Table 2-2).

Table 2-2: SRI ITS Applications Grouping Compared with U.S. ITS User Service Bundles

ITS Sector	ITS Application	U. S. User Service Bundles
Traffic management	Traffic control Integrated traffic management systems Automatic toll collection	Travel and transportation management Electronic payment
Driver information and trip planning	Pre-trip information In-vehicle navigation En route information Driver access and information	Travel demand management
Fleet management	Automatic vehicle location and tracking Passenger transit management Freight distribution and logistics	Public transportation operation Commercial vehicle operation
Vehicle safety and control	Collision avoidance Hazard warning Automatic vehicle control Safety status monitoring Emergency notification Other safety applications	Emergency management Advanced vehicle control and safety systems

Figure 2-1 illustrates the number of ITS projects by province. Ontario, Quebec, Alberta, and British Columbia are the most active provinces in implementing ITS. Ontario has implemented ITS projects in each of the User Service Bundle areas.

Figure 2-1: Canadian ITS Initiatives – Projects by Province

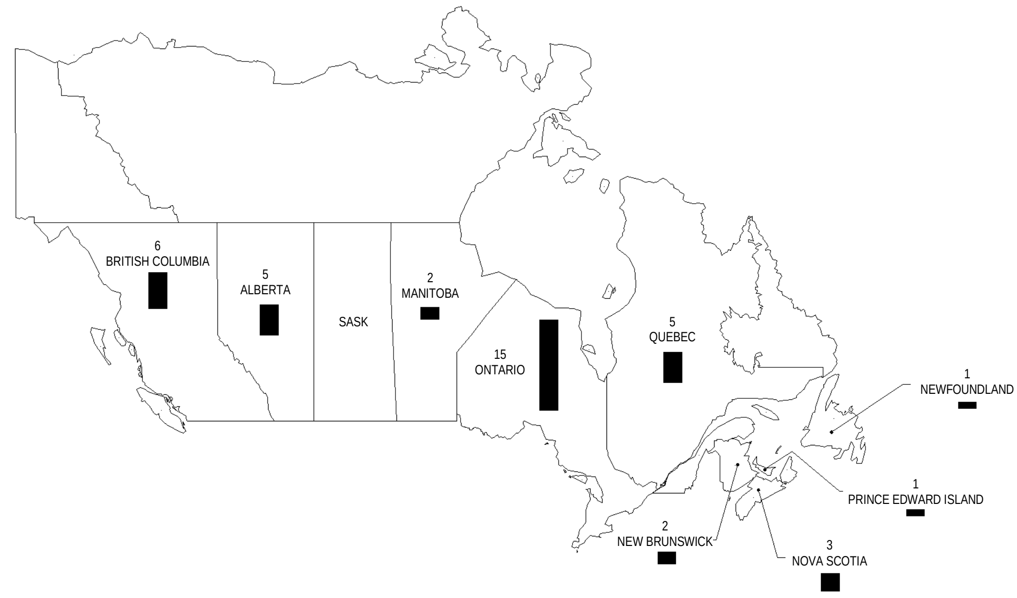
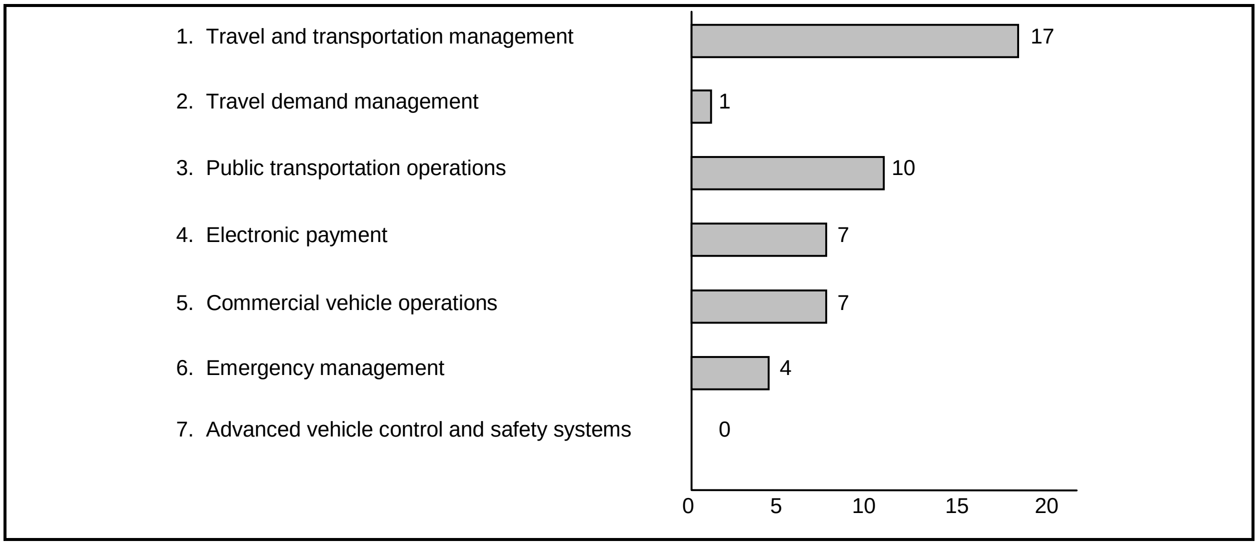


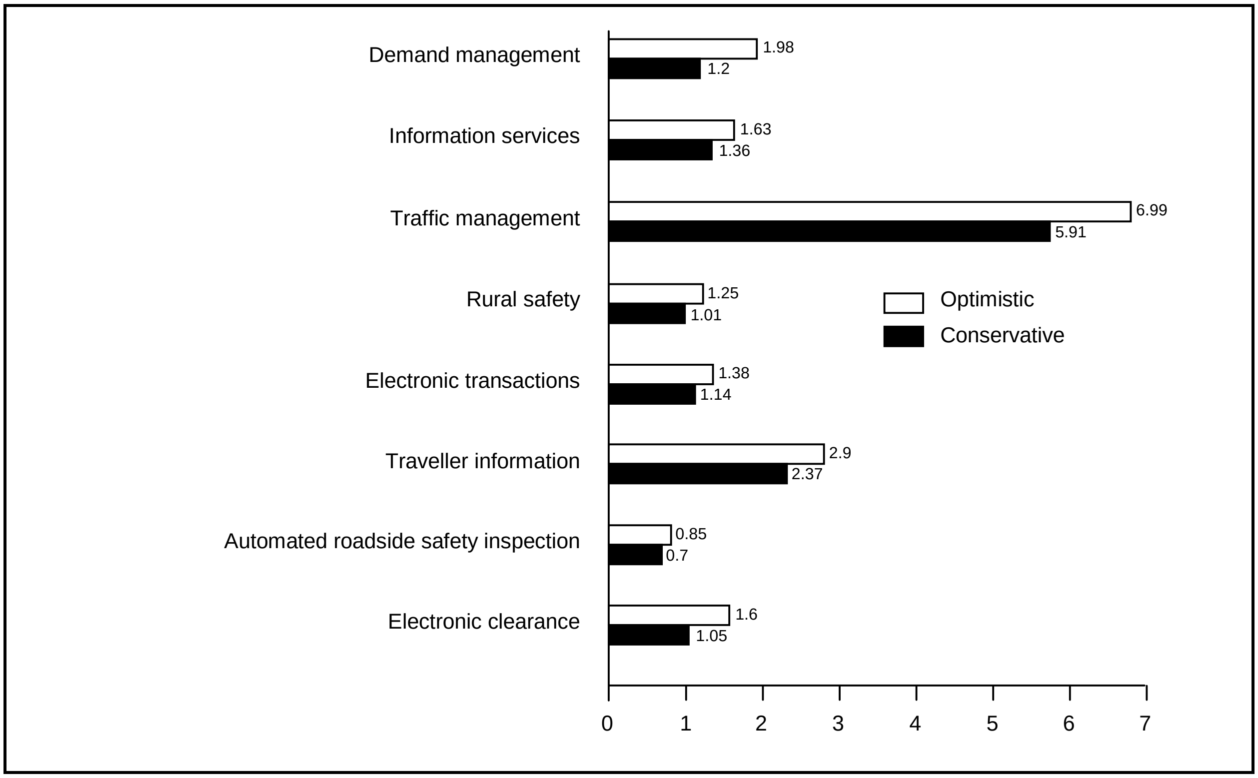
Figure 2-2 illustrates the distribution of Canadian ITS initiatives by user service bundle. The majority of ITS projects are in the area of travel and transportation management, representing more than 40 percent of the overall projects in this country. Other user services that have attracted significant ITS project activity are advanced public transportation systems and commercial vehicle operations, which together account for roughly the same level of activity as in the area of travel and transportation management.

Figure 2-2: Canadian ITS Initiatives – Projects by User Service Bundle



A general assessment of the benefit-cost associated with implementation of ITS for selected user services was undertaken by Transport Canada in 1995-96 (reference 5, Appendix A). Figure 2-3 summarizes the results from some of this work. As can be seen from the diagram, urban traffic management provided the highest quantified benefit to cost ratio. Rural traveller information and demand management provided optimistic forecasts for benefits and cost ratio of three to two respectively. In some cases, costs exceeded benefits (e.g. automated roadside safety inspection); however, this analysis incorporated only benefits that could be easily quantified. Non-quantified benefits may account for a decision to implement such an initiative. Furthermore, the benefit-cost ratios representing implementation across Canada and local or site specific varied widely.

Figure 2-3: Canadian ITS Initiatives – Benefit-Cost for Selected User Services



Some examples of Canadian ITS initiatives by user service bundle follow.

2.3.1 Travel and Transportation Management

- COMPASS in Ontario, Montreal FTMS in Quebec;
- Traffic adaptive signal control system using the SCOOT system in various cities across Canada;
- Reversible lane, using lane control signals for peak hour traffic control;
- FM radio broadcast highway radio advisory systems.

2.3.2 Electronic Payment

- Highway 407 Express Toll Route (ETR), Ontario;
- Highway 104 Electronic Toll Collection (ETC), Nova Scotia;
- Smart card transit applications in Mississauga and Ajax;
- Dartmouth Bridge ETC, Nova Scotia;
- Fredericton-Moncton ETC, New Brunswick;
- Saint John Harbour Bridge ETC, New Brunswick.

2.3.3 Public Transportation

- Traffic signal pre-emption for streetcar, transit, LRT vehicles;
- Automatic vehicle locationing (AVL) for transit vehicles in numerous cities, including Hull, London, and Hamilton.

2.3.4 Commercial Vehicle Operation

- Heavy vehicle electronic licence plate (HELP) Crescent Weigh Station Bypass from Texas to British Columbia;
- AVION/Advantage I-75, Interstate 75 commercial vehicle weight enforcement pre-clearance on Highway 401;
- Ground traffic management systems at Lester B. Pearson International Airport in Toronto and Winnipeg International Airport.

2.3.5 Travel Demand Management

- Highway 407 ETR in Ontario uses travel demand management by modifying toll charges by time of day.

2.3.6 Emergency Management

- COMPASS in Ontario, Montreal FTMS in Quebec.

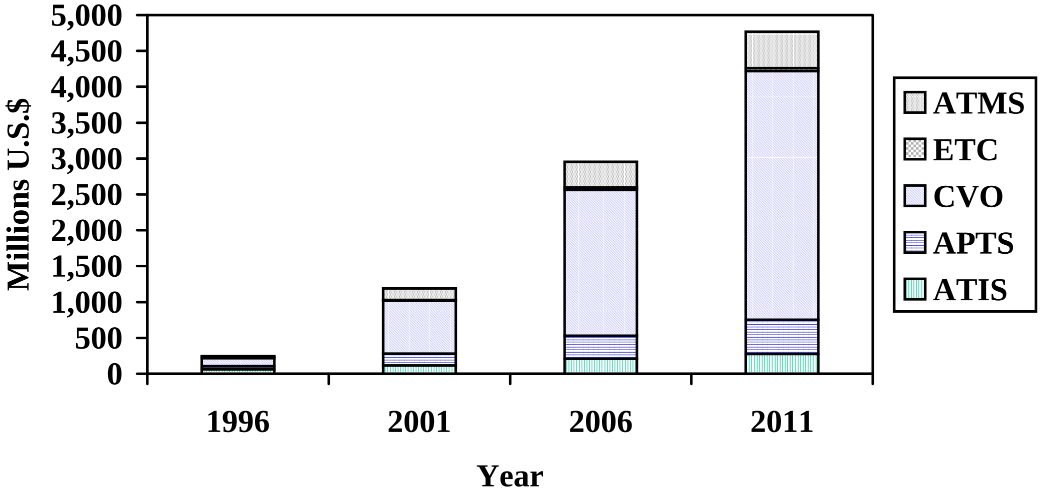
2.3.7 Advanced Vehicle Control and Safety Systems

The technologies required for implementing ITS user services under this user service bundle have not yet matured to a point where there is any significant Canadian deployment. However, the automotive industry has a strong presence in Canada and is active in the research and development of the technologies required.

2.4 CANADIAN ITS PRODUCTS AND SERVICES

Figure 2-4 (reference 4, Appendix A) illustrates the projected annual ITS sales worldwide by five-year intervals. Commercial vehicle operations (CVO) are anticipated to account for a majority of annual ITS spending. Advanced traffic management systems (ATMS) and advanced public transportation systems (APTS) each accounted for just under 10 percent of the annual ITS sales activity.

Figure 2-4: Canadian ITS Initiatives – Projected Annual ITS Sales



This projection is based on the market for the provision of equipment and services for travel and transportation management, electronic payment, commercial vehicle, public transportation, and travel demand management user service bundles, as defined by the National ITS Architecture. The ITS market included North America, Europe, Japan and, on a smaller scale, the emerging industrial nations of both the Pacific Rim and Latin America/South America, as well as the unique markets of India and China. The ITS market will increase as enabling technologies mature, as in the case of advanced vehicle control and safety systems, which was not included in the market forecast because of uncertainties associated with technological evolution.

In the report, *Strategy for Developing an ITS Industrial Base in Canada* (reference 4, Appendix A), it was noted that all levels of Canadian government are active in ITS. Canada has some of the leading ITS companies, with competitive strengths in many of the key enabling technology areas including the Geographic Information System (GIS), displays, sensors, system integration and software, and positioning and navigation technologies. The report also identified traffic management, fleet management, and public transit management as significant Canadian ITS service areas.

Canada’s primary market for ITS is the U.S. It is a market that is well known, and intergovernmental co-operation and mechanisms for ITS joint ventures are well established. The secondary market for Canadian ITS providers is the emerging industrialized countries in the Pacific Rim and Mexico/Latin American regions. Canadian ITS providers support markets of electronic toll collection, traffic management, and freight mobility.

Europe is also recognized as a potential market for ITS technologies and services. For example, Canadian companies are already in place and competing in the areas of traffic management, electronic tolling, and public transit management. Japan is regarded as a tertiary market, because its main market matches poorly with the Canadian ITS industry’s strength.

The most promising Canadian ITS market package is traffic management, as illustrated by Figure 2-2. For the North American market, the commercial vehicle, traffic management, and emergency management represent promising ITS market packages. In Europe, traffic management that encompasses transportation management and electronic payment also dominated as the most promising market package. Japan’s traffic management market package includes transportation and travel demand management.

2.5 CANADIAN PARTICIPATION IN STANDARDS WORK

The key to standards setting activities is to provide a tool to implement an architecture that results in interoperability of all system elements. The U.S. effort to develop a national ITS architecture has placed them in a position of de facto leadership on ISO committees. Through the co-ordination efforts of Transport Canada, Canadian participants are active in international standards development work, particularly the ISO/TC204 efforts (see Table 2-3). The Canadian Advisory Committee for ITS Standards (CAC) is actively supporting Canadian activities in the ISO/TC204 standards setting committees. Canadian ITS industry and federal and provincial government experts are also participating, either directly or under the auspices of ITS Canada and the CAC, in a host of North American standards-related committees. These committees are either standards policy committees, such as those under the North American Free Trade Agreement (NAFTA), ITS America, and ITS Canada or technical standards development committees, such as those under the American Society for Testing and Materials (ASTM), the IEEE, the SAE, National Transportation Communications for ITS Protocol (NTCIP), and the American Association of State Highway and Transportation Officials (AASHTO).

Table 2-3: ISO/TC204 Efforts

Working Group (WG)
Architecture
Quality and reliability requirement
TICS database technology
Fee and toll collection
General fleet management
Commercial/freight
Public transportation/emergency
Integrated transportation information, management and control
Traveller information systems
Route guidance and navigation systems
Vehicle/roadway warning and control system
DSRC for TICS application
Wide area communication/protocols and interfaces

In addition to the ISO/TC204 committees, Canadian experts are actively involved in the following standards development organizations, which are directly responsible for developing ITS standards for North America.

- National Transportation Communications for ITS Protocol (NTCIP) – provides a communication standard that ensures the interoperability and interchangeability of traffic controller and ITS devices. NTCIP provides communication interface between different hardware and software products. These standards aim to maximize the existing infrastructure and allow flexible expansion in the future, without reliance on specific equipment when there is already customized software.

Table 2-4: NTCIP Efforts

Working Group (WG)
Activated signal control (ASC)
Base standards and protocols (BSP)
Centre-to-centre profiles (C-2-C)
Closed circuit TV (CCTV)
Data collection and monitoring (DCM)
Environmental
Global object
Joint Committee on NTCIP
Profiles
Signal control and privatization
Transportation sensor system
Technical Co-ordination Forum (TCF)

- American Association of State Highway and Transportation Officials (AASHTO) – Is directly involved in oversight activity and initiating major standards development efforts, such as ATMS data dictionary, message sets for DSRC, location reference specifications, message sets for external TMC communications, on-board land vehicle mayday reporting interfaces, ATIS data dictionary and message sets, and message sets for incident management.

Canadian experts have participated directly in these efforts, which address message sets for the DSRC.

- Institute of Electrical and Electronics Engineers (IEEE) – The Standards Co-ordinating Committee (SCC) of ITS, the IEEE SCC is responsible for co-ordinating, developing, and maintaining standards recommended practices and guidelines related to ITS.

Table 2-5: IEEE Efforts

ITS Standards – Efforts
Guide for microwave communications systems development
Standards for message sets for vehicle/roadside communications
Fibre-optic cable in ITS system ground-based transportation of collision avoidance radar
Applications of synchronous optical network (SONET) technology to ITS communications
Standards for message set templates for ITS systems
Standard for data dictionary for ITS systems
Data dictionary for ITS systems – Part II (registration and quality attributes)
Common incident management message sets for use by emergency management centres
Traffic incident management message sets for use by emergency management centres
Public safety incident management message sets for emergency management centres
Hazard material incident management sets for emergency management centres
Emergency management data dictionary
Message sets for backoffice applications/roadside resource management communication

- National Electrical Manufacturers Association (NEMA) – Provides a forum for standardization of electrical equipment.
- North American Free Trade Agreement (NAFTA) DSRC Harmonization Committee – This effort is primarily directed towards a harmonization of DSRC technology across the U.S., Canada, and Mexico. Canadian representatives have been extensively involved in developing this harmonization of standards for commercial vehicle operations across the entire North American road network.
- Society of Automotive Engineers (SAE) – Is a major resource for technical information and expertise used in designing, building, maintaining, and operating self-propelled vehicles for use on land or sea, in air or space. The primary purpose of this organization is to share information and exchange ideas for advanced engineering surface systems. The technical committee is involved in developing standards for ITS.

3 ITS ARCHITECTURE ISSUES

3.1 OVERVIEW OF CANADIAN NATIONAL ITS ARCHITECTURE ISSUES

Identification of issues associated with the application of the U.S. National ITS Architecture within Canada begins with the review of goals and objectives of the U.S. National ITS Program Plan (NPP). Ideally, Canada would undertake a similar exercise to provide a comprehensive top-down structure for ITS deployment in this country. Canada would inherently need to adopt the goals and objectives set out in the NPP for the U.S. National ITS Architecture effort to apply directly. The goals and objectives are:

- Create compatibility and interoperability;
- Create opportunities for Canadian ITS companies in the world marketplace;
- Improve the safety of Canada's surface transportation system;
- Increase the operational efficiency and capacity of the surface transportation system;
- Reduce energy and environmental costs associated with traffic congestion;
- Enhance present and future productivity;
- Enhance personal mobility, convenience, and comfort of the surface transportation system;
- Create an environment in which the development and deployment of ITS can flourish.

These goals and objectives should be reviewed for appropriateness. Issues that might be encountered include:

- **Trans-Canadian and international activity** – It is desirable that the goals and objectives build on the Canadian federal government's role in establishing a seamless transportation network across Canada, north-south corridors, and border crossings.
- **Prioritization of goals and objectives** – It is important that the relative emphasis of the various goals and objectives enumerated for the NPP be reviewed and established to ensure that the Canadian ITS program is directed appropriately.
- **Emphasis on domestic versus international ITS outlook** – Given that the majority of the North American ITS market lies beyond Canada's borders, it is important to Canadian industry and independent service providers that Canada's ITS architecture minimize conflicts and inconsistencies and maximize its competitiveness – especially in the case of border crossings and interoperability within NAFTA.

Many features distinguish the Canadian surface transportation network. These unique features will need to be reviewed thoroughly to determine their impact on the adoption of the national ITS architecture within Canada:

- **Characteristics of the Canadian surface transportation system** – A number of features distinguish the Canadian road and transportation network, including:
  - requirement for bilingual signing and messaging,
  - environmental considerations for ITS equipment,
  - complete adoption of the metric standard,
  - adherence to different traffic control legislation.
- **Compliance of existing ITS infrastructure** – It will be important to determine the levels of compliance of existing ITS infrastructure with the U.S. National ITS Architecture. High levels of non-compliance may require that the U.S. National ITS Architecture be reviewed for minor modifications. Conversely, high levels of compliance will increase the argument for adoption of the U.S. National ITS Architecture and negate the need for costly modifications.

- **Communications infrastructure** – Canada's telecommunications industry and the associated infrastructure have a significant bearing on the development and deployment of ITS in this country. Since the infrastructure, the licensing of frequencies, and the requirements for licensing differ from those of the United States, there may be an impact on the adoption of the U.S. National ITS Architecture and the associated communications components.
- **Institutional/organizational framework** – The Canadian government and transport agencies are organized quite differently from their counterparts in the U.S. Roles, relationships, and procedures differ significantly. The impact of these variances on the information flows, interfaces, and roles will need to be examined.
- **Funding** – The adoption, implementation, and enforcement of the U.S. National ITS Architecture will be at least partially tied to funding mechanisms. In Canada, funding for various transportation initiatives varies substantially from that of our southern neighbour. Funding source(s), availability, and ties to an adopted ITS architecture will need to be reviewed.

3.2 DISCUSSION OF ARCHITECTURE ISSUES

3.2.1 Characteristics of Canadian Surface Transportation

Canada is a country with 29 million people in 100,000,000 km^2 (reference 4, Appendix A). Whereas 12 percent of Americans live in urban areas that have a population of over one million, only 6 percent of Canadians live in the urban centre of three cities that falls within this category. Canada's public road network extends more than 900,000 km. Approximately 35 percent of the network is paved and 57 percent has gravel surface (reference 14, Appendix A). Differences in technology choice or performance requirements exist between the U.S. and Canada. These divergences originate from differences between the two countries, including such issues as environmental concerns, traffic control legislation, and language requirements. The following section will provide a look at examples of areas in the U.S. National ITS Architecture where data flow or process definitions of the logical architecture would require work to ensure that the architecture is suitable for the Canadian context.

3.2.1.1 Language Issues

Canada, as a bilingual country, already has a number of regulatory requirements regarding traffic control signing in both French and English. The U.S. is primarily English and places few, if any, requirements on providing multiple languages for traffic control applications. The requirement for two languages can affect the format/content of information exchange between the control centre and travellers. The information exchange between the ITS subsystems has to allow for users of the ITS services to be able to communicate in the language they prefer. Examples of bilingual issues include duplicate messaging requirement for centre – traveller/vehicle communication, bilingual display requirement for roadside equipment, and bilingual language requirement for centre – centre communication. The following sections provide examples where the need for bilingualism may present itself as an issue in the Logical Architecture.

Centre – Traveller/Vehicle Communication

One of the main issues in the centre – traveller/vehicle communication is the requirement for duplicated messaging, or selective messaging based on stated preference or access in English and/or French. An example found in the U.S. National ITS Architecture that requires further investigation to determine where a bilingual parameter could be inserted is the *incident_description* data flow. This data flow is a sub-data flow under the *traffic_data_for_personal_device* data flow, which provides data on actual and predicated traffic flowing in the road network for output to a traveller's personal device. The data flow travels from the information service provider subsystem to the personal information access subsystem.

In the U.S. National ITS Architecture, the data dictionary entry (DDE) is used to give a textual description of the data flow and identifies any lower level data elements that make up the data flow. The DDE for the incident description defines a predefined dictionary of three characters. This DDE defines the content of the incident description, but does not include a statement to ensure that the language of the predefined dictionary is bilingual. To accommodate the Canadian bilingual requirement, the content of the predefined dictionary would have to be defined to be bilingual through a logical language definition for the *incident_description* data flow.

The issue of a bilingual communication requirement should also be referenced to current standards that support such a requirement. One such standard is the International Travel Information Interchange Standards (ITIIS), which provides 255 messages codes that can be sent to the vehicle, translated on board using canned messages/vocabulary and communicated to the driver in his/her language of choice. Many standards have been developed in Europe to deal with the issue of bilingualism, which is obviously more significant there. ITIIS message sets were produced in English North American, French Canadian, and Mexican Spanish by the Enterprise program, with a host of Canadian, U.S., and Mexican organizations. The U.S. National ITS Architecture is lacking in the use of ITIIS, since it is not a big issue for the U.S. and, furthermore, is not made in America. For the U.S. National ITS Architecture to apply in the Canadian context, it is important that the inclusion of ITIIS as a critical standard be identified.

Centre – Roadside Communication

In some regions of Canada, the roadside equipment used to display messages for the travellers, such as variable message signs (VMS), may have to be capable of showing both English and French messages. However, some provinces use both languages on their messages and others use English or French only. In the U.S. National ITS Architecture, *vms_advisory_text* data flow contains details of the actual advisory text strings that are to be output to drivers and pedestrians using VMS; the advisory text string is defined to give information such as highway open/close, incident warning, and weather warning. Through an assessment of the DDE of all data flow that leads from the centre to the roadside communication for VMS, it is clear that the content of the data flow is provided by the logical architecture. To address the bilingual issues, a definition of the logical language would need to be included in the definition of the VMS advisory text.

Centre – Centre Communication

The bilingual language parameter is crucial to the ability of centre – centre communication. In the Canadian environment, some roads have different English and French names, resulting in different sets of maps. Certain traffic operations personnel use maps that have French-named streets, while others may use English maps. In emergency situations, to facilitate communication, without the need for operations personnel to translate the map names, the interface for centre – centre communication should allow for bilingual road and freeway listings. The U.S. National ITS Architecture defines a data flow called *Map_gazetteer* that contains a list of names of every road and freeway covered by digital map data, for use as the background for display of traffic data requested by traffic operations personnel. In this data flow, a bilingual parameter may be required to ensure that this list provides for both the English and French road and freeway names.

3.2.1.2 Environmental Issues

Much of Canada traditionally experiences extreme weather conditions during both summer and winter months. By comparison, many American states have relatively consistent and generally less extreme weather patterns (e.g., California and Florida). This leads to far less emphasis in the choice of ITS application equipment with respect to environmental considerations. Whereas within the U.S. National ITS Architecture, this aspect may be lightly addressed, a Canadian architecture may need to emphasize these considerations. The COMPASS FTMS in Toronto exemplifies this issue.

The Toronto COMPASS FTMS uses a variety of electronic devices ranging from closed circuit TV (CCTV) cameras to large changeable message signs (CMS) for the purposes of congestion management. Through years of experience, they have developed standardized specifications that place significant emphasis on environmental housing for each of the main electronic components. Electronic component enclosures, including CMS sign enclosures, CCTV camera enclosures, and controller cabinets are all readily equipped with thermostat and both heating and cooling systems. In certain American states, such as California, where they share comparable quantities of the same components, less emphasis is placed on the heating system.

In addition, Canada uses the metric system, while the U.S. uses their own measurement system for speed regulatory control. This may lead to significant differences in traffic control software applications. This concern is especially important with regard to interoperability with U.S. in the eventual adaptation of in-vehicle information systems for centre – vehicle communication. The main issue is related to the fact that the units, whether metric or U.S. system based, are attached to ITS measurements, such as speed, vehicle length, travel time, and weights. Units of measurement provide a reference in the magnitude of the measurement to help travellers understand the significance of the number that is attached to the measurement.

The U.S. National ITS Architecture was examined to ensure that at a minimum, metric units are acceptable for use. However, in one example found in the architecture, the *vehicle_speed* data flow, which defines the measurement of the speed of vehicle detected by a detector on the highway, defines the unit of measurement to be miles per hour (mph) with a maximum output of 127 mph. This data flow definition would not be suitable in the Canadian context. The unit of measurement would have to be changed into kilometres per hour. To ensure interoperability of the U.S. and Canadian ITS infrastructure, the *vehicle_speed* data flow may even have to be defined to allow both units.

3.2.1.3 Legislation

Canada generally adheres to the *Manual for Uniform Control Devices*; however, legislation on traffic control, traffic prohibitions, speed limits, and weight limits does vary with that in the U.S. In some cases, the information required to support a specific legislation is still under development in Canada, while it might already be used in the U.S. For example, the Ontario Ministry of Transportation is in the process of finalizing the carrier safety rating system for commercial vehicle operations. However, the U.S. National ITS Architecture already defines a data flow called *fga_carrier_safety_ratings*, which contains the current safety rating for a carrier determined as a result of previous roadside safety inspection. This is an example where the difference in information requirements to support any particular legislation may affect the adoption of the U.S. National ITS Architecture.

3.2.2 Compliance of Existing Infrastructure

A major issue in adopting the U.S. National ITS Architecture is its significance and relevance to the existing Canadian ITS infrastructure. While it is not within the scope of this report to provide a comprehensive assessment of Canada's existing ITS infrastructure's compliance with the ITS National Architecture, an approach by which to gauge compliance is developed and discussed.

The U.S. National ITS Architecture provides a model for ITS functionality (logical architecture) and a model for physical entities (physical architecture), and establishes interfaces, data flows, and communications requirements. In addition, performance evaluation elements are incorporated into the architecture description.

An evaluation of compliance will compare, contrast, and analyse the relevant design for individual Canadian ITS initiatives with the U.S. National ITS Architecture. For the purposes of this report, we have chosen an example to illustrate the compliance evaluation process. It is the COMPASS system, implemented by the Province of Ontario for major freeways in the Greater Toronto Area. This ITS initiative is well known and significant within the North American ITS landscape. It involves more than a decade of ITS deployment experience and activity.

The basic components of the ITS architecture that are relevant to the COMPASS project include:

- **Functional components** – Detailed descriptions of the system capabilities and characteristics for each of the functions identified within the ITS architecture (e.g., the function associated with signal and ramp meter co-ordination is found under Manage Traffic, Provide Device Control functional description; this process is responsible for implementing the selected control strategies on some or all of the ramps on the control road and highway networks).
- **Communications components** – Description of the communications requirements needed to support the data and information flows associated with ITS architecture functions (e.g., for interjurisdictional computer linkages, the physical architecture requires that the communications infrastructure support regional TOC, TOS, and control centres being connected electronically).
- **Evaluation components** – The ITS architecture requires various undertakings and activities associated with the ongoing evaluation of ITS initiatives (e.g., establishment of the effectiveness of an ITS initiative requires development and approval of an evaluation plan methodology, cost analysis, analysis of non-technical issues, incorporation of traffic modelling and communication modelling, and evaluation plans associated with enhancement and expansion of the system in order to prove the effectiveness of various elements and the overall system).
- **Performance components** – Identifies requirements for system and subsystem performance (e.g. maximize person throughput – use of various evaluation components to establish and quantify the increase in person throughput at a given location).
- **Other components** – Cost and other items associated with the ITS architecture.

The sample review of the COMPASS system incorporates functional, communication, and performance/evaluation components. Appendix D provides the case study review for COMPASS. As can be seen from section 6, for the most part, the COMPASS system complies with the ITS architecture. It should be stressed that this comparison was done for illustrative purposes and to demonstrate the output and types of issues that will be encountered in the application of the national ITS architecture within Canada.

3.2.3 Communications Infrastructure

Many current and upcoming ITS products or services rely on wireless communication systems as fundamental components of their operation. The Canadian Radio-Television and Telecommunications Commission (CRTC) and the Federal Communications Commission (FCC) in the U.S. oversee the frequency allocation in either country in a manner that most adequately addresses the needs of both public and private sector agencies. This results in variances between the radio frequency spectrum allocation between the U.S. and Canada. The digital audio broadcasting (DAB) system serves as an example of such difference.

DAB is a wireless audio and data transmission system developed for point-to-multipoint data broadcast applications. A number of ITS agencies worldwide are considering applications that use DAB for traffic information broadcasting, as well as GPS system integration. Canadian broadcasters have adopted the Eureka 147 system and the CRTC has allocated L-Band frequency for this application. The U.S. is currently considering its own proprietary in-band on-channel (IBOC) system for DAB transmission, which would make use of the existing AM/FM frequency allocations. These potential differences in spectrum allocation and communication protocol may lead to significant differences in the overall standards or requirements for any future DAB ITS applications.

3.2.3.1 Philosophy

One of the fundamental guiding philosophies in developing the U.S. National ITS Architecture was to leverage the existing and emerging transportation and communication infrastructures. This was to maximize the feasibility of the architecture, and to mitigate the risk inherent in creating and offering intelligent transportation systems, services, and products, all of which are quite new and in need of acceptance. This flexibility reduces the constraints on the communications services that may otherwise be applicable to the Canadian implementation of the national architecture.

The communication architecture definition adopted the same philosophy. It starts from the basic network functions and building blocks and proceeds to the definition of a network reference model, which identifies the physical communication equipment (e.g. base station), to perform the required communication functions and the interfaces between them. These interfaces are the most salient element of the model from an ITS perspective; some of them should be standardized to ensure interoperability.

Because of the variances in the ITS user service requirements (from a communication perspective), it is clear, even from a cursory examination, that the user services do not share a common information transfer capability. Specifically, ITS user services such as ETC demand communication needs that can only be met by dedicated infrastructures with the applicable technical characteristic, notwithstanding institutional, reasons.

3.2.3.2 Communication Architectural Goals

The goals of the U.S. National ITS Architecture’s communications component may be summarized as an architecture that will:

- support communication services, which include voice (speech), data, image, video, and signalling;
- accommodate a wide variety of terminals, i.e., fixed, portable mobile, and in-vehicle mobile;
- preserve upward/downward terminal compatibility;
- allow mobile and fixed users to use the services regardless of geographical location (i.e., seamless communication);

- provide service flexibility, so that any combination of services may be used;
- make efficient and economical use of the spectrum;
- provide user authentication and billing functions;
- provide varied degrees of network security that preserve user privacy;
- have modular structures that will allow the systems to start from small and simple configurations, then grow as needed in size and complexity;
- use an open architecture that will permit the easy introduction of technology advancement and support of new applications.

These goals will enable ITS users to share scarce and valuable resources, and distribute their cost over a significantly broader population. By embracing the heritage of the broad telecommunications industry, the cornerstone of whose success has been fulfilling users' needs and meeting with their acceptance, ITS will be on the right path towards a wide-scale presence. This evolutionary approach is essential to maximizing the feasibility of the architecture, and to mitigating the risk inherent in creating and offering ITS services, and products, all of which are quite new and in need of acceptance.

3.2.3.3 Canadian Implementation Issues

Three levels of ITS services that have the most direct impact on the communications architecture and integrity were identified in a report by ADGA Systems International Ltd. on the assessment of communication needs and standards for IVHS. These services included general advisory services that are broadcast to all users (e.g., highway advisory radio), specific guidance services that are interactive on a voluntary basis, and control services that are interactive with users on a non-voluntary basis provided as a part of in-vehicle navigation systems. The technological considerations in providing these communication requirements are wireline and wireless communications.

Technology Considerations

Wireline Services

The wireline architecture is not considered to impose any constraints on the manner in which it would be implemented in Canada from a technical perspective. Many options are available; they include:

- existing copper backbone which, due to recent enhancements made possible by developments by Nortel and others, can now support data rates considerably greater than those required by most ITS services;
- fibre-optics, which is rapidly becoming available as local networks as well as providing economic long-distance services;
- multipoint microwave systems;
- RF cable, as used by the cable TV industry.

Wireless Services

The physical layers of the wireless systems are of greater significance to the ITS user than the wireline layers. The user end of the wireless component will often be owned, or maybe leased, by the ITS user and, for the most part, will be fitted in the vehicle if not carried by the user. As a consequence, it will be desirable to minimize the number of different equipment necessary to carry as the vehicle or user traverses different ITS service areas or accesses different ITS service providers.

Wide Area Services

Broadcast

It could be expected that most vehicles will subscribe to some form of broadcast service, if only for entertainment purposes, and that this service will be required as vehicles travel over large areas. It is therefore an obvious candidate for the distribution of ITS traffic to a very large number of users. It should be remembered, however, that the broadcast traffic is not user specific and that some form of intelligent filtering at the vehicle will be desirable if the broadcast means of distribution is not to suffer neglect resulting from information overload.

The broadcast industry is currently exploring means by which it may deliver improved and expanded services, and a number of candidate technologies are becoming available. They fall into two categories:

- **Standard analogue FM sub-carrier broadcasting.** The U.S. is considering two implementations: data radio channel (DARC) and subcarrier traffic information channel (STIC). Recent announcements by the Consumer Electronics Manufacturers Association (CEMA) appear to indicate that DARC will be favoured and will become the sub-carrier method of providing ITS services. This will become specification EIA-794, which is largely based on the European Radio Data Service (RDS), which has been used for ITS services for several years. RDS has a number of near term, low data rate (~1200 baud) capacities, such as text and program type information. Canadian manufacturers and broadcasting organizations are investigating the possibility of using the radio data system-traffic message channel (RDS-TMC) to provide traveller information via an FM subcarrier.
- **DAB.** DABs have been developed in Europe (Eureka 147) that can carry multiple (five) audio channels plus high capacity data channels. They are well suited to the European environment where several broadcast channels may be supplied by a single broadcast agency. This has raised opposition in the U.S., particularly among small broadcasters, because of a lack of capital funding that would be required and concerns about loss of market share to the larger, more technologically capable broadcasters.

Recent announcements by the FCC will likely allow the introduction of these new technologies in the U.S. within the foreseeable future. The huge inventory of legacy equipment and the restricted availability of frequency assignments will influence the rate of implementation of either technology. It is not likely, therefore, that the new technologies would enjoy widespread coverage for a number of years. The potential of the new digital technologies, which will have extensive capability, will most likely hinder the commercial implementation of sub-carrier systems onto the existing analogue technologies for the purpose of carrying ITS traffic, and this may also hinder the use of broadcast transmissions for ITS purposes.

Two-Way Wide Area

Two-way wide area services fall into two categories:

- public, as typified by cellular radio services and personal communications services (PCS);
- private, as typified by radio dispatch services.

The almost ubiquitous use of cellular radio services makes them an obvious carrier of choice for ITS communications. Several competitive system standards have evolved in the cellular and personal communications services, which again complicates the selection of radio equipment used by the ITS user. Early generations of cellular radio systems use circuit-switching principals to allow subscribers time-shared access to a shared group of radio channels. The circuit switching is not efficiently compatible with the short transactions associated with ITS architecture's short message structure. Later generation systems using time division multiple access (TDMA) and code division multiple access (CDMA) techniques can allow short messaging and may be more suitable techniques for carrying ITS communications. Traffic studies show, however, that the traffic load due to ITS will be small relative to the other voice and data communications carried by cellular networks. It can therefore be anticipated that ITS would not be treated as a special service by the cellular communications service suppliers and would have to be accommodated using the specific formats and protocols applicable to the host system.

The announced settlement between Ericsson and Qualcom concerning the intellectual rights to the CDMA technology is forecast by industry observers to clear the way for a common CDMA standard that would then be the most likely candidate for a single international standard. Further investigation of the outcome of the Ericsson and Qualcom settlement would appear to be warranted.

Typically, users of dispatch type services are dedicated vehicles that are used extensively throughout the day and have a high value for time. The economic payback to these vehicles due to the use of ITS is probably higher than for any other class of vehicle. The service areas covered are often limited to city or regional levels rather than the long-distance requirements of many heavy commercial vehicles.

Dispatch radio systems are still primarily analogue systems and require external modems to facilitate data communications. As digital technology developed for cellular systems becomes less expensive, transition to digital transmission will probably occur. At such time, the dispatch radio systems would provide an efficient means of ITS communications to these high value users. As these systems will in most cases remain private, the overall ITS traffic volume carried by each system will be small and some form of intelligent gateway between the dispatch radio and the ITS service provided will probably be required.

Short Range

Although the early stages of the U.S. architecture study discontinued the idea of an all-encompassing short-range communications system, short-range communication was recognized as an essential component of the triad of communications services. Essentially, it was reserved for applications that were very location specific, such as electronic toll collection, commercial vehicle management and enforcement, parking lots, and border crossings – hence the reference: dedicated short-range communication (DSRC). Approximately eleven million mobile units (called transponders, although most are actually transceivers) are in circulation in North America. All use the 915 MHz band and almost two thirds are active transceivers as opposed to backscatter transponders. Canadian manufacturers currently supply most of the DSRC units sold in North America. There are two competing technologies: one passive and one active. For the purpose of interoperability, the Canadian DSRC interim standards only support the more advanced and capable active technology. However, there has been, particularly in the U.S., a proliferation of proprietary incompatible specifications in the 900 MHz ISM band, which has become common for toll applications. Proponents of a North American multi-applications standard look at the proposed 5.8 GHz frequency allocation and the proposed 5.8 GHz standard development as the solution for wide interoperability within five to ten years. Meanwhile, NAFTA countries have signed an agreement to use an interim standard for commercial vehicle operations (same as the Canadian Interim Standard). This standard has been implemented by various CVO corridors (HELP states, North West Green program states, I-75 states, AVION/Ontario), border crossings on the Canada/U.S. and U.S./Mexico borders, and Highway 407 in Ontario.

Another important development in the field of short-range communications systems that may affect ITS is the system known as Bluetooth, which is being developed by a major consortium of companies in the

U.S., Europe, and Japan. Unlike many of the 900 MHz and 5.8 GHz systems, this will be a worldwide open standard operating in the 2.4 GHz frequency range. In addition to providing the physical layer of the ISO communications protocol stack, Bluetooth provides all layers, but misses the application layer (normally provided by the computers it links). Bluetooth's main application is wirelessly connecting computers, peripherals, and other electronic devices in a short-range area.

Specifically of interest to many users, it provides very high security with high-level encryption and an even higher level of authentication. Bluetooth will support multiple users (up to seven) in a small space without interference, voice and data communications, and direct interfaces to the application layer. With projected sales volumes of over 500 million per year, Bluetooth will be embedded in all computers, cell-phones, and many other electronic devices. With ranges of 10 to 100 m, depending on power output and antenna, it has the potential to be a suitable and cost effective form of short-range ITS communications. A short description is attached in Appendix E.

Vehicle – Vehicle

Many vehicle – vehicle communications concepts have assumed the use of much higher frequencies. A number of these higher frequency bands could, in addition to communications, support applications such as short-range distance measurement. As these systems become available, it is possible they would be used in either in a purely autonomous anti-collision mode or a co-operative anti-collision mode. When operating in an autonomous mode, there would be very little impact on the means of implementation. For co-operative anti-collision purposes, as may be used in car-train applications, it is clear that a universal standard will be necessary. The development of this standard will probably be undertaken in the automotive industry.

3.2.3.4 Institutional Issues

Institutional issues can arise from organizational, funding, and legal requirements. The need for inter-agency co-ordination, capital and ongoing funding, and determination of liability and intellectual property can be barriers to deployment. Institutional issues must be resolved to provide the best communication infrastructure to support ITS.

Wireline Services

The change from the highly regulatory environment to the present open competition has removed many of the difficulties that would previously have been faced with the provision of ITS communications services, as almost any service may be interconnected onto the existing infrastructure. This capability allows not only the interconnection of technically different services, but also independent service providers. Thus, many constraints have disappeared.

Perhaps the biggest issue will be that of demand. Unless there is sufficient demand, neither the large general-purpose service providers nor small dedicated ITS services providers will be economically sustainable. It may therefore be necessary for the public sector to initially subsidize these services either directly or by granting rights of way along roads and other desirable routes.

Wireless Services

Broadcast

Unlike the U.S., Canada has one strong national public broadcaster, as well as many smaller commercial broadcasters. This situation creates a possibility that the publicly funded CBC could offer country-wide ITS services, a capability not so easily facilitated by the commercial broadcasters. However, as commercial broadcasters probably enjoy a wider audience, it is highly desirable that ITS services be provided by both the public and commercial broadcasters. Although initially there has been useful co-operation between public and commercial broadcasters, care will be necessary to ensure that economic and competitive factors are harmonized and do not create conflicts among the different broadcasters.

Two-Way

As most two-way wireless services are either private or are provided by the highly competitive cellular communications service providers, regulatory issues are not expected to be related to the two-way communications. The biggest issue is likely to be related to liability: who is responsible if a vehicle, acting with ITS information, is delayed by traffic conditions or involved in an accident. A second issue will be how to ensure that ITS service providers have an equal or some other agreed level of access to the ITS information available from transportation agencies.

Communication Architecture Issues

A commercial wireless data network is available today to meet the projected ITS requirements. Future wireless data networks and commercial wireless networks in general will be even more capable and will place few technical constraints on the means of implementing an ITS architecture in Canada that is interoperable with the U.S. National ITS Architecture.

With the capacities achievable today with fibre, whether leased or owned, wireline performance adequacy is not really an issue. The key issues, therefore, pertain to the costs of installation and sustained operation for any given ITS deployment scenario.

Issues that need to be pursued in determining the appropriateness of U.S. National ITS Architecture in Canada include:

- growth from 900 MHz to 5.8 GHz DSRC;
- liability issues related to traffic information made available over public radio services;
- digital radio standards to be used for broadcasting in Canada and North America;
- future development of CDMA standards for cellular and PCS.

3.2.4 Stakeholders

There are five main stakeholder groups in Canada: federal, provincial, and municipal governments; academia; private sector transport service providers; ITS suppliers and manufacturers; and users. Various federal departments, such as Transport Canada, Industry Canada, Environment Canada, and the Department of Foreign Affairs and International Trade (DFAIT), are involved. Transportation ministries of each province are the stakeholders representing the provincial governments. Transport and public works departments typically represent municipal government interests.

The federal government is responsible for ensuring that national standards and regulations are in place to assist in providing a seamless transportation system. The federal government departments that have been most active in ITS are Transport Canada and Industry Canada. They have been involved in reviewing ITS technologies and policy in a high-level assessment of the ITS industrial base in Canada. Transport Canada's mission is to "develop and administer policies, regulations, and services for the best possible transportation system for Canada and Canadians". Industry Canada's mission is to foster a growing competitive, knowledge-based Canadian economy. Environment Canada and DFAIT are also involved in ITS. Environment Canada is a stakeholder because ITS traffic management and traveller information systems deliver energy and emissions savings. DFAIT is important in ensuring that trade and investment agreements for ITS products and services are negotiated on behalf of Canadian stakeholders in the international arena.

Provincial governments are responsible for regulating and licensing both commercial and private vehicles. They also collect gasoline tax to offset some of the costs associated with licensing and regulating vehicles. The provincial transport ministries are active in various aspects of research, development, and implementation of ITS initiatives, such as traffic, transportation management on provincial highways, commercial vehicle operations, and overseeing of some toll highways.

Municipal governments are responsible for ITS on urban, rural, and arterial roads within their jurisdiction. They are also responsible for the provision of public transit through transit authorities. Traffic and transportation management services provided by municipal governments include traffic control systems, arterial road traffic management, and emergency services. Business licences, such as taxi permits, are obtained through municipal departments.

The ITS industry provides products and services for the delivery of ITS initiatives. Many companies or agencies are offering ITS products used for the development of the ITS system infrastructure. For example, some ITS companies are involved in providing communication technologies, such as cellular, DSRC, wireline, and DAB. Other companies or agencies offer ITS services. In addition, ITS services, such as commercial vehicle pre-clearance, can be used for a variety of applications, such as automated assistance for customs and immigration processes at border crossings.

ITS Canada provides a forum for Canadian ITS participants across the country to share the latest information on ITS developments in Canada and abroad. ITS Canada's mission is to promote the application of ITS in Canada.

Table 3-1 summarizes the proposed action plan (reference 4, Appendix A) for Transport Canada, Industry Canada, and ITS Canada to act as leading agencies in the development of ITS market strategies, technology intelligence, industry development, and standard setting. The roles of the supporting agencies do not necessarily suggest additional resource requirements, rather a specific set of actions that may take place in the context of their normal function and/or administrative structure as part of the overall action plan.

Table 3-1: Proposed Action Plan

Action Plan	Supporting Agencies
Leading Agency: Transport Canada	
Foster/provide showcase opportunities for Canadian industry and expertise	Industry Canada ITS Canada Revenue Canada Immigration Canada Finance Canada provincial governments municipal governments
Monitor the evolution of enabling technology, particularly overseas	Industry Canada, ITS Canada, industry, universities, NRC
Promote government to government relations in ITS technical matters, particularly with U.S.	Industry Canada, DFAIT, provincial governments
Provide technical support for product development and showcasing support to Canadian industries in ITS project development efforts	Industry Canada, NRC, CRAD, TC/TDC, universities, provincial governments, municipal governments, federal agencies
Participate in international standards setting activities, such as the ISO, NTCIP, ASTM, CEN	CSC, Industry Canada, industry, CRC, NRC, ITS Canada
Encourage Canada/U.S. co-ordination and co-operation for ITS-related standard setting within North American context	Industry Canada, industry, ITS Canada, CRC
Leading Agency: Industry Canada	
Identify international opportunities for Canadian ITS technology suppliers	Transport Canada ITS Canada DFAIT, CIDA
Assist industry in pursuing market opportunities	DFAIT, CIDA, provincial governments CCC, EDC
Ensure internal co-ordination within government with respect to ITS-related sector interest	Transport Canada
Provide partnered research support programs	Transport Canada universities, NSERC, NRC (IRAP), TPC Program
Leading Agency: ITS Canada	
Co-ordinate/foster international profile of Canadian ITS capabilities	Industry Canada, Transport Canada
Provide advice to the government on actions required to promote and develop Canadian ITS industrial base	Industry, universities, provincial governments
Provide advice to the government on ITS standards requirements	CRC, industry, ITS technology users ITE, CSCE, TAC, CUTA, CTA

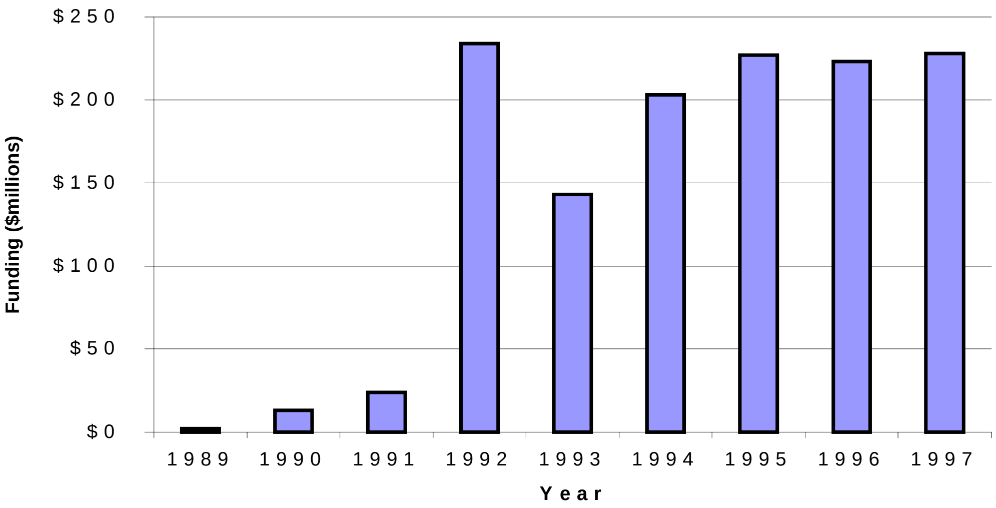
3.2.5 Funding

ITS projects in the U.S. have been funded by the U.S. government since the early 1990s with the provisions of the 1991 Intermodal Surface Transportation Efficiency Act (ISTEA), which allowed for funding of $6.66 billion (reference 8, Appendix A). The U.S. DOT's regular budget includes the provision of ITS program expenditure. A summary of centrally provided public funding for ITS programs for U.S. ITS research and development and deployment is provided in Figure 3-1 (reference 4, Appendix A). The Canadian federal government has committed money for ITS through R&D programs. Provincial and municipal governments have committed funding for ITS through transport programs and special projects.

As part of the TEA-21, U.S. DOT provides funding for ITS through the ITS Deployment Program, which contains two components, including the ITS Integration Program and the Commercial Vehicle Intelligent Transportation Infrastructure Deployment Program, commonly known as the Commercial Vehicle Information Systems and Networks (CVISN) program. For the Fiscal Year 2000, $80 million in federal ITS funding has been allocated for the integration of multimodal ITS components in metropolitan areas, rural areas, or in statewide, multi-state, or multi-city settings. Federal ITS funding of $30.2 million has been allocated to improve the safety and productivity of commercial vehicles and drivers and to reduce costs associated with commercial vehicle operation and regulatory requirements for the CVISN program.

The Canadian ITS deployment program does not reflect these funding sources. No current funding is allocated specifically for ITS deployment at a federal level. However, it should be recognized that several programs at the federal level could potentially support ITS funding. For example, the Natural Sciences and Engineering Research Council of Canada (NSERC) offers opportunities for Canadian industries to develop ITS infrastructure and technology, by jointly funding collaborative R&D projects with scientists and engineers in universities. Another example is the Industrial Research Assistance Program (IRAP), which involves research collaboration with Canadian industry through the NRC/NSERC Research Partnership Program. Other potential partners include DFAIT and Environment Canada. Two DFAIT mandates of particular interest to ITS planners are: to "co-ordinate Canada's economic relations" and to "foster expansion of Canada's international trade". These mandates showcase the need for DFAIT to support Canadian ITS products and services through funding to enhance Canada's ability to compete on the international front. Environment Canada is a potential funding partner through its Green Program.

Figure 3-1: U.S. Federal Government ITS Research and Development and Deployment Funding



The issue of funding is fundamental to the implementation and co-ordination of ITS programs. To ensure that funding is available to assist in ITS deployment, a Canadian national ITS program is needed. Only by committing ITS funding can a consistent and interoperable national ITS deployment be assured. The U.S. has committed funding of over $200 million per year of federal funding since 1994 for ITS projects. Based on the ratio of our country's population, funding of some $25 million per year would be warranted for Canadian ITS.

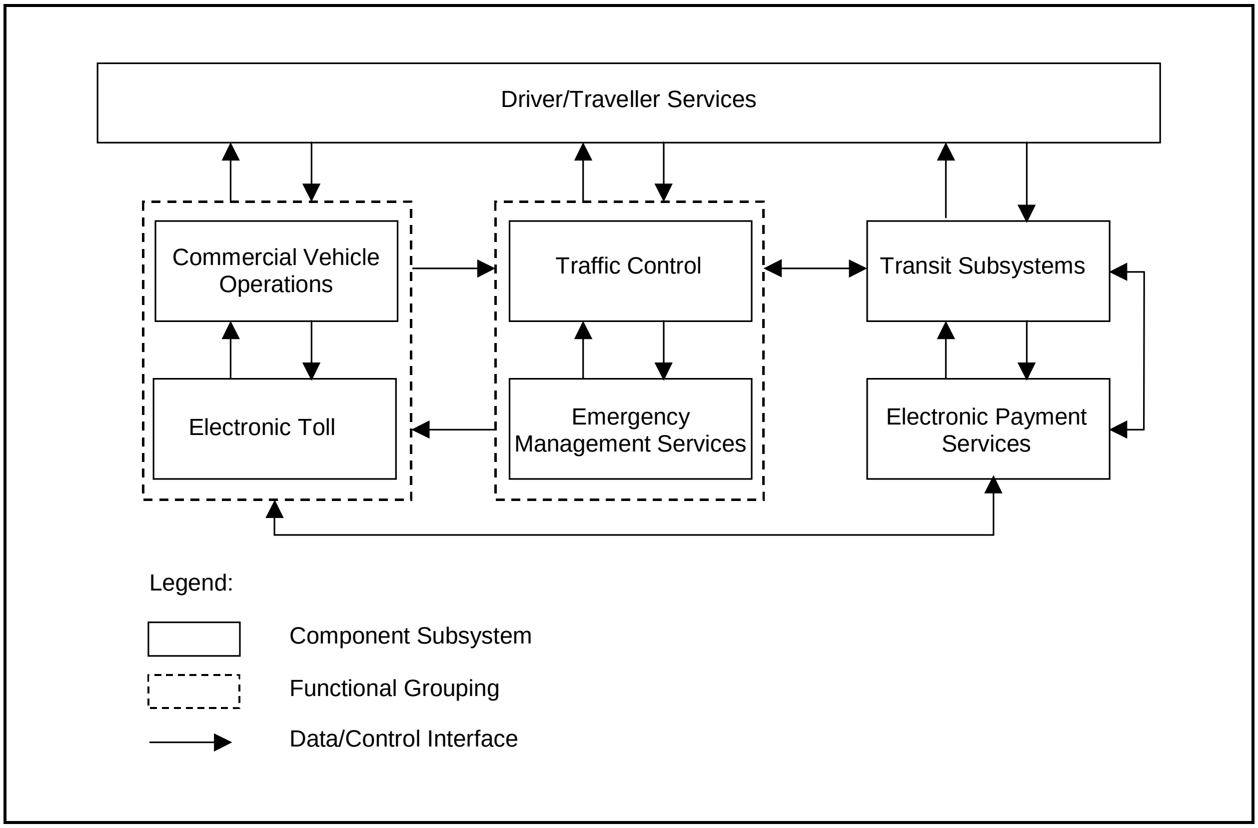
3.3 CANADA'S ITS NATIONAL ARCHITECTURE

3.3.1 Reviewing an Alternative Architecture

The U.S. National ITS Architecture contains extensive documentation that is highly suitable in the Canadian context. The system architecture offers a framework for a system design. A starting point in developing the design is to look at the architecture at a conceptual level and to identify examples of various ITS deployments.

A partially decentralized architecture that reflects, for example, the commonalities between commercial vehicle operations and electronic toll is shown in Figure 3-2. This is an example where related logical functions can be grouped.

Figure 3-2: Proposed Alternative Architecture



A comprehensive study will be required to identify the candidate architecture that best suits the Canadian environment.

3.4 ACTIVITIES REQUIRING FURTHER INVESTIGATION

The following is a short list of some of the issues that need to be addressed to determine the suitability of the U.S. National ITS Architecture in the Canadian environment. These issues are categorized into “Canadian context”, “institutional”, and “communication” issues.

3.4.1 Canadian Context

- Provide resources to showcase and demonstrate advanced ITS technologies.
- Encourage ITS technologies that provide immediate “bottom-line” payback to users, such as commercial vehicle and electronic tolling, to accommodate resource constrained environments.
- Provide an ITS architecture that is suitable to mid-size cities, since only three cities (reference 4, Appendix A) in Canada have populations of over one million.
- Provide provisions in ITS subsystem equipment standards requirements to ensure that equipment used is suited to Canadian climatic conditions and maintenance techniques.
- Ensure that standards allow for interoperability of ITS systems across North America.
- Create incentives to develop domestic ITS demand through advocacy and product differentiation.

3.4.2 Institutional Issues

- Ensure that a national co-ordinating (not dictating) mechanism is formed to guarantee that all sectors are involved in the architecture development.
- Build a true government-industry partnership on ITS.
- Identify and provide catalytic funding to support ITS activities in Canada at all levels of government.
- Promote international co-operation and co-ordination to allow for new market opportunities for Canadian ITS industries.
- Raise the profile of ITS and its potential benefits, promote the vitality of Canadian ITS industries, and participate in standards-setting activities through government co-ordinated initiatives.
- Resolve legality, liability, privacy, and security concerns.

3.4.3 Communication Issues

- Identify the ITS communication service providers and regulators.
- Determine appropriate frequency allocations for ITS throughout Canada. Combine elements of the required communication service categories into a unified ITS service category with its own frequency allocation(s).
- Facilitate frequency assignments such that the spectral requirements for the highest levels and densities of ITS services are minimized, thereby enhancing the possibility of seamless ITS services throughout Canada and, preferably, North America.
- Encourage competitive industries to provide ITS communication services that are highly reliable and widely available.
- Consider the expansion of ITS protocols in the user terminals to include infrastructure and network layer protocols.
- Determine the mechanism and agencies that will resolve the communications standards applicable to ITS to ensure interoperability across ITS systems.

3.5 STEPS TO DEVELOPING A CANADIAN ITS ARCHITECTURE

- **Develop a vision statement for Canadian ITS deployment** – Similar to the U.S. architecture, the vision statement should provide direction to Canadian ITS deployment for the next twenty years. It should demonstrate how the ITS architecture might help to bring the vision to reality.
- **Confirm applicable ITS National Architecture definitions** – Confirm applicable definitions, such as ITS user services and user bundles. The suitability of processes and data flow definitions for the Canadian environment should also be examined.
- **Investigate issues** – Investigate issues such as institutional framework, interoperability, communications, bilingual requirements, and metric referencing to ensure that areas in the U.S. architecture that are not suitable in the Canadian environment are addressed.
- **Develop alternative solutions** – Provide alternative solutions to adapt the U.S. ITS architecture into a Canadian ITS architecture.
- **Analyse solutions** – Use showcase examples to ensure that the solutions satisfactorily resolve the issues.
- **Recommend regional variations to the U.S. National ITS Architecture** – Assess ITS deployments at a regional level. Establish boundaries for regional deployment to facilitate seamless ITS deployment.
- **Define roles/responsibilities** – Clearly define the roles and responsibilities of all stakeholders to ensure efficient ITS deployment.
- **Develop implementation/funding plans** – Develop strategies for implementing ITS services in a phased approach, along with plans for funding.

4 CONCLUSION

The U.S. is currently involved in standards development activities and ITS project deployment consistent with their national ITS architecture. Current activities include the development of a list of critical standards, a guideline for U.S. National ITS Architecture conformity, and regional architectures. The U.S. National ITS Architecture provides at a high level an ITS system architecture that is compatible with the Canadian ITS infrastructure. An opportunity exists for Canadian ITS planners to use the U.S. National ITS Architecture as the basis for the Canadian national ITS architecture.

Canada is already active in the ITS services bundles defined by the U.S. program – except for advanced vehicle control and safety systems – with Ontario, Quebec, and British Columbia taking the lead. The case for the development of a Canadian ITS architecture is growing, especially with the need to ensure that ITS deployments have interoperability across the country and into the U.S.

The issues identified in this study should offer a starting point for the development of a Canadian national ITS architecture. The key issues regarding the development of the Canadian ITS architecture include the suitability of the U.S. program and the institutional communication requirements for Canadian ITS infrastructure. Factors such as the bilingual language requirement, not identified by the U.S. program, must be defined in the Canadian ITS architecture.

APPENDIX A
ITS REFERENCE MATERIAL

The following relevant documents have been assembled and reviewed by IBI Group.

REPORTS/DOCUMENTS

1. TEA-21: Interim Guidance on Conformity with National Architecture and Standards, December 1998

2. "Proposed Criteria and Draft List of Critical ITS Standards", Federal Highway Administration, December 1998

3. U.S. National ITS Architecture, Version 2.0
www.odetics.com/itsarch/

4. Strategy for Developing an ITS Industrial Base in Canada, Industry Canada, December 1996

5. Benefit-Cost Assessment of Intelligent Transportation Systems (ITS) – Implementation in Canada: Summary Report, Transportation Development Centre, TP 12936, October 1996

6. ITS Communications Infrastructure Implementation Strategy, Final Report, Transport Canada, December 1996

7. Communications Working Group Technical Report on ITS Communications Infrastructure, Final Report, Transport Canada, November 1996

8. North American Intelligent Transportation Special Report, Janes's Information Group, 1996

9. Assessment of Communications Needs & Standards for IVHS, Transport Canada, 1994

10. Waltho A., Chandan A., "Candidate Communication Architecture for the Development of ITS in Canada", Proceedings of the 1996 Annual Meeting of ITS America, Houston, Texas, April 15-18, 1996

11. Johnson, W., "Intelligent Transportation Systems in Canada: Current Priorities and Future Directions", Proceedings of the Second World Congress on Intelligent Transport Systems, Yokohama, Japan, 1995

12. National Inventory of IVHS Programs and Related Activities in Canada, Transport Canada, December 1994

13. Ontario ITS Products and Services Inventory Version 1.2, Ontario Ministry of Transportation, May 1998

14. Transportation in Canada 1996 Annual Report, Transport Canada, 1996

15. Giezen, J., Blonk, J., Jesty, P., "Reference Models for a Transport Telemetric System Architecture", Proceedings of the Second World Congress on Intelligent Transport Systems, Yokohama, Japan, 1995

16. “Analysis of MDI Incident Management Message Set for Traffic Management Subsystem to Other Traffic Management Subsystem Communications”
www.its.dot.gov/its-mdi/private/arch-stds/imarch.htm

17. “Development of Traffic Signal Control Systems Using the National ITS Architecture”, U.S. DOT Intelligent Transportation Systems Joint Program Office, February 1998

18. “Intelligent Transportation Systems (ITS) Opportunity”
www.its.dot.gov/arch/execsum.htm

19. “Introduction to the National ITS Architecture and Standards Resource Guide”
www.its.dot.gov/aconform/rg-toc.htm

20. “Minutes of the Metropolitan Model Deployment Initiative Participants Workshop”, November 18-21, Flushing, N.Y. 1997

21. “National ITS Architecture Team Support for Model Deployment Initiatives”
www.its.dot.gov/its-mdi/public/arch-stds/mdi4pagr.htm

22. “Overview of the National Architecture”
www.its.dot.gov/arch/overview.htm

23. Architecture Development Team, “Standards Requirement Packages Abstract: Information Service Provider to Traffic Management Subsystem and Information Service Provider to Transit Management Subsystem”, Federal Highway Administration
www.its.dot.gov/its-mdi/private/arch-stds/stdreqpa/isptmt.htm

24. Developing Freeway and Incident Management Systems Using the National ITS Architecture, U.S. DOT Intelligent Transportation Systems Joint Program Office, August 1998

25. Developing Intelligent Transportation Systems Using the National ITS Architecture: An Executive Edition for Senior Transportation Managers, U.S. DOT Intelligent Transportation Systems Joint Program Office, July 1998

26. Developing Traveller Information Systems Using the National ITS Architecture, U.S. DOT Intelligent Transportation Systems Joint Program Office, August 1998

27. Electronic Toll & Traffic Management (ETTM) User Requirement for Future National Interoperability, Draft Version 3.1a, ETTM User Group, ITS America, June 1995

28. Euler, G., Robertson, H., National ITS Program Plan, Synopsis, First Edition, ITS America, March 1995

29. Euler, G., Robertson, H., National ITS Program Plan, Volume I, First Edition, ITS America, March 1995

30. Euler, G., Robertson, H., National ITS Program Plan, Volume II, First Edition, ITS America, March 1995

31. Ice, R., "Model Deployment Location Referencing: Scope of LRMS Application in the Model Deployments", Draft, Rockwell International, March 1997 *www.its.dot.gov/its-mdi/private/arch-stds/mdiscope.htm*

32. ITS Architecture Development Program Summary Report: Phase I, ITS America, November 1994

33. ITS Deployment Guidance for Transit Systems Executive Edition, Federal Highway Administration, April 1997

34. The National Architecture for ITS: A Framework for Integrated Transportation into the 21st Century, US DOT

PRESENTATIONS

35. "Dialog on Data Requirements", Volpe Centre

36. "Integration: Concepts and Measures", Volpe Centre

37. "ITS Standards Update", Architecture Development Team, November 19, 1997

38. "San Antonio TransGuide Model Deployment Initiative Status Update, November 19, 1997

39. "Seattle Status Report: Smart Trek", MMDI Quarterly Workshop, Flushing, N.Y., November 18-19, 1997

40. DeBlasio, A., John, A., "Institutional Benefits Study Update: Positive Approaches to MDI Deployment" Volpe National Transportation Systems Centre, MMDI Workshop, November 19, 1997

41. Dellenback, S., "San Antonio TransGuide Model Deployment Initiative Common Software Architectures for ITS Applications", Southwest Research Institute

42. Goodspeed, C., Metropolitan Model Deployment Initiative: Evaluation Progress Report, New York Workshop, November 19-20, 1997

43. Peters, J., "Indicators of Metropolitan ITS Infrastructure Deployment: Comparing Some MMDIs with National Averages", ITS Joint Program Office

44. Sweeney, L., "Marketing ATIS Products and Services: One Private-Sector Perspective: A Pragmatic Approach", ETAK Inc.

APPENDIX B
U.S. ITS ARCHITECTURE DOCUMENT SUMMARIES

Category	Information Contained for Each Document Category
Executive summary	• An overview of the most important aspects of the national architecture
Architecture definition	• Vision statement – possible scenarios of ITS development over the next 20 years • Mission definition – overall mission of ITS deployment, as well as the operational concepts and requirements • Logical architecture – description, process specification diagrams that show processes and associated data flows, and data elements • Physical architecture – flow diagrams that show data passing among physical subsystems, and provide characteristics and constraints on the data flow • Theory of operations – details how architecture supports ITS user services • Traceability matrix – technical document listing all the user services requirements that define the highest level functional specification for ITS
Evaluation	• Communication document – analysis of the communication requirement and discussion of options for implementing various communication links • Evaluatory design document – evaluation of three conceptual scenarios at various points in time based on performance, benefits, and costs • Cost analysis document – cost estimate associated with ITS component implementation and unit prices and systems costs for ITS subsystems • Performance and benefits study – technical performance related to system-level and operational-level criteria • Risk analysis document – potential critical risks that may delay or prevent the deployment of ITS technologies, and mitigation plans recommended for reduction or elimination of risks • Evaluation results document – summary of various evaluations documented in the evaluatory design, communications analysis, cost analysis, performance, and benefits and risk analysis documents
Implementation strategy	• Process for implementing ITS services, including recommendations for future research and development, operational tests, standards activities, and training
Standards	• Standards requirement document – set of 12 standards requirement packages detailing data flow and interface information • Standards development plan – issues involved in the development of system interface standards

APPENDIX C
INVENTORY OF ITS INITIATIVES

System	System Description	ITS User Service Bundle
British Columbia		
Route 123 AVL demonstration project, Vancouver	Demonstration project using GPS based with differential correction to provide real-time monitoring for 12 buses	Public transportation operations
Route 123 signal pre-emption demonstration project, Vancouver	Demonstration project using active and conditional signal pre-emption based on bus schedule adherence. Bus to roadside communications using infrared transponders and roadside to intersection communications by radio link	Public transportation operations
George Massey Tunnel reversible lanes, Vancouver	Lane control signals used to manage peak hour flow traffic in the four-lane tunnel. Three lanes in peak direction during peak hours	Travel and transportation management
Lions Gate Bridge reversible lanes, Vancouver	Lane control signals on the three-lane bridge. Two lanes in peak direction during peak hours	Travel and transportation management
Pitt River Bridge reversible lanes	Lane control signals on the four-lane bridge to manage peak hour flow. Three lanes in peak direction during peak hours	Travel and transportation management
Heavy-vehicle electronic licence plate (HELP) Crescent weigh station bypass, Texas to British Columbia	Automatic identification and processing of commercial vehicles for pre-clearance at inspection stations using DSRC technology	Commercial vehicle operations
Alberta		
Automatic vehicle counts and weights retrieval	An ongoing project to develop automated system to track the number of commercial vehicles and their weights through static and mobile weigh stations	Commercial vehicle operations
FM radio broadcast highway radio advisory system	Trial project to provide up-to-date road information, including winter advisories and construction activities	Travel and transportation management

Alberta (cont'd)		
Motorist advisory changeable message signs	Two changeable message signs for road advisory, from Edmonton to Calgary, on an as required basis	Travel and transportation management
Calgary LRT Transit priority systems	Traffic pre-emption provided for LRT travelling at-grade	Public transportation operations
SCOOT traffic signal control, Red Deer	Traffic adaptive signal control system for real-time adjustments to signal timing to optimize traffic flow	Travel and transportation management
Manitoba		
FM radio broadcast highway radio advisory system	Provides up-to-date road information including winter advisories and construction activities on the Trans-Canada Highway from Winnipeg to Portage La Prairie	Travel and transportation management
Winnipeg International Airport ground traffic management system	Automated commercial vehicle dispatching system for terminal curb passenger pickup using DSRC technology	Commercial vehicle operations
Ontario		
COMPASS freeway traffic management system (FTMS)	Traffic, incident, and emergency management on Highway 401, Toronto, Ontario, Burlington Skyway, and Queen Elizabeth Highway using closed circuit TV, loop detectors, and changeable message signs	Travel and transportation management Emergency management
SCOOT traffic signal control, Toronto	Traffic adaptive signal control system for real-time adjustments to signal timing to optimize traffic flow	Travel and transportation management
RESCU corridor traffic control	Provides traffic management, traveller information and incident detection and response management along the Toronto Lakeshore corridor	Traffic management
Highway 407 ETR	75 km of electronic toll collection highway using transponder and licence plate reading to process toll charge	Electronic payment Travel demand management

Ontario (cont'd)		
Toronto transit priority system	Allows transit vehicle pre-emption for four streetcars and two bus routes	Public transportation operations
Automated vehicle identification in Ontario (AVION), Highway 401 from Windsor to Whitby	Automatic identification and processing of commercial vehicles for pre-clearance at inspection stations using DSRC technology	Commercial vehicle operations
Lester B. Pearson International Airport ground traffic management system	Automated commercial vehicle dispatching system for terminal curb passenger pickup using DSRC technology	Commercial vehicle operations
Toronto Transit Commission communication system	A full-scale AVL and communication system that provides vehicle location for all buses and street cars	Public transportation operations
Trapeze paratransit scheduling system	Trapeze provides real-time vehicle scheduling and routing system. Software was developed in Ontario	Public transportation management
Ottawa transit automatic vehicle location (AVL) system	In the process of acquiring a GPS-based AVL system	Public transportation operations
London transit automatic vehicle location (AVL) system	In the process of acquiring a GPS-based AVL system	Public transportation operations
Intelligent transportation border crossing system	Systems are in place at the Peace Bridge crossing at Fort Erie, Ontario; Ambassador Bridge Crossing at Windsor, Ontario Michigan-Ontario-New York. Commercial vehicle pre-clearance using transponders	Commercial vehicle operations
Advanced road weather information system	System provides the ability to target winter maintenance through the use of atmospheric data gathering and road condition remote sensing system	Travel and transportation management
Smartstations	Inspection stations along Trafalgar Road, using WIM equipment	Commercial vehicle operations
Combocard smart card, Ajax and Burlington	System uses smart card for fare payment on buses	Electronic payment

Quebec		
Freeway traffic management, Montreal	Traffic, incident, and emergency management on the A-720, A-40, A-25 highways, using closed circuit TV, loop detectors, variable message and mobile signs	Travel and transportation management Emergency management
Louis-Hippolyte Lafontaine Tunnel Bridge	Tunnel beneath the St. Lawrence Seaway and a bridge across the southern branch of the river. Traffic, incident, and emergency management using closed circuit TV and lane control signals	Travel and transportation management Emergency management
Ville-Marie Tunnel	Traffic, incident, and emergency management in tunnel beneath downtown Montreal using closed circuit TV, lane control signs	Travel and transportation management Emergency management
Outaouais Transit automated vehicle location (AVL) system, Hull	In the process of acquiring a GPS-based AVL system	Public transportation
Champlain Bridge	Lane control signal used to manage traffic	Travel and transportation management
Nova Scotia		
Hwy 104 ETC	45 km stretch of road in Halifax. Toll system using DSRC and cash	Electronic payment
Dartmouth Bridge ETC, Halifax	Installation of electronic toll collection through automatic vehicle identification system	Electronic payment
SCOOT Traffic Signal Control, Halifax	Traffic adaptive signal control system for real-time adjustments to signal timing to optimize traffic flow	Travel and transportation management
New Brunswick		
Fredericton-Moncton electronic toll collection	Toll plaza supporting both transponder equipped and fare payment options	Electronic payment
Saint John Harbour Bridge ETC	Installation of electronics toll collection through automatic vehicle identification system	Electronic payment

Prince Edward Island		
Confederation Bridge, bridge between New Brunswick and Prince Edward Island	Toll system includes toll collector and self-serve lanes with cash, credit, and debit payment options. Traffic and incident management are provided by emergency telephone, video surveillance, variable speed signs, changeable message signs and weather monitoring components	Electronic payment Travel and transportation management
Newfoundland		
Automatic vehicle location (AVL) system, St. John’s	In the process of acquiring a GPS-based AVL system	Public transportation

APPENDIX D
U.S. ITS ARCHITECTURE COMPLIANCE CASE STUDY: COMPASS

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1 METHODOLOGY

To compare, contrast, and analyse the relevant functional design of the MTO COMPASS system to the U.S. National ITS Architecture, it is important to identify the relevant components that would map directly to major functions identified in the logical and physical architecture of the program. Once these functional areas have been established, comparison can be made to evaluate the compliance with each of the detailed functionality and design guidelines.

The methodology used in this analysis to identify, compare, and analyse each of the functional, communications, evaluation, and performance requirements between the U.S. National ITS Architecture and the COMPASS architecture is achieved by the following process.

The basic components of the ITS Architecture that will be relevant to the COMPASS project can be identified as:

- functional components;
- communication components;
- performance evaluation components.

The relevant COMPASS components that map to the U.S. National ITS Architecture components are compared in sequence to identify compliance, non-compliance, and ambiguity between similar functions. The process by which this is achieved is comparing detailed functional components of the logical, physical, and evaluation architecture programs of the U.S. National ITS Architecture against COMPASS architecture components. Tables are defined with a third column identifying the compliance or non-compliance factor.

2 MAJOR COMPONENTS OF U.S. ITS ARCHITECTURE THAT ARE RELEVANT TO COMPASS

The following table identifies the basic components that are common to both architectures. The format would follow the high level ITS Architecture logical/physical function which is relevant to this application, followed by a brief description of the COMPASS implementation of the function.

U.S. National ITS Architecture	COMPASS Architecture
• **Manage traffic**. This functional process includes all the functionality needed for management of the traffic network. Included are traffic surveillance, traffic control, incident management, and demand management functions, plus all associated capabilities. Of the user services included in this functional area, the relevant user services that are part of the COMPASS system are: – traffic control; – incident management.	• **Advanced traffic management systems**. The functionality identified in the COMPASS system related to ATMS map directly to incident management functions identified in the ITS Architecture. Specific detailed functionality related to ATMS functions within the COMPASS project includes: – complete freeway traffic operations centres; – corridor balancing.

U.S. National ITS Architecture	COMPASS Architecture
• **Provide driver and traveller services**. This functional process provides a multimodal trip planning, route guidance, and advisory functions for travellers and all types of drivers. It also enables them to confirm and pay for Yellow Pages page services and provide personal emergency and notification functions. The multimodal trip planning function also includes the provision for ridesharing facilities. The detailed subfunctions within this application area that are relevant to the COMPASS project are: – pre-trip traveller information; – en-route driver information; – ride and reservation; – traveller services information.	• **COMPASS system – traffic and road information systems**. The COMPASS project intends to provide the following traveller information systems that comprise subset of the ITS Architecture travel services. They include: – procedures for information released to media; – fax and pager service; – Internet service.
• **Plan system deployment and implementation**. This functional process analyses the long-term system performance to make permanent changes that will improve ITS operation. This process provides facilities in addition to those required by the user services, such as changes to the road network data, used by the system, that can be passed back to the managed traffic functions.	• **COMPASS system management systems**. The COMPASS project contains a series of initiatives based on management systems that constitute system deployment and implementation process. These include: – performance evaluation system; – formal information exchange procedures; – co-ordination of system infrastructure provisions.

3 COMPASS FUNCTIONAL COMPONENTS COMPLIANT WITH U.S. ITS ARCHITECTURE

The following tables identify each of the detailed functional, communications, and performance evaluation components of the COMPASS Project and the related U.S. National ITS Architecture.

3.1 Compliant Architectural Functional Components

COMPASS Functional Components	ITS Architecture Functional Components
Signal co-ordination Co-ordinate signals on significant arterial roads in the corridor (Burlington Skyway).	**Manage traffic – provide device control** Traffic management is provided through co-ordinated control of signals at junctions, pedestrian crossings, multimodal crossings, ramp signals, variable (or changeable) message signs, and parking lot signage. • process traffic data; • implement strategy; • output control data.

COMPASS Functional Components	ITS Architecture Functional Components
Traffic responsive ramp metering Instead of changing timing plans only at fixed times of the day, co-ordinated ramp signal timing plans are implemented based on traffic volume and occupancy data collected by mainline system detectors.	**Manage traffic – provide device control** Strategies provide ramp signal co-ordination based on algorithms using real-time data, historical data, or local control by the roadside equipment itself. • process traffic sensor data; • select strategy; • implement strategy; • output control data.
Diversion timing plans Develop co-ordinated timing plans that maximize throughput for critical moments used by traffic diverting around freeway incidents. These plans would be introduced manually or by traffic responsible plan selection when incidents occur.	**Manage traffic – manage incidents** • when an incident becomes current, a predefined strategy to mitigate is fixed, and it is automatically implemented; • the predefined incident strategies can be set up in advance by the traffic operations personnel using policy data provided by jurisdictional authorities; • the presence and effects of incidents are also fed through to the predicted traffic model and to the criteria used for vehicle road selection.
Internet traveller info Provide www site displaying current corridor traffic conditions, video, planned events, etc.	**Manage traffic – manage traveller information** • travellers can plan trips and obtain information on traffic conditions, transit services, and Yellow Pages services; • trip plans may be multimodal, including such things as paratransit and ridesharing; • provide kiosk-type facilities for travellers at roadside in shopping centres and in other major trip generating sites. • provide traveller interface (6.3.3). This process acts as a direct interface with the traveller, converting all audio and mechanical inputs into digital data. Output data is converted in displays, audio, and hard-copy output for the traveller to study.
Procedures for information released to media Develop procedures for timely and controlled release of accurate travel conditions information to the electronic media.	**Manage traffic – provide driver and traveller services – manage traveller information** • travellers can plan trips and obtain information on traffic conditions, transit services, and Yellow Pages services; • travellers may also obtain current traffic and transit services information without making trip plans or reservations.

COMPASS Functional Components	ITS Architecture Functional Components
Real-time corridor database Develop a dynamic database for real-time data automatically collected by surveillance systems in the corridor.	**Manage traffic – provide traffic surveillance** • processing collection and dissemination and storage of traffic data obtained from passage of vehicles and pedestrians through the road and highway network served by the traffic management centre; • collected data is stored as either current data or long-term data, which may be several months or years old; • data from long-term store, plus any relevant data from users and traffic management centres used by algorithms to provide producer predictive models of future traffic conditions; • this data is also available to traffic operations personnel and media.
Formal incident management procedures Develop procedures for co-ordinating the efforts of the involved agencies in response to traffic incidents in the corridor.	**Manage traffic – manage incidents** • details about location, extent, start, duration, and traffic impact of instance can be provided by the emergency services, system operator, event promoters, and road construction and maintenance organization; • traffic operations personnel can update the incident database on information received from other sources; • real-time incident strategies can be set up in advance by traffic operations personnel using policy data provided by jurisdictional authorities.

3.2 Compliant Communication Architecture Components

COMPASS Communication Components	ITS Architecture Communications Components
Develop a wide area network Design and develop a wide area network that would link all existing traffic control centres and traffic operations centres to exchange real-time data, voice, and video information.	**ITS Physical Architecture** • defines requirements for wide area networking capability; • defines requirements for tying traffic operation centres; • identifies requirements to tie traffic control centres; • identifies requirements to exchange real-time data voice and video information.
Reliability High reliability, building redundancy, and user-proven technology to provide network availability are critical COMPASS corridor network requirements.	**ITS Logical Architecture – performance specification** • identifies reliability and redundancy requirements.

3.3 Compliant Evaluation Procedures

COMPASS Evaluation Components	ITS Architecture Evaluation Components
Initial cost (public sector) These costs are the capital costs of the system elements. They include such things as purchasing and installing hardware, writing software (one-time cost).	**Architecture Evaluation Plan** • methodology; • detailed evaluation approach; • cost analysis evaluation plan; • non-technical issues; • traffic modelling; • communication modelling.
Recurring cost (public sector) These costs represent the operating and maintenance costs of the element, including labour, telephone charges, equipment rental, replacement parts, and other recurring costs.	**Architecture Evaluation Plan** • methodology; • detailed evaluation approach; • cost analysis evaluation plan; • non-technical issues; • traffic modelling; • communication modelling.
Maximize person throughput This represents whether the measure being evaluated helps increase person throughput in a given location.	**Architecture Evaluation Plan** • methodology; • detailed evaluation approach; • cost analysis evaluation plan; • non-technical issues; • traffic modelling; • communication modelling.
Contribution to air quality improvement This is a measure of the element's ability to help improve air quality by reducing stops and starts, smoothing traffic flow, and having a beneficial environmental impact.	**Architecture Evaluation Plan** • methodology; • detailed evaluation approach; • cost analysis evaluation plan; • non-technical issues; • traffic modelling; • communication modelling.
Contribution to safety This is a measure of how well the element contributes to improving overall traffic safety.	**Architecture Evaluation Plan** • methodology; • detailed evaluation approach; • cost analysis evaluation plan; • non-technical issues; • traffic modelling; • communication modelling.
Opportunities for private sector participation This is a measure of how well the element would attract private sector participation, through funding, providing equipment and technology, operation, or other means.	**Architecture Evaluation Plan** • methodology; • detailed evaluation approach; • cost analysis evaluation plan; • non-technical issues; • traffic modelling; • communication modelling.

4 COMPASS PROJECT FUNCTIONAL COMPONENTS THAT ARE NON-COMPLIANT WITH U.S. ITS ARCHITECTURE

The following tables list the COMPASS detailed components and the comparable ITS Architecture components, with the third column identifying a value for the incompatibilities perceived at this stage.

4.1 Non-Compliant Architectural Functional Components

COMPASS Functional Components	ITS Architecture Functional Components
Vehicle tracking using toll tags Install roadside readers for all toll tags being used for automated toll collection on Highway 407. Within constraints this can be used to track vehicles as probes.	No comparable ITS Architecture component.
Public relations program Develop a public relations program including press releases that inform the public of the COMPASS and its various elements: the system's purpose, what changes can be expected (including apparent set of conditions for the specific locations at times), how to make best use of the system, etc.	No comparable ITS Architecture functional components.

5 AMBIGUOUS AREAS BETWEEN COMPASS PROJECT AND U.S. ITS ARCHITECTURE

The tables below identify the COMPASS functional communications, evaluation, and performance components and the related ITS Architecture components that may not map correctly and that may result in ambiguity.

5.1 Ambiguous Architecutral Functional Components

COMPASS Functional Components	ITS Architecture Functional Components
HOV bypass lanes for all ramp meters Provide HOV bypass lanes at all future metered on-ramps.	**Manage traffic – provide device control** • additional strategies are available to keep priority for emergency and high occupancy (HOV) vehicles, as well as transit vehicles, and will override all other strategies; • strategies are also available for co-ordination of messages sent out by VMS so that drivers may be guided away from congestion, as well as toward parking lots with available spaces.
Incident management team Form one or more teams responsible for rapid response to traffic incidents in the corridor.	No direct functional component in the ITS Architecture.

COMPASS Functional Components	ITS Architecture Functional Components
Performance evaluation system Provide a system for monitoring corridor travel performance and producing periodic reports for all involved agencies. The system would use both automatically collected and human input data.	**2.1.3.6 Traffic control – information managed** • the system shall support real-time collection management in excess of current traffic surveillance and control parameters; • incident management: – surveillance information. The system will access current traffic surveillance information on a real-time basis.

5.2 Ambiguous Communication Architecture Components

COMPASS Communication Components	ITS Architecture Communication Components
Develop local area networks within every jurisdiction This would enable a standard interface that could be developed to interface between local area networks and the wide area networks.	**ITS Physical Architecture** • identifies requirements for local area networks within every control environment.
Infrastructure base communications COMPASS project includes agency-owned fibre-optic network, which would carry CCTV information as well as data and other high bandwidth requirement information.	**ITS Physical Architecture** • supports both infrastructure-based communication systems as well as fully distributed communication networks.
Use of public switch networks COMPASS uses public switch networks for some local connections. These networks are a practical solution because of the geographic distribution of the agencies involved in this project.	**ITS Physical Architecture** • the Physical Architecture supports use of public switch networks.
Network performance requirements Should include standard network interfaces and protocols.	**ITS Performance Specifications** • supports DS1 and DS4 communication bandwidths; • supports 7-day, 24-hour support capability.
Network flexibility COMPASS network architecture would be capable of accommodating all existing systems and communications requirements and be easily expanded to accommodate future needs.	**ITS Logical Architecture/Physical Architecture** • network flexibility supports complete flexibility with respect to network architecture to accommodate future expandability.

5.3 Ambiguous Evaluation Procedures

COMPASS Evaluation Components	ITS Architecture Evaluation Components
Contribution to recurring congestion reduction This measures the ability of the element to reduce recurring congestion, which occurs in the same location on a regular basis.	**Architecture Evaluation Plan** • methodology; • detailed evaluation approach; • cost analysis evaluation plan; • non-technical issues; • traffic modelling; • communication modelling.
Contribution to incident congestion reduction This measures the ability of the element to reduce incident-related congestion.	**Architecture Evaluation Plan** • methodology; • detailed evaluation approach; • cost analysis evaluation plan; • non-technical issues; • traffic modelling; • communication modelling.

6 STUDY FINDINGS AND RECOMMENDATIONS

Following the structured approach of breaking down the U.S. National ITS Architecture into manageable components of functional, communications, evaluation, and performance entities allowed a comparison with the COMPASS project design. This effort led to the following findings:

- for the most part, the COMPASS project functional components comply favourably to the ITS Architecture components;
- the communications component of the COMPASS architecture has some components that comply directly with the ITS Architecture, while others were not specifically identified in the ITS Architecture. This led to a set of components being identified as ambiguous with respect to compliance with the U.S. ITS program;
- with respect to evaluation functions identified in the COMPASS architecture, the U.S. National ITS Architecture evaluation criteria globally encompass all of the specific COMPASS components;
- the following functions are not specifically addressed in the ITS Architecture:
  - vehicle tracking using technology that is a component in the COMPASS architecture;
  - institutional issues regarding agreements and information exchange procedures that are common in implementation projects such as the COMPASS system;
  - traffic management from an operations perspective that would reflect specifications that lead to requirements for traffic operations personnel, etc.;
- ITS Architecture does not reflect any public relations program requirements;
- ITS Architecture does not identify interface process components required to interface with similar systems currently in existence.

A comparison and evaluation exercise such as this yields functions that are not entirely covered by the ITS Architecture and that lead to ambiguous compliance. Examples are:

- in the communications components of the ITS Architecture, specific implementation-related issues, such as development of local area networks within every jurisdiction, are not identified;
- ITS Physical Architecture does not reflect any specific data distribution requirement;

- ITS Physical Architecture does not identify network requirements that are typically identified in the COMPASS-type ITS project.

On the basis of this case study, it is apparent that to accurately compare, contrast, and evaluate functional components of any ITS project against the U.S. National ITS Architecture requires more extensive study than has been made for this report.

APPENDIX E
SHORT DESCRIPTION OF BLUETOOTH

1 GENERAL DESCRIPTION

Bluetooth is a short-range radio link intended to be a cable replacement between portable and/or fixed electronic devices. Key features are robustness, low complexity, low power, and low cost.

Bluetooth operates in the unlicensed ISM band at 2.4 GHz. A frequency hop transceiver is applied to combat interference and fading. A shaped, binary FM modulation is applied to minimize transceiver complexity. The gross data rate is 1 Mb/s. A slotted channel is applied with a nominal slot length of 625 ms. For full duplex transmission, a time-division duplex (TDD) scheme is used.

The Bluetooth protocol is a combination of circuit and packet switching. Slots can be reserved for synchronous packets. Each packet is transmitted in a different hop frequency. A packet nominally covers a single slot, but can be extended to cover up to five slots. Bluetooth can support an asynchronous data channel, up to three simultaneous synchronous voice channels, or a channel that simultaneously supports asynchronous data and synchronous voice. Each voice channel supports a 64 kb/s synchronous (voice) channel. The asynchronous channel can support maximally 721 kb/s half duplex (and still up to 57.6 kb/s in the return direction), or 432.6 kb/s full duplex.

The Bluetooth system consists of a radio unit, a link control unit, and a support unit for link management and host terminal interface functions.

The Bluetooth system provides a point-to-point connection (only two Bluetooth units involved), or a point-to-multipoint connection. In the point-to-multipoint connection, the channel is shared among several Bluetooth units. The channel is denoted as a piconet. One Bluetooth unit acts as the master of the piconet, whereas the other unit(s) act(s) as slave(s). Up to seven active slaves can be supported by the piconet. Channel access is controlled by the master.

2 PHYSICAL CHANNEL

2.1 Frequency Band and RF Channels

Bluetooth operates in the 2.4 GHz ISM band. Although globally available, the exact location and the width of the band may differ by country. In the U.S. and Europe, a band of 83.5 MHz width is available; in this band, 79 RF channels spaced 1 MHz apart are defined. A smaller band is available in Japan, Spain, and France; in this band, 23 RF channels spaced 1 MHz apart are defined. Efforts are being made to consolidate the hopping band on a worldwide basis.

2.2 Channel Definition

The channel is represented by a pseudo-random hopping sequence through the 79 or 23 RF channels. The hopping sequence is unique for the piconet and is determined by the Bluetooth identity of the master. The channel is divided in time slots where each slot corresponds to a hop. Consecutive hops correspond to different RF hop channels. The nominal hop rate is 1600 hops/s. All Bluetooth units participating in the piconet are hop synchronized to the channel.

Country	Frequency Range	RF Channels
Europe* & USA * except Spain and France	2400 - 2483.5 MHz	f = 2402 + k MHz k= 0,...,78*.
Japan	2471 - 2497 MHz	f = 2473 + k MHz k= 0,...,22
Spain	2445 - 2475 MHz	f = 2449 + k MHz k= 0,...,22
France	2446.5 - 2483.5 MHz	f = 2454 + k MHz k= 0,...,22

2.3 Time Slots

The channel is divided into time slots each 625 ms in length. The time slots are numbered according to the Bluetooth clock of the piconet master. The slot numbering ranges from 0 to 2 27-1 and is cyclic with a cycle length of 2 27. In the time slots, master and slave can transmit packets. The packet start shall be aligned with the slot start. Packets transmitted by master or slave may extend over up to five time slots. If a packet occupies more than one time slot, the hop frequency shall remain the same for the duration of the packet; the hop frequency applied shall be the hop frequency as applied in the time slot the packet transmission was started. A TDD scheme is used where master and slave alternatively transmit. The master shall start its transmission in even-numbered time slots only; the slave shall start its transmission in odd-numbered time slots only.

2.4 Modulation and Bit Rate

The data transmitted has a gross bit rate of 1 Mb/s. A Gaussian-shaped, binary FSK modulation is applied with a BT product of 0.5. A binary one is represented by a positive frequency deviation, a binary zero by a negative frequency deviation. The maximum frequency deviation shall be between 140 kHz and 175 kHz.

2.5 Direct-Sequence Modes

When Bluetooth units are involved in paging or inquiry modes, the operation can be considered as a hybrid FH/DS spreading. In this document, the spreading gain as obtained in the DS component is described. For the definition of DS spreading and its processing gain, the following texts found in the FCC rules are used.

“The information to be conveyed is modulated onto a carrier frequency by some conventional technique, such as AM, FM, or digital, and the bandwidth of the signal is deliberately widened by means of a spreading function.”

In the Bluetooth system, frequency modulation is applied. During the transmission of the access code, the signal is widened by the access code sequence. The actual information conveyed is the presence or absence of the access code. If the access code would be sent continuously, giving one bit of information every 68 ms for each access code sent, an information rate of 14.7 kb/s is obtained. In contrast, the access deliberately widens the spectrum with a chip rate of 1 Mchips/s.

“Direct sequence systems modulate the carrier with a combined information signal and a much faster binary code signal. The binary code signal typically is a fixed length, pseudorandom sequence of bits. It dominates the modulating function and is the direct cause of the spreading of the transmitted signal.”

In Bluetooth, the information signal is the control signal that indicates to transmit the access code or not; the binary code spreading the signal is represented by the access code itself. As shown before, the spreading is at a rate 68 times the information rate.

"A spread spectrum system in which the carrier has been modulated by a high speed spread code and an information data stream. The high speed code sequence dominates the 'modulating function' and is the direct cause of the wide spreading of the transmitted signal."

Again, it can be argued that in Bluetooth, the modulating function is the code sequence of the access code which broadens the spectrum. It is not the frequency modulation that is responsible for the spreading, but the binary access code.

Binary data at 1 Mb/s is provided to a shaping filter with a Gaussian filter characteristic and a *BT* product of 0.5. The shaped signal is then fed to a FM modulator with a modulation index between 0.28 and 0.35. The modulation is directly on the VCO. However, other implementations can be envisioned providing the same modulation function. The output of the VCO may be fed into a power amplifier before the RF signal is transmitted by the antenna. The output spectrum of the RF signal (for h=0.35) is a symmetrical (two-sided) spectrum with a -20dB bandwidth of 1 MHz.