IC

INDUSTRY CANADA
TRANSPORT CANADA

ASSESSMENT OF SYSTEM INTEGRATION AND INTELLIGENT SOFTWARE FOR ITS

FINAL REPORT

JULY 1996

IBI
GROUP

INDUSTRY CANADA
TRANSPORT CANADA

ASSESSMENT OF SYSTEM INTEGRATION AND INTELLIGENT SOFTWARE FOR ITS

FINAL REPORT

JULY 1996

IBI GROUP

REPORT DOCUMENTATION FORM

1. Transport Canada Report No. Industry Canada Report No.	2. Recipient's Catalogue No.
3. Title and Subtitle Assessment of System Integration & Intelligent Software Technologies for ITS	4. Report Date March 1996 5. Performing Organization Report No. TO-5267
6. Author(s) Mr. R. Nelson and Mr. D. Robertson	7. Industry Canada File No. 126-9506-4-6
8. Performing Organization Name and Address IBI Group 230 Richmond Street West, 5th Floor Toronto, Ontario M5V 1V6	9. DSS File No. 10. Industry Canada Control No. 67HAB-5-0142
11. Sponsoring Agency Names and Addresses Industry Canada, Aerospace & Defence Branch 6 East, 235 Queen Street Ottawa, Ontario K1A 0H5 Transport Canada, Research & Development 26B, Tower C 235 Sparks Street Ottawa, Ontario K1A 0N5	12. Type of Report and Period Covered Final 13. Sponsoring Agency Code
14. Supplementary Notes	15. Project Manager Mr. Arjan Chandan

16. Abstract

The report defines the various system integration services and intelligent software applications required to support Intelligent Transportation Systems (ITS) functions. Each software application is defined in terms of functional requirements, architecture, and examples. An outreach to selected industry contacts has resulted in a profile of the current and expected future state of technology for system integration and software applications. An assessment of domestic and foreign industry activity has yielded recommendations for Canadian industry pursuing ITS system integration and software markets.

17. Key Words: ITS, System Integration, Software, Algorithms, Architecture	18. Distribution Statement: Limited number of copies available from Industry Canada

19. Security Classification (of this report)	20. Security Classification (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	36	No charge

FORMULE DE DONNÉES POUR PUBLICATION

1. N° de la publication de Transport Canada N° de la publication de Industry Canada	2. N° de catalogue du destinataire
3. Titre et sous-titre Estimation de Technologies STI - Technologies d'Intégration de Systèmes et de Logiciels	4. Date de la publication Mars 1996 5. N° de document de l'organisme TO-5267
6. Auteur(s) M. Richard Nelson et M. D. Robertson	7. N° de dossier de l'Industrie Canada 126-9506-4-6
8. Nom et adresse de l'organisme exécutant IBI Group 230 rue Richmond Ouest, 5e étage, Toronto, Ontario, M5V 1V6	9. N° de dossier - ASC 10. N° de contrat - l'Industrie Canada 67HAB-5-0142
11. Nom et adresse des Organismes parrain Industries Canada, Aéronautique et Défense 6 E, 235 rue Queen Ottawa, Ontario K1A 0H5 Transport Canada, Recherche et Développement 26B, Édifice C 330 rue Sparks Ottawa, Ontario K1A 0N5	12. Genre de publication et période visée Finale 13. Code de l'organisme parrain
14. Remarque additionnelles	15. Gestionnaire Arjan Chandan

16. Résumé

Ce rapport défine les différents services d'intégration des systèmes et des applications de logiciels intelligents qui doivent supporter les fonctions des Systèmes de Transport Intelligent (STI). Chaque application de logiciels est caractérisé en termes de demandes fonctionnelles, architecture, exemples et standards applicables. Une enquête sur le sujet s'est concrétisée dans un profile de l'état présent et futur de la technologie d'intégration de systèmes et logiciels. Une estimation de l'activité dans le domaine s'est ensuivie de recommandations pour l'industrie Canadienne au sujet de l'intégration STI et les marchés de logiciels.

17. Mots-clés: STI, Systèmes d'Intégration, logiciels, algorithmes, architecture	18. Diffusion: Des copies sont disponibles de Transports Canada

19. Classification de sécurité (de cette publication)	20. Classification de sécurité (de cette page)	21. Nombre de pages	23. Prix
non-classifié	non-classifié	36	Gratuit

DISCLAIMER

The contents of this report reflect the views of the authors and not necessarily the official views or opinions of the Research and Development Directorate of Transport Canada, or the Aerospace and Defence Branch of Industry Canada.

NOTE

This report is one of the following series of reports produced under the joint Industry Canada/Transport Canada study into: "Strategy for the Development of an ITS Industrial Base in Canada". The reports to be produced in this series include:

1. Assessment of Communications Needs and Standards for ITS
   by: A. Waltho Engineering
2. Assessment of Geographic Information Systems (GIS) Technologies for ITS
   by: Intergraph Canada
3. Assessment of Positioning and Navigation Technologies for ITS
   by: IDI Ltd.
4. Assessment of Sensor Technologies for ITS
   by: IBI Group
5. Assessment of Display Technologies for ITS
   by: IBI Group
6. Assessment of System Integration and Intelligent Software for ITS
   by: IBI Group
7. Assessment of FM Sub-Carrier Broadcast Technology Applications for ITS: Lapp-Hancock Associates Ltd. and L-P Tardif & Associates (Sponsored by: Transport Canada, Heritage Canada, Canadian Association of Broadcasters and Canadian Broadcasting Corporation).
8. Review of the Canadian Role in ITS Standards Development
   by: E.R. Case and Associates (Produced for: Transport Development Centre - TDC, of Transport Canada).
9. Benefit-Cost Assessment of ITS Implementation in Canada by: IBI Group, SNC-Lavalin, Parvianen & Associates, A. Waltho Engineering, Richard Zavergiu (Produced for: Transportation Development Centre - TDC, of Transport Canada).
10. Assessment of the Demand, Markets and Commercial Development of Global ITS Industry
    by: SRI Consulting.
11. Strategy for the Development of an ITS Industrial Base in Canada
    by: Delphi Systems Inc.

For information on any of these projects please contact:

Mr. Arjan Chandan
Senior Advisor ITS and Project Executive
Industry Canada
Aerospace and Defence Branch
235 Queen Street
Ottawa, Ontario K1A 0H5
Tel: (613) 952-1036 Fax: (613) 998-6703
E-Mail: chandan.arjan@ic.gc.ca

ACKNOWLEDGEMENTS

IBI Group and the authors wish to sincerely acknowledge the helpful guidance provided by Mr. Arjan Chandan, Senior Advisor, ITS, of the Industry Canada Aerospace & Defence Branch, who managed this project and served as Chairman of the Steering Committee for the ITS Industrial Base Development Program of Industry Canada.

IBI Group and the authors wish to thank all who provided comments on the technical memoranda and presentations provided throughout the course of the project. These constructive comments helped to provide a comprehensive and useful final product. Individuals assisting in this capacity include:

Arjan Chandan	Aerospace & Defence, Industry Canada
Barbara-Anne Brown	Spectrum Engineering, Industry Canada
Michel Gaudreau	Spectrum Management, Industry Canada
Gerry Chan	Spectrum Engineering, Industry Canada
Gilles Gagnon	Automotive, Industry Canada
Alan Jones	Service Industries Branch, Industry Canada
Joanne St-Onge	Marketing & Promotion Services, Industry Canada
Luc Fournier	Communications Development, Industry Canada
William Johnson	Transportation Development Centre, Transport Canada
Michael Ball	Research & Development, Transport Canada
Brian Hicks	Highways, Transport Canada
Lara Forbes	Research & Development, Transport Canada
Ghislain Blanchard	Special Infrastructure Project, Transport Canada
Gilles Gagnon	Automotive Branch, Industry Canada
Gus Pokotylo	Research & Development, Transport Canada
Gaetan Deschamps	Canada Post Corporation
John Robinson	Delphi Systems Inc.
Sultan Akhtar	Aerospace/Defense Robotics, Industry Canada
Norman Yanvesky	Policy - Science Strategy, Industry Canada
Dave Benson	SRI California
Peter Trau	Aerospace & Defence, Industry Canada
Guy Gallant	Aerospace & Defence, Industry Canada

Assessment of System Integration and Intelligent Software for ITS - Final Report

EXECUTIVE SUMMARY

All Intelligent Transportation System (ITS) applications share a strong focus on system integration and customized software algorithms. This emphasis stems from the fact that ITS applications typically process data from a variety of input sensors to produce multi-media outputs, and combine a variety of high technology computer and communications components.

The system integration process coordinates the interoperability of various ITS field components, central processing, external interfaces, and operator functions. While the importance of the integration role is often overlooked by transportation authorities, the system integration process is crucial to the delivery of a seamless, fully functional operating system. Canada has a strong presence in the ITS integration market, primarily resulting from domestic traffic management system deployment programs in the 1980's. The challenge for Canadian system integration firms is to remain competitive in the international marketplace through the appropriate alliances with local partners and other ITS industry participants, such as hardware vendors.

ITS deployment requires specialized software algorithms to support various traffic management, route guidance, fleet management, electronic payment, and vehicle control/safety functions. Various agencies are applying artificial intelligence techniques to these applications, including fuzzy logic, expert systems, and neural networks. The ITS software industry is relatively fragmented, with few examples of widely accepted/utilized routines. The market is characterized by numerous firms of varying size, typically fulfilling a given niche processing application. The Canadian ITS industry has demonstrated success in selected niches, including transit management, traffic incident detection/management, and traffic network simulation/analysis.

The worldwide market for ITS integration and software applications continues to expand, with particular emphasis on electronic toll collection and commercial vehicle operations. The well organized U.S. program emphasizes deployment for all areas within ITS, and the emerging markets of Asia-Pacific provide growth opportunities for traffic management systems deployment.

In order to further develop the Canadian industrial base for ITS integration and software, Industry Canada and Transport Canada should consider mechanisms aimed at:

- fostering the development of industry alliances to facilitate turnkey system solutions in the international market;
- showcasing Canadian ITS expertise including unique or powerful algorithms and integration capabilities;
- inducing ITS software research and development in Canada;
- participation in foreign ITS programs and standards initiatives;
- updating the state of the ITS integration and software industry on a regular basis;
- creation of an ITS office within Industry Canada to ensure that the recommendations as set forth are acted upon.

Table of Contents

Table of Contents (Cont'd)

1. SYSTEM DEFINITION

1.1 INTRODUCTION

The field of intelligent transportation systems (ITS) incorporates a wide range of applications. In the 1995 National ITS Program Plan, the Intelligent Transportation Society of America and the United States Federal Highways Administration classify ITS applications according to the services they provide to users of a transportation system. Twenty-nine separate *User Services* are identified, with related services being grouped into seven *Service Bundles*. The Service Bundles and the User Services which they include are shown in Exhibit 1.1.

While there are many different ITS User Services, they all share at least two features:

- application of software to process inputs for the production of desired outputs;
- integration of various hardware and software components into a single unified system.

The purpose of this section is to develop an understanding of the requirements for the current state of technology for ITS software with intelligent algorithms and ITS system integration.

1.2 SYSTEM INTEGRATION

System integration is the process through which various hardware and software components are combined into a unified and fully functioning system. The system integration process involves a number of different steps or procedures. These vary considerably depending on the type of system being integrated, but generally include:

- **subsystem integration** - components and subsystems are tested individually, then added one by one to the system with testing at each stage;
- **software integration** - system software is tested in conjunction with system hardware and software parameters are configured to match the system configuration;
- **system calibration** - algorithm parameters are calibrated using real (stored or real-time) data to produce outputs within acceptable tolerances;
- **system burn-in** - the full system is operated and tested continuously for a set period of time (e.g., two weeks);

EXHIBIT 1.1

ITS SERVICE BUNDLES AND USER SERVICES

From ITS America/U.S. DOT, National ITS Program Plan (March, 1995)

SERVICE BUNDLE	USER SERVICES
Travel and Transportation Management	En-Route Driver Information Route Guidance Traveller Services Information Traffic Control Incident Management Emissions Testing and Mitigation
Travel Demand Management	Pre-Trip Travel Information Ride Matching and Reservation Demand Management and Operations
Public Transportation Operations	Public Transportation Management En-Route Transit Information Personalized Public Transit Public Travel Security
Electronic Payment	Electronic Payment Services
Commercial Vehicle Operations	Commercial Vehicle Electronic Clearance Automated Roadside Safety Inspection On-Board Safety Monitoring Commercial Vehicle Administrative Processes Hazardous Material Incident Response Freight Mobility
Emergency Management	Emergency Notification and Personal Security Emergency Vehicle Management
Advanced Vehicle Control and Safety Systems	Longitudinal Collision Avoidance Lateral Collision Avoidance Intersection Collision Avoidance Vision Enhancement for Collision Avoidance Safety Readiness Pre-Crash Restraint Deployment Automated Highway Systems

- **system documentation** - operating and technical manuals are prepared covering all aspects of system operations and maintenance;

- **operator training** - system operators (or users where appropriate) are trained to use the system properly and to its full potential;

- **system management** - system implementation and integration are managed to assure quality and compliance with schedule and budget;

- **initial operations** - commencement of formal system operations is monitored to identify any system or procedural modifications.

1.2.1 Tools and Technology

System integrators use a variety of software and hardware tools to carry out or assist in system integration tasks. The more common types of tools include:

- **off-line system simulators** - system software is run on off-site computers or on a system central computer with no active links to field devices using recorded or real-time data to test the effects of software parameter/code changes or for operator training;

- **spreadsheet applications/analysis tools** - used to carry out statistical and/or graphical analysis of simulation run results to identify optimum results during system calibration;

- **database applications** - used for tracking test results, parameter values, documentation content and status, etc.;

- **event logs** - manual or software recording of specific system software or hardware events, used in system testing and debugging;

- **data collection tools** - include central software routines for recording field data, laptop computer with software for data collection directly from field devices, traffic data collection devices such as counters and travel time/distance measurement instruments - used for checking system performance and assembling data sets for use in simulation runs;

- **testing and diagnosis instruments** - devices ranging from very simple (e.g., multimeter) to very complex (e.g., optical time domain reflectometer) used for testing system hardware and diagnosing faults identified during system integration testing.

1.2.2 Example Applications

- **Gardiner–Lake Shore Corridor Traffic Management System (CTMS; Toronto)** - The system integration effort carried out by IBI Group for the implementation of this advanced traffic management system included: calibration of travel-time calculation, queue detection, and incident-detection algorithms. This work made extensive use of off-line simulators, spreadsheets, event logs, and central software data collection tools. Other integration work included: configuration of central system and field controller hardware and software; operator training; preparation of system documentation; and system management.

- **Toronto Transit Commission - Communications and Information System (CIS; Toronto)** - This advanced public transit system was integrated by an affiliate of Bell Canada. At the time of its commissioning in the early 1990s it made the Toronto Transit Commission arguably the most advanced major transit property in North America. Every surface vehicle is equipped with a device that calculates the vehicle's location on a route (based on roadside "signpost" beacons and wheel revolutions) and upload this to the central system. The central system calculates each "run's" schedule adherence. It also provides scheduled-arrival information for every surface stop; real-time stop information will soon be available. As well, the in-vehicle device allows queued two-way voice communication between the operator and controller; and emergency voice communication over cellular.

1.3 SOFTWARE ALGORITHMS

ITS software takes input from various sources, including sensors and human operators, and processes this information through one or more algorithms to produce ITS outputs ranging from condition alarms for operators to actual control of a vehicle. Exhibit 1.2 lists thirteen significant types of ITS algorithms along with their typical inputs and outputs. The list includes only those algorithm types which directly produce ITS outputs; it does not include, for example, sensor algorithms such as image or digital signal processing. These are considered to be bundled with the related hardware as a functional subsystem.

EXHIBIT 1.2

ITS ALGORITHMS

ALGORITHM TYPE	INPUT(S)	OUTPUT(S)	EXAMPLES
Incident/ Queue Detection	• Traffic flow data (volume, occupancy and speed)	• Incident or queue alarms • Queue length updates	• McMaster Algorithm • All Purpose Incident Detection (APID) Algorithm
Travel Time Calculation	• Traffic speed • Queue lengths and locations	• Link or route travel time estimates	• Gardiner-Lake Shore CTMS (Toronto) • TRANSMIT (New York/New Jersey)
Response Plan Generation	• Incident and queue data (location, description, cause, etc.) • Weather/road conditions • Scheduled events	• Recommended advisory messages, traffic control device states, emergency services response	• INFORM (New York) • Orange County TMC (California)
Traffic Control	• Traffic flow data (volume and occupancy) • Incident and queue data	• Traffic signal, signing and barrier control plan updates	• Split, Cycle, Offset Optimization Technique (SCOOT) • Sydney Coordinated Adaptive Traffic (SCAT)
Data Fusion	• Travel time estimates • Incident and queue data • Emergency services/road patrol data • Motorist calls • Weather reports/data	• Consolidated roadway and traffic conditions reports	• MTIPS (Toronto) • TIGRE (France)
Route Guidance	• Travel time estimates • Incident and queue data • Traveller/vehicle origin/location and destination • Road network data • Traveller mode/route preferences • Vehicle routing restrictions	• Recommended travel route	• TravTek (Orlando) • TravelGuide (Toronto)
Ride Matching & Reservation	• Traveller origin, destination and preferred departure/arrival times • Vehicle space availability • Ride provider location, destination and schedule	• Traveller/ride provider match • Ride reservation	• Sacramento Rideshare • Seattle Smart Traveller
Vehicle Dispatch	• Vehicle availability • Vehicle location • Required destination • Road network data • Travel time estimates	• Dispatch best vehicle to required destination	• SMART (Detroit) • Gandalf Cabmate (Taxi fleet management)

EXHIBIT 1.2 (Cont'd)

ALGORITHM TYPE	INPUT(S)	OUTPUT(S)	EXAMPLES
Vehicle/Driver Pre-clearance	• Vehicle/driver identification • Vehicle/driver records • Vehicle size and weight (from on-road sensors) • Vehicle status (from on-board sensors)	• Vehicle/driver clearance or inspection recommendation/ requirement	• Advantage I-75/AVION • HELP/Crescent
Payment Authorization	• Account identification • Account balance and restrictions • Short-term payment history • Payment type and amount	• Payment authorization or rejection	• Lockheed IMS • Combitech PREMID
Collision Risk Assessment	• Vehicle speed, direction and acceleration/deceleration • Obstacle or other vehicle proximity, direction and closing speed • Steering, throttle and/or brake inputs	• Collision risk warnings	• Delco FOREWARN collision warning system
Vehicle Control	• Collision risk warnings • Vehicle lateral position (relative to roadway or other vehicles) • Vehicle longitudinal position (relative to other vehicles) • Steering, throttle and/or brake inputs • Vehicle, driver and/or cargo safety status	• Evasive action recommendations • Throttle, brake and/or steering control	• PATH (California) • Nissan • Volkswagen
Vehicle/Driver Safety Monitoring	• Driver physical state (e.g. head position, eye movement, steering input pattern) • Vehicle status (e.g. brake adjustment/pressure, engine status) • Cargo status (e.g. temperature, position shifts)	• Evaluation of vehicle, driver and/or cargo safety status warnings • Safety status warning messages or interventions (e.g. ignition lock-out for impaired driver)	• Drowsy Driver Monitor (NHTSA & Virginia Polytechnic)

Each of the seven ITS Service Bundles uses one or more of the thirteen algorithm types, and each algorithm type may be used in more than one of the Service Bundles. This is shown in Exhibit 1.3, which lists the algorithm types typically employed for each ITS Service Bundle.

1.3.1 Functional Requirements

The specific functional requirements of an ITS algorithm are determined by its intended application. In general terms, however, the functional requirements specify:

- type and number of inputs;
- desired output(s);
- required degree of output accuracy;
- possible error conditions and algorithm response to them;
- processing environment, speed requirements, and/or restrictions.

1.3.2 Systems Architecture

In the logical architecture of an intelligent transportation system, the ITS algorithm can be viewed as a "black box" between the system's inputs and its outputs. What is in the box depends on the specific application and the functional requirements.

The physical location of the software containing a system's ITS algorithm(s) also varies depending on the application and functional requirements. Algorithms may be executed by:

- a field controller unit;
- the system central computer;
- a vehicle's on-board computer.

A single system may include algorithms running in one or all of these locations.

1.3.3 Technologies

ITS algorithms vary considerably in complexity, depending on the particular functional requirements which must be addressed. The simplest algorithms perform straightforward calculations or threshold comparisons, using limited inputs to produce specific outputs. For example, the simplest form of travel time calculation algorithm simply divides the known length of a roadway link by the speed measured at a vehicle detector station on that link. More complex algorithms are required for applications which include requirements such as:

EXHIBIT 1.3

ALGORITHM TYPES USED BY ITS SERVICE BUNDLES

ITS Service Bundle / Algorithm Type	Travel & Transportation Management	Travel Demand Management	Public Transportation Operations	Electronic Payment	Commercial Vehicle Operations	Emergency Management	Advanced Vehicle Control and Safety Systems
Incident/Queue Detection	●						
Travel Time Calculation	●		●		●	●	
Response Plan Generation	●					●	
Traffic Control	●						
Data Fusion	●	●	●		●	●	
Route Guidance	●		●		●	●	
Ride Matching & Reservation		●	●				
Vehicle Dispatch			●		●	●	
Vehicle/Driver Pre-clearance					●		
Payment Authorization				●			
Collision Risk Assessment							●
Vehicle Control							●
Vehicle/Driver Safety Monitoring					●		●

C:\WP51\5267\INTSO1-3.XLS - 7/19/96/SD

- multiple inputs of various types;
- complex calculations or decision-making (e.g., identifying and disregarding erroneous raw data);
- high degrees of accuracy in outputs (e.g., vehicle braking and/or steering control algorithms for collision avoidance).

In such cases, "intelligent" algorithms may be applied. These may include features such as:

- fuzzy logic (e.g., a route guidance algorithm which accommodates gradual changes in traffic conditions rather than suddenly switching the suggested route for all traffic as a traffic variable threshold is exceeded);
- expert systems (e.g., a traffic control algorithm which uses traffic engineers' knowledge and experience to select the best signal timing plan from among options provided by different signal timing packages);
- neural networks (e.g., an incident/queue detection algorithm which can learn to distinguish between traffic patterns caused by incidents and recurrent congestion);
- other artificial intelligence techniques.

For example, a complex network travel time calculation algorithm may incorporate some of these features to estimate the effects of incidents, queues, traffic signals, driver characteristics, and advanced traveller information systems.

The current state of the art in ITS algorithms includes both "intelligent" and traditional computational algorithms. Either type may be better suited to a given application, and both are subjects of on-going research aimed at enhancing the performance of existing algorithms or developing new algorithms.

1.3.4 Example Applications

- **SCOOT Traffic Adaptive Signal Control Algorithm -** SCOOT (Split Cycle and Offset Optimization Technique) generates frequent small adjustments to coordinated signal timings to optimize signal operations in response to real-time intersection traffic flow data. Developed by the British Transport Research Laboratory; current Canadian implementations include Toronto and Halifax.

- **Advanced Driver and Vehicle Advisory Navigation ConcEpt (ADVANCE) Data Fusion** - Developed for the Chicago-area ADVANCE operational test, this algorithm integrates travel time data from probe vehicles, incident reports and road/weather condition information. Consolidated road/traffic conditions reports are transmitted to probe vehicles for use by the on-board route guidance system.

- **Intelligent Dynamic Contraflow Lane Control System** - Developed by the British Columbia Ministry of Transportation and Highways for control of the three reversible lane systems operated by the Ministry. The system seeks to optimize counterflow implementation times based on real-time demand and queue lengths on the approaches. It incorporates real-time traffic demand detection, fuzzy logic pattern recognizer, and on-line control optimization algorithms.

2. TECHNOLOGY ASSESSMENT

2.1 APPROACH

The technology assessment is intended to define the current and future state-of-the-art for ITS System Integration and Intelligent Software.

An outreach was conducted to include 20 agencies world wide, to provide an industry cross-section, and to include leading companies in this field, such as:

- foreign industry participants, such as Loral AeroSys;
- Canadian industry participants, such as Delcan;
- industry representative bodies, such as the I-95 Corridor Coalition and the Japanese Traffic Management Association;
- transportation authorities with ITS experience, such as the United Kingdom Department of Transport;
- ITS research agencies, such as Texas Agricultural and Mechanical University.

Question sheets for intelligent software applications and for ITS integration were developed and faxed to the agencies to be surveyed. Follow-up telephone contact was used to solicit responses to the question sheets. Thirteen agencies provided an insightful response. It is estimated that 200-300 organizations compete in this market worldwide. It is difficult to accurately identify the level of industry involvement because the software industry is characterized by countless small businesses, comprised of 1 or 2 individuals.

Copies of the survey question sheets are included as Appendix A. A listing of industry contacts is provided as Appendix B.

2.2 SYSTEM INTEGRATION

2.2.1 Length of Involvement in ITS System Integration

Integrators of intelligent transportation systems have typically expanded "horizontally" from related fields. Some, for example, are consulting-engineering firms with historical practices in traffic control; they took the "natural" expansion to a higher order of technology in ITS. Others, particularly in the United States, applied to the growing ITS market methodologies, development technologies, and marketing techniques developed in the aerospace and defence industries; this process was catalysed by the U.S. government. Still others expand from product development.

Our surveyed firms say they have been in the business of ITS system integration from three to ten years, but this obviously depends on the definition of "ITS"; firms such as Delcan involved in early computer control of traffic can claim ITS experience thirty years long.

2.2.2 Other Services Provided by ITS System Integrators

The types of services provided by system integrators is largely determined by how the firm got into the business. Most SI firms, except those based on hard products, are reluctant to define exactly what kinds of systems they integrate, though they will often state their focus. Firms with background in consulting engineering will offer other transportation or civil engineering services; firms from a more general SI background will add procurement. All offer project or system management.

We have not identified a single firm that could be characterized as only an integrator of intelligent transportation systems.

In firms with significant product offerings (e.g., SNC Lavalin, Plessey, etc.), system integration gets bundled with turn-key deployment, which may lead clients to overlook the importance of the SI role.

2.2.3 Standards and Interoperability

From the perspective of the system integrator, standards and interoperability are issues for the technical configuration of the system, as well as for the processes employed to perform system integration functions.

From the standpoint of technical configuration (or system architecture) there are no accepted international industry standards. The most noteworthy exercise to date has been the U.S. National ITS Architecture Development initiated by the Joint Program Office of the U.S. Department of Transportation. The results of this exercise (reflected in over 5,000 pages of documentation) became available in June 1996. The architecture addresses configuration, interoperability, and information flows among all types of ITS features. The challenge at this point in time is to translate the "big picture" overall architecture into specific directives that the system administrator/engineer can use to guide individual deployment initiatives.

The current trend for communications interfaces among ITS devices is towards an open systems architecture compliant with the Open Systems Interconnect (OSI) 7 layer model developed by the International Standards Organization (ISO). The most notable efforts to date in this regard lie within the U.S. ITS program in the form of the National Transportation Communications for ITS protocol (NTCIP). The accompanying table summarizes the proposed communications profile for each OSI layer. This standard, and in particular the data link layer and physical layer, will facilitate interoperability among subscribing central systems, communications architecture, and field controllers for all ITS applications. This standard is presently under development, and working papers are available from the NTCIP Steering Group.

For Canadian system integrators to remain competitive, it is imperative that they participate and subscribe to this process. At present, it is not clear whether NTCIP will be adopted elsewhere in the world, however compliance with the OSI model supports this transportability.

THE NTICP PROTOCOL

OSI Model Layer	Communication Profile
Application Layer	Simple Mail Transfer Protocol (SMTP) & Simple Network Management Protocol (SNMP) OR File Transfer Protocol (FTP)
Presentation Layer	None
Session Layer	None
Transport Layer	Transmission Control Protocol (TCP) OR User Datagram Protocol (UDP) (optional)
Network Layer	Internet Protocol (optional)
Data Link Layer	High-Level Data Link Control (HDLC)
Physical Layer	RS232 OR Frequency Shift Keying (FSK)

Source: NTCIP Steering Group http://www-atms.volpe.dot.gov/ntcip/

Regarding system integration processes, there is not an industry-wide accepted set of standards. One impediment to the use of formal standards is that clients such as public sector agencies or large automakers, often insist upon the use of their own standard processes. There are some international quality assurance standards which can be brought to bear when commissioning and documenting ITS applications. These include:

- ISO 9000 Certification;
- Institute of Electrical and Electronics Engineers (IEEE) integration standards.

2.2.4 Primary Tools

No industry-wide tool can be identified. SIs use common system-development tools and platforms, such as CASE tools, Visible-type compilers and interpreters, and database programming languages (4GLs and SQLs).

2.2.5 Recent Projects

National ITS Architecture, Washington, D.C. (Loral AeroSys): This is a comprehensive design and a set of prototypes of a "standardized" architecture for a wide variety of ITS functions. One concrete example is inter-traffic management centre communication, which uses TCP/IP to communicate incident information and response plans between centres responsible for adjacent roadways and corridors (such as county road and state highways). As much as possible, commercial off-the-shelf (COTS) and near-industry-standard products and platforms are used.

2.2.6 Characteristics, Special Talents or Unique Abilities Important to Success

The system integration function is human resource intensive, and draws upon a variety of disciplines including traffic engineering, transportation planning, communications engineering, electrical/electronics engineering, software developers, and program managers. Successful system integrators are typically responsible for delivering some of the critical components within the systems they have integrated. For example, North American consulting engineering firms with an active ITS integration practice such as PB Farradyne or SAIC will typically provide the central system software for the systems they integrate. Because the central system interacts with all system components, as well as other systems, it is important for the system integrator to have control over this component of the work.

2.2.7 Anticipated Changes to ITS System Integration Functions in General

It is generally recognized that ITS work will become increasingly commoditized. It is already moving into a turnkey market, which rewards design that emphasizes reusable and reconfigurable components and functions. Standards will become increasingly important and prevalent over the coming five years.

2.2.8 Barriers to Selling off Shore

System integrators universally enter offshore markets using domestic partners, usually as prime contractors. Domestic partners give the offshore contractor a local flavour; as most ITS work is for a public agency, support of local procurement policy-whether explicit or not-is important. As well, a domestic partner knows its way around the local country's engineering standards and practices, and the client agency's decision-making process.

In addition, one respondent reported barriers to the European market sufficiently daunting that it has abandoned the region, though another has found its way around those with a European partner.

2.2.9 Trends in the Domestic and off Shore Markets

The universal trend is towards fewer pure consulting/project management/contracting arrangements, and more public/private partnerships, design-build, and build-operate-transfer projects. These "turn-key" project approaches are typical of emerging markets, and becoming increasingly common in the developed markets such as North America.

2.2.10 Growth Areas

No one firm has a dominant share of the world market for ITS integration; most firms anticipate future growth. Firms see themselves moving into developing countries, where all First World firms complete more equally, that is, where "being local" is irrelevant. Firms such as IBI and Delcan continues to expand geographically, whereas firms such as Loral sees itself expanding functionally by moving more into the territory of the traditional engineering firms, such as the integration of "outside" facilities (cameras, other sensors, etc.). One firm felt that there is considerable market in upgrading existing traffic management centres.

The critical point here is that even huge firms (e.g., Loral, now part of Lockheed Martin, the largest defence contractor in the world; or Hughes, a unit of General Motors) do not dominate the market for system integration. Consequently, their "growth" strategies are similar in that they emphasize incremental, risk-averse penetrations of vertically or horizontally adjacent markets, or markets where principal officials of the firm have contacts or feel comfortable working in.

2.3 INTELLIGENT SOFTWARE

Software refers to both complete ITS application programs and any algorithms, subroutines, processes, etc. which are or can be incorporated into complete programs.

2.3.1 Length of Involvement in ITS Software Development

ITS software development is closely related to system integration, such that the timeframes for industry involvement are similar. Most (though not all) business development flows from the same causes as SI, so involvement in ITS software development is similar-three to ten years.

2.3.2 Type of Organization

ITS systems integrators are often involved in ITS software development, since this is a natural extension of their integration activities. The involvement of SI firms is most prevalent in ATMS, ATIS, and CVO applications, since these tend to be customized for a particular client and often involve the integration of a number of outsourced software components into a unified system.

Specialist software firms (e.g., Giro Enterprises, Teleride Sage) dominate the market for transit applications (APTS). Large equipment suppliers/systems integrators (e.g., IBM, Cubic, Siemens) dominate the market for toll (ETTM) and traffic signal control software. In these cases, the applications are largely "off the shelf" and bundled with hardware, so the same software can be sold to multiple clients with little modification.

In addition to the larger firms noted above, intelligent-software developers also include small operations that act as consultants to larger SIs or agency clients or provide highly specialized software products or algorithms. These small firms generally commercialize products/algorithms developed in university research organizations. Some of the larger specialist firms started out this way.

Software houses per se (e.g., Computer Associates, Software AG) have not entered this market noticeably, but do provide software tools (e.g., database management, development environments) which support the development of ITS software applications by others.

2.3.3 Primary ITS-Related Software Products

ITS software includes a range of products, but tend to be analysis products for making "intelligent" decisions about traffic management: detection of incidents or queues, selection of response plans, scheduling of transit vehicles, throughput-maximizing signal control. The last is a major market area, with SCOOT, SCAT, MOTION, PRODYN, UTHOPHIA, and others available.

Simulators are another class of ITS software products. They can be real-time (used in selection of response plans, signal timing plans, etc.) or off-line (used to model the effects of ITS for feasibility studies or design).

As noted in the previous section, different firms tend to specialize in different ITS applications. While commercial software is available for virtually any ITS application, no one firm supplies software for all applications itself.

2.3.4 Representative Examples

INTEGRATION (M. Van Aerde and Associates, Kingston, Ontario) is a traffic simulation model developed specifically for ITS applications. It is able to simulate the effects of ATMS, ATIS, ETTM and APTS on traffic in very large, integrated freeway/arterial road networks. The model optimizes controls such as traffic signals or ramp meters and produces estimates of efficiency, safety and environmental benefits to support ITS application planning, design and assessment.

The primary product of Teleride Sage Ltd., Toronto, is **TELETRANS**, an integrated, modular transit software package. This software suite includes modules for: computer-aided dispatch and automatic vehicle location (CAD/AVL); vehicle and crew scheduling; driver management; provision of public information; and vehicle maintenance/materials management. The CAD/AVL and public information modules operate in real time. Available scheduling modules include artificial intelligence/heuristics features to automate run-cutting.

IBI Group, Toronto, developed the central software for Metro Toronto's **RESCU corridor traffic management system.** The software includes ATMS and ATIS functions such as incident and queue detection, response plan generation, automatic fax generation, on-line traffic information, voice message generation for phone-in information line, control of changeable message signs, etc. Incident detection is carried out using the All-Purpose Incident Detection Algorithm (APID), with provisions for the future implementation of the McMaster algorithm. Many system functions are integrated and semi-automated, to reduce operator workload. The system is controlled through a simple graphical user interface (GUI). The RESCU software is a typical example of current ATMS/ATIS central control software.

G2 (Gensym Corp., Massachusetts) is a **graphical, object-oriented expert system development environment.** While G2 is not ITS software, it is an example of a software tool used to support the development of ITS applications. A recent example of the application of G2 is the traffic management system for a large ATMS in Neuchâtel, Switzerland. The ATMS includes more than 900 traffic lights and 650 variable message signs for controlling traffic on an urban expressway/tunnel system. In order to reduce operator workload and ensure safety, G2 uses a knowledge base of traffic flow and behaviour, safety procedures, geographic constraints and operating procedures to calculate the best response plan for re-routing traffic around an incident. The response plan is confirmed by an operator, then automatically implemented.

2.3.5 Algorithms, Subroutines, etc. from Outside Sources

Software intended to communicate with and/or control field equipment incorporates device drivers and communications protocols which are either provided by hardware suppliers or are industry standards. Many ITS applications also make use of commercial development environments and database software.

Both public-domain (e.g., APID) and proprietary (e.g., McMaster) algorithms are commonly used for ITS applications such as incident and queue detection in ATMS software. Some intelligent software provides a link between preexisting algorithms or software. For example, the B.C. Ministry of Transportation and Highways has expert-system software to select the optimal signal timing plan from among plans calculated by three commercial software packages (AAP, Passer II, and Transyt-7F).

2.3.6 Most Advanced Features

Most software vendors cite the integrated nature of their software as its most advanced feature. This may refer to the software's ability to carry out a variety of functions through a single interface (e.g., the RESCU software), accommodate multiple ITS applications (e.g., INTEGRATION) or be adaptable to different clients' needs through the "mixing and matching" of a family of related software modules providing various functions (e.g., TELETRANS). Other advanced features promoted by software suppliers include real-time functionality, easy-to-use (usually graphical) interfaces and artificial intelligence.

Software is becoming available that can interpret video images - not just occupancy of a roadway, but, for example, licence plate numbers. Commercially available new approaches, such as groupware, may be adapted to the needs of ITS, such as data fusion. Knowledge-based approaches will be added to adaptive control systems in the near term.

2.3.7 Development Standards

From a technical standpoint, the communications interfaces for software products are increasingly being governed by standards efforts such as the U.S. National Architecture and the NTCIP as discussed in Section 2.2.3.

As a general comment, industry-wide standards are not employed in the development and documentation of ITS software products. The approach employed is typically governed by the client or the developer. With the increasing role of the U.S. aerospace and defence contractors within the industry, there is an increasing use of U.S. military standards (MILspec) governing software structure, coding, testing, and documentation.

2.3.8 Artificial Intelligence

While AI is not in general use in ITS applications, it is beginning to be adopted in certain market niches. The most common examples are the application of expert systems for response plan generation in ATMS and for developing transit system schedules constrained by system timetables, union agreements, equipment and staff availability, etc. AI approaches have also been tried for incident detection, but these are not yet in widespread use.

Where an ITS software application has been successfully implemented using traditional programming techniques, AI may not be necessary or appropriate. The best applications for AI are those where it can automate functions which previously required human input or improve the efficiency/reliability/accuracy of processes previously carried out by traditional software.

2.3.9 Trends

One overall trend in ITS software is the inclusion of more features in integrated software packages. This is a reflection of the increasing deployment of ITS technology and the sharing of field hardware among different applications (e.g., use of vehicle transponders for electronic tolling and data collection for ATMS). Where multiple ITS applications are implemented on the same facility, the control for all applications is generally centralized in one control room/central computer system with one central software package. The increasing size and complexity of ITS applications has resulted in another trend - the automation of system functions to reduce operator workload. This is coupled with the widespread implementation of graphical user interfaces to simplify system operation.

In simulation software such as INTEGRATION, there is a need to incorporate the simulation of more ITS applications, such as demand management features (e.g., dynamic mode shift or departure time shifts). These features have traditionally been assessed with static planning models, but this is not an efficient way of determining the demand management benefits of ITS implementation.

2.3.10 Barriers

A major barrier to the development of more advanced software is the cost of development time. A very large amount of staff time can easily be consumed in developing a novel approach to an ITS application into a usable software product. Software and SI firms have to recover the cost of this development time from purchasers of the software. Unless a client hires a firm specifically to develop new software, the firm generally has to finance the development time from its own resources. In a highly specialized market, this is not always practical, since the pay-back is not guaranteed. Universities and other "pure research" organizations are more able to develop new software techniques, algorithms, etc., but they also face limitations on research staff and funding availability. Research organizations may also lack the skills and resources to develop the results of research into a complete, marketable new software product.

Another barrier is hardware, since more complex software, interfaces, etc. make greater demands on processing power.

2.3.11 Growth Areas

Because the ITS software market covers such a broad range of applications, no one firm can claim a significant market share. Many firms compete in most market segments, but it is possible for a small number of firms to dominate specialized market niches. For example, Teleride Sage and Giro Enterprises hold dominant positions in the domestic and international markets for transit system software. The INTEGRATION software is a leader in the ITS simulation market.

Demand for all types of ITS software applications is seen as growing or at least stable, paralleling the deployment of ITS technology. Specific growth areas include: ETTM and commercial vehicle operations for the increasing number of privately financed, user-pay transportation facilities; new ATMS/ATIS implementations to fight the growing congestion-related problems in cities worldwide; increasing implementation of ATIS World Wide Web pages; upgrades to existing systems' software as technology changes and systems expand.

There is a growing demand for ITS simulation software products, but supply is short. There are not many products that meet customers' needs. For Mike Van Aerde's INTEGRATION package, an important growth area is add-in modules for modelling features such as ramp metering, dynamic traffic signal control and bus signal preemption.

2.4 SUMMARY

ITS system integration remains the preserve of specialist engineering or government-contracting firms. The large SI houses (Systemhouse et al.) have not entered the market in a big way.

The technology of ITS system integration remains local, home-grown, with standards becoming a growing and increasingly critical presence. There is considerable growth in exporting ITS SI expertise.

ITS software and algorithms are in considerable technical ferment, with many competing "inventors" offering their developments.

3. INDUSTRY ASSESSMENT

3.1 MARKET SEGMENTATION

Many firms compete as general-purpose integrators of intelligent transportation systems. Others, however, choose to focus on particular segments of the market for intelligent transportation system integration.

The market can be segmented several different ways. We discuss segmentation:

- by technology;
- by product; and
- by customer.

3.1.1 Market Segmentation by Technology or Product

Firms may choose to focus according to the central, enabling, or critical technology of the systems they integrate. Many intelligent transportation system integration can equally be viewed as marketers of turn-key systems, such as for urban traffic control.

Firms may indicate that they specialize in systems for such and-such a submarket (urban traffic control, bus management) when what they specialize in is the technology for those submarkets.

Having said that, firms may also choose to specialize by their product (in broad terms) or submarket: commercial vehicle operations, electronic tolling, traffic control or management, traveller information services.

One advantage of specialization is that such specialization does not shut the firm out of any given job, but rather allows it to form consortia with attractive and useful partners. Put another way, a general-purpose system integrator is surrounded by competitors-firms that can do at least part of what the general-purpose firm can do; but a specialized firm is surrounded by potential partners.

3.1.2 Market Segmentation by Customer

The market can also be segmented by customer group. The market for intelligent transportation systems already seems to be falling into three distinct groups of customers:

- public-sector roadway operators;
- private-sector roadway operators;
- transit properties;

- commercial vehicle operators (CVOs);
- motorists.

Roadway Operators

Both the North American and European names for the systems being discussed here (*intelligent transportation systems* and *advanced transport telematics*, respectively) suggest multimodal systems. The history and present state of the industry, however, would be better reflected in its old North American name, *intelligent vehicle highway systems*. Most implemented intelligent transportation systems are traffic management systems implemented on busy, important freeways. With a few notable exceptions now coming on line, most such freeway systems belong to and were funded by public-sector roadway operators, typically state departments of transportation or turnpike authorities.

These agencies typically have an engineering-oriented culture and certain methods of procurement that firms have adapted to. They also buy systems of a particular kind and are willing to invest the sums necessary to get what they want. Firms serving this market typically have a background in consulting civil engineering.

Private-sector roadway operators are very much a new breed (or, more exactly, a revived breed). In North America particularly, these turnpike operators tend to be consortia that include firms that will perform most software development and system integration.

Transit Properties

Just as system integrators serving highways agencies often started as consulting engineers serving those agencies, so SIs serving transit properties often have roots in consulting to that industry.

Transit properties are now moving into intelligent transportation systems, typically starting with schedule management and moving through traveller information and automatic vehicle locationing.

From the point of view of competitors, however, the number of transit properties is finite, their budgets are now under considerable restraint (as discussed below), and the market is dominated (in terms of passengers, vehicles, etc.) by a handful of large properties. As an example, of the several transit properties involved in recent greater Toronto transit integration work, a single property-the Toronto Transit Commission-had more than eighty percent of whatever was being measured-vehicles, fares, passenger-miles, employees.

Commercial Vehicle Operators

Operators of for-hire or private truck fleets are reluctant to spend funds on advanced technology or to support local industry, but by contrast are quick and eager to spend when results are financially demonstrable. The movement for just in-time delivery has heightened awareness of the value of time, but the industry had a sense of that in any event; and some intelligent transportation systems, starting with computer-aided dispatch, with route selection and vehicle-based management tools, have been rapidly penetrating the industry as the costs come down and the reliability rises.

This is more of a turn-key market, and although the industry is concentrating, there are many operators large enough to fund ITS implementations.

Motorists

As intelligent transportation systems move in-vehicle, motorists (or, perhaps more precisely, car purchasers) will be asked to invest in these products. If the history of earlier products (e.g., anti-lock brakes, in-car stereos) are typical, early adopters will be drawn to the technical and performance characteristics of the devices and systems. "Middle" adopters will take the yes/no decision from the manufacturer's set of option packages. Late adopters will find the device or system built in.

Note that motorists will not exercise much choice when faced with purchasing electronic-tolling or vehicle-identification devices. Currently available optional ITS features include vehicle navigation, crash warning/blind spot monitoring, and "mayday" emergency notification.

3.2 DEMAND TRENDS FOR LARGE-SCALE INTELLIGENT TRANSPORTATION SYSTEMS

3.2.1 Canada

Participants in the Canadian ITS industry generally hold that Canada offers limited market opportunities in terms of large-scale, heavy-infrastructure intelligent transportation systems. Specifically,

- Canada's major cities and corridors have achieved a measure of deployment, and;

- the benefits of intelligent transportation systems have not been clearly demonstrated to the public such that continued investment can be rationalized.

One important and unique aspect of the Canadian market for intelligent transportation systems is the primacy of provincial authorities. Specifically, highways and public transit are sectors of provincial jurisdiction, and the national authorities have neither the constitutional authority nor the financial presence to lead the provinces' efforts. This means that competitors in the market must sell directly to the provincial transportation departments or, in a very few cases, to major metropolitan transportation departments. (By contrast, the United States' national authorities' constitutional right to regulate interstate commerce has been broadly interpreted, and the federal government has used its fiscal power to lead ITS efforts by funding state-level agencies to implement them.)

3.2.2 United States

As in Canada, federal, state, and local governments in the United States are subject to fiscal restraint, which does constrain growth of spending on intelligent transportation systems. However, the U.S. environment differs considerably from the Canadian in a number of important respects:

- a political system that encourages public capital-works projects, and disperses them geographically;
- a marriage of environmental (particularly air-quality) goals with transportation goals; and
- a strong federal presence.

This last requires some elaboration. The Federal Highway Administration provides the bulk of funding for most intelligent transportation systems implemented on state and local roadways; the administration is involved in the development and selection of programmes, working as a partner with state departments of transportation. This funding is somewhat independent of fiscal restraint because much of it is derived from the Interstate Highway Trust Fund, the result of an hypothecated tax on motor fuel.

Intelligent transportation systems are widely seen, at least at the political level, as contributing to air quality. Cities in what are called "non-attainment areas" - i.e., areas with bad air pollution - can receive more funding for systems intended, at least in part, to clean the air through indirect means. The attainment of air-quality goals is to be achieved partly by reducing congestion, and partly by encouraging travellers to switch from "bad" modes-single occupancy vehicles-to "good" modes-pool cars, transit.

"Priority corridors" have been designated-for example, I-95 from Richmond, Virginia, to the Canadian border, and Gary-Chicago-Milwaukee - and coalitions of local transportation agencies have formed to programme and administer federally sourced funds in these corridors. These coalitions may take on a life of their own, and may also, it is to be hoped, bring to critical mass "travelshed" transportation systems that rise above jurisdictional boundaries.

In addition, more functionality focused corridor coalitions have formed, such as ADVANTAGE I-75, which, with the AVION project in Ontario, seeks to streamline the commercial-vehicle traffic.

In this context, the recent announcement of the "National ITS Initiative", which is intended to implement intelligent transportation systems in the United States' 75 largest cities, must give considerable cheer to integrators of such systems. This initiative is not funded, but the political will does seem to exist to implement at least part of the initiative's vision.

Finally, early implementations of intelligent transportation systems may be upgraded. Early-generation traffic management centers, in particular, may be refurbished to take advantage of new technologies.

3.2.3 Europe

The European Union's DRIVE programmes have been criticized as being too academic, too focused on research. In addition, many DRIVE projects have been dominated by automotive manufacturers.

The need to support multiple languages - in effect, a set of smallish markets - imposes a disadvantage on North American firms.

Eastern Europe however, presents a different story, similar in outline to the developing countries discussed in Section 3.2.5. However, most ex-Communist countries have serious fiscal and legal difficulties to overcome; and western European firms must be granted an advantage by propinquity.

3.2.4 Japan

Japan has a deep and broad installed base on intelligent transportation systems that is subject to highly centralized policy and funding. We expect Japanese investments in intelligent transportation systems to be well funded, but the perception in the industry is that it is a very closed market.

3.2.5 Developing Countries

The highest rates of growth in urban population and in car ownership are found in the so-called developing world-especially the Four Tigers of East Asia (Korea, Malaysia, Singapore, and Taiwan), but to some considerable degree also in poorer but still wealth-accumulating countries (Indonesia, India, Pakistan, Philippines, South Africa, Thailand). These countries are eager to modernize, to leapfrog the installed infrastructure of the West, and to transfer technology and know-how from the West to local firms. As there are no existing competitors, First World-based firms compete equally in the search of partners first, work second.

3.2.6 Effect of Cost on Demand

Demand is a function of cost; so as costs fall, demand will rise. Costs of large-scale traffic management systems will fall partly on cheaper and more effective computing, but also as the technology of surveillance no longer requires inpavement sensors or right-of-way cabling. Current negative views of investment in intelligent transportation systems in Canada and (to a lesser degree) the United States may be proved wrong as surveillance gets cheaper.

As well, the focus on intelligent transportation systems has shifted, to some extent, from infrastructure-heavy traffic management systems to traveller information systems. These have a more readily perceived benefit to the public and the further virtue of not necessarily requiring massive capital investments.

3.2.7 Development of New Vertical Markets

Both ITS system integrators and developers of ITS software have had a more reactive posture than otherwise. Private-sector participants in these markets are, as discussed elsewhere, mostly consulting firms, and often much smaller than their customers. Such participants in any industry do not engage in proactive development of markets or technology on a major scale.

In particular, the application of an "old" or "in-stock" technology (such as an algorithm or a particular system integration competence) to new vertical markets, or the development of new verticals that use a firm's competencies requires an investment, an investment that carries with it some risk. Because of the cashflow-oriented nature of even the large participants in the market, investments that would be modest for firms in goods-producing industries can be firm-killers in the service sector.

What expansion that does take place is *incremental*, so as to minimize the risk. For example, an integrator may deliberately add competence in advanced public transit systems by hiring experienced staff (which carries some risk) and by cultivating transit properties where the firm is based and with whom the firm might have some pre-existing relationship. By contrast, developing and presenting to the market a new "product" into a new vertical market without a firm order is virtually unknown.

The application of ITS technology and system integration competence to under-systemized niches in the transportation system - such as using adaptive traffic control technology on heavy rail networks or in extending public transit to areas of very low population density - will depend on the *client's* determining that these technologies will be helpful, rather than firms developing and promoting such "products" on an at-risk basis.

3.3 BARRIERS TO ENTRY

3.3.1 Knowledge of Served Industry

The first barrier to any entry into a market is the present competitors' knowledge of the industry they serve. In the case of intelligent transportation systems, firms attend or even sponsor conferences, encourage their staff to contribute papers and read journals. Competitors make a point of getting to know the decisionmakers on the customer side, but also to understand the issues and concerns that have the attention of the engineers who will make recommendations up the line.

As discussed several times, most competitors in intelligent transportation system integration were already in the transportation industry. Consequently, this industry's "culture" - its language, assumptions, trends - are known to the competitors. They are not known to firms outside the industry, and this lack of knowledge - not, in itself, necessarily detrimental to a project - can nonetheless be detrimental to a firm's chance at work.

On the customer side, most decisionmakers are transportation or civil engineers, and successful competitors use similarly qualified engineers to develop offerings (e.g., responses to requests for proposals) or to "market" the firm's offerings. Consequently, at the level of personal relationships, the market has the culture common to all branches of engineering, a culture that is in contrast to that of most software firms. A competitor that does not partake of this culture can have difficulty making its message heard by the decisionmakers on the customer side.

The engineering culture of ITS system integration is common at least to Canada, the United States, and Europe. However, American defence contractors (e.g., Loral, Hughes) that have benefited from the United States Department of Transportation's defence-conversion programme have not entered the ITS market with a large cadre of transportation or civil engineers, and have nonetheless found, with help from government agencies, a way to "speak" to the market, to apply competencies developed in aerospace or defence to ITS.

3.3.2 Barriers That Favour Local Competitors

Highly competent firms outside a particular region often have difficulty getting work. This section addresses the barriers that favour local competitors.

Knowledge of Local Customers

First and foremost, local competitors are plugged into the local buyers. Local firms are particularly well plugged into the local "dialect" of the more general transportation culture; they know the decisionmakers; they know how decisions are made within the agencies; and they're familiar with local procurement policy.

Local Presence

Local presence has value in two aspects:

- first, the local competitor can claim to understand, or at least know uniquely local conditions;
- second, a non-local competitor suffers a cost disadvantage, having to fly its own professionals into a location, and then house them.

Industrial Policy

Buyers in this market are public agencies or closely allied with them. Public agencies feel a duty - express or not - to support local firms, local jobs, local expertise.

An example of industrial policy has been the United States Federal Highway Administration's concerted effort to involve aerospace/defence contractors in intelligent transportation systems. These firms often have a bureaucratic way of doing things required by the specification-rich and high-control environments of the Department of Defense and National Aeronautics & Space Administration, and consequently high overheads and thus fewer professional hours per dollar.

3.3.3 Acquisition of Key Competencies

The most formidable barrier to new entrants is the need to acquire or develop competencies that are key - whether to do the work, or to get the work.

Some of these competencies are widely dispersed in the information technology industry, such as programming and data management.

Others are in short supply in all industries, such as network management, communications analysis, and most notably wireless communications expertise. Finally, some are unique to transportation engineering and allied fields, such as an understanding of traffic flows and their impediments.

The marriage of these competencies marks a formidable competitor, and because the mix is unique to the industry it presents a barrier to new entrants.

In this regard, the trend toward traveller information systems and away from traffic management systems represents an opening to system integrators not rooted in transportation. Traveller information systems do not depend on a unique understanding of traffic management, but rather on an understanding of how humans make decisions and indicate what they want, areas already of interest to developers of computer systems.

3.4 PECULIARITIES OF PUBLIC-SECTOR MARKETS

Public-sector buyers - typical for both large-scale intelligent transportation systems in general, and for transit systems-have peculiarities that successful competitors humour.

3.4.1 Transparency of Procurement

In the developed world, the procurement process' cardinal virtue is transparency. Specifications are usually broadly distributed in the form of a request for proposals; proposals are usually reviewed by committees, often graded in a semi-objective point system; contacts between bidders and customer are regulated; and failed bidders can get candid post-mortems from the customer.

This process arose in all democratic countries as a response to procurement scandals in the XIXth and XXth centuries. In that regard, the current process may be generally viewed a success, as corruption in public-sector procurement is much more noteworthy in its discovery than in its absence.

On the other hand, this process undermines legitimate efforts by firms to build a "franchise", something that is common and honourable in the private sector. If a firm with a good new idea approaches a public agency, they may find the idea shopped around in a request for proposals. And successful accomplishment of one phase of a programme only means that the firm will be well regarded for the second phase - but will still have to compete for that work.

The process is also fairly slow and cumbersome, and rewards firms with the patience to devote expensive professional hours to doing unpaid project planning in the form of proposal-writing.

3.4.2 Billing Procedures

Once a job is awarded, public-sector clients, particularly in North America, demand a thorough documentation of invoices. Billing is typically done on an "actual expenditure" basis to an "upset limit"; that is, contractors are only paid what they spend, up to a maximum agreed in advance. Contractors are thus not rewarded for managing their costs effectively. In addition, many public-sector clients (particularly in the United States) use a self-reported (but audited) assessment of the contractor's overhead for labour payments. Again, efficient firms are not well rewarded.

Finally, the process of invoicing public-sector clients is usually very labour-intensive.

3.5 ENTERPRISE STRUCTURE

Projects to integrate intelligent transportation systems are growing more complex in their organization. The classic single client–to–single contractor relationship is being replaced by different structures, in particular, consortia and public/private partnerships.

The point is that firms have to be prepared to network to take advantage of business opportunities in intelligent transportation system integration.

3.5.1 Consortia

System integrators, even very large ones, find the formation of a consortium an advantage in seeking business. A "good" consortium will:

- combine the strengths of two or more system integrators in a project's critical technologies;
- include some "local presence" in the form of one or more firms with a local office or (best of all) a history of good working relations with the client; and
- (for many jobs in the United States) include a "disadvantaged business enterprise".

A good consortium will be constructed so that, absent the details of the proposal itself, the consortium is the obvious choice for a job.

The trend toward consortia is only good for smaller or more focused or offshore firms. A firm with an excellent reputation in (for example) vehicle-to-roadside communications will find itself included in consortia to work on jobs that otherwise would have been an impossible stretch for the firm.

Similarly, providing the experience in intelligent transportation systems to a consortium led by a local firm is the usual way a Canadian firm enters an offshore market.

Although this section speaks of "consortia", these are usually (though not always) organized with a single firm as the prime contractor and the other members of the consortium subcontractors to the prime. Clients are often uncomfortable with consortia at law or joint ventures; they want a single line of accountability, and they understand the law of prime-versus-subcontractor relationships.

3.5.2 Public/Private Partnerships

One of our respondents referred to the "alleged" interest in public/private partnerships but, if measured in words of type or attendance at conferences, the interest is real. At the high end of the scale of intelligent transportation systems - such as the California State Route 91 project or toll-road projects elsewhere - work is usually structured as some form of public/private partnership, with the government participating in the business in some way. (In the example of S.R. 91, the California Department of Transportation is "participating" in the highway through its contribution of significant capital - the right of way.)

From a smaller or more focused point of view, a public/private partnership looks much like a consortium, but the willingness to explore different ways to arrange affairs with the public sector will become essential.

3.6 ADVANTAGES AND DISADVANTAGES OF SIZE

Size is not an overwhelming advantage to integrators of intelligent transportation systems. Middle-sized firms - close to the standard government definition of "small business" - structured as partnerships seem the most viable form of organization. Although results for integrators of intelligent transportation systems organized as divisions of large aerospace/defence firms (such as Hughes Transportation Management Systems or Loral AeroSys) are not available, incidental data (such as overhead rates) and anecdotal evidence suggest that they are not as profitable as smaller, partnership firms. Small firms do not have the scale to be considered except as specialized, focused firms in consortia.

Note that in consulting engineering, a very similar industry, there is room for Bechtel and a few other firms of that scale to manage truly massive projects; but also room for many thousands of profitable smaller firms; and the very large firms cannot successfully compete for projects below a certain level.

3.6.1 Advantages of Size

- Large firms have the personnel depth both to absorb variable workloads, and also to provide back-up to key personnel.
- Large firms have the financial resources to support large-scale integration work.
- Large firms typically have a broad set of competencies to draw on without the complications of a consortium.
- Within a large firm there will be experience with a broad set of projects, with new clients will want to tap.

3.6.2 Disadvantages of Size

- The larger a firm is, the more resources it must devote to managing itself. If there are economies of scale in the central process, these can outweigh the diseconomies of managerial scale. In system integration, economies of scale seem to have an upper limit. In a word, larger firms tend to be bureaucratic.
- Very large firms are rarely organized as partnerships. Consequently, management often has no direct stake in the financial success of a project, and cost control is not as vigilant.
- Larger firms are less flexible with respect to business arrangements.

Because of the history of the industry, clients may not like dealing with a firm large enough that customary power relationships don't obtain.

4. SUMMARY AND RECOMMENDATIONS

4.1 CANADIAN INDUSTRY STRENGTHS AND WEAKNESSES

System Integration

The principal strength of Canadian ITS system integrators is the experience they gained in early ITS deployments in a few major centres. Subsequently, some of the SI firms have leveraged this domestic experience to gain further experience off shore.

In this strength lies the Canadian industry's weaknesses:

- Canada is a "small pond": there are relatively few clients for large- or even medium-scale intelligent transportation systems, so firms hoping to expand or to build a strong specialty base in their domestic market are limited. Canada's population, and thus her road and transit systems are unusually concentrated in a handful of centres, which limits the market even if all else were equal.

- Canada's ITS clients are generally retrenching fiscally, with expenditures being reduced and little appetite for pre-deployment research and development.

- As part of Canada's "small pond", even the large SI firms are small by international standards. They thus don't have the apparent strength of larger, if less experienced firms off shore.

- Canada does not have a well articulated national programme for the deployment of intelligent transportation systems, and the development of enabling technologies.

- Related to the above, the Department of Foreign Affairs & International Trade is not prepared or briefed to support ITS system integrators seeking toeholds off shore.

Intelligent Software

The principal strength of Canada's developers of ITS software is the support offered by the (relatively) well funded university environment, and by the informal personal connections between the universities and the ITS system integration firms.

Developers of software for the ITS market suffer from many of the same weaknesses as the system integrators: a limited number of clients and deployments, the lack of a national programme. In particular, the limited number of deployments caused by Canada's population concentration in a few centres hurts the software industry especially hard because it does not allow different approaches to be tried and demonstrated in real-world environments. For example, the Toronto Transit Commission operates what is far and away the largest and most expensive paratransit operation in Canada. Few other operations in Ontario, even in the larger centres, have the need for a sophisticated and powerful scheduling and routing engine. Thus, GIRO's world-leading work in this area has fewer opportunities to be seen; and other solutions that might be better or offer advantages in certain dimensions are not seen.

As part of the "big fish in small pond" problem, the relatively few number of large system integration firms means that the number of connections software developers can make is limited.

4.2 OPPORTUNITIES FOR CANADIAN INDUSTRY

4.2.1 Market Opportunities

The greatest market opportunity for all First World integrators of intelligent transportation systems lies in developing countries. As affluence and traffic volumes build, developing countries are seeking to leapfrog the 1940-80 phase of road-building directly to the present "intelligent" phase.

In addition, in-building will continue in the developed countries, including Canada and the United States. Opportunities will exist for firms that can tolerate innovative contract or enterprise structures to create business by proposing to public agencies private or quasiprivate solutions to problems of congestion, environmental degradation, etc. And success in any high-profile implementation of intelligent transportation systems can be leveraged to new work.

From a functional perspective, the market analysis conducted by SRI confirms that the greatest opportunities lie in revenue-oriented applications, namely ETTM and CVO.

4.2.2 Market Threats

The biggest threat to existing firms comes from general-purpose system integrators. The business of designing and integrating traffic management systems, particularly the field infrastructure, will remain relatively safe to manufacturing- or civil engineering–based firms, as at present. However, information-oriented systems, such as traveller information systems don't require a great deal of specialized knowledge, and are available to large-scale, general-purpose integrators that have the patience to attack the market.

Also, some aspects of the market are becoming highly turnkey-oriented. For example, once the ten or so biggest transit properties in North America are automated, the smaller ones will look for those systems to be delivered on a turn-key, semi-custom basis.

4.3 RECOMMENDATIONS AND PROPOSED COURSE OF ACTION

The following section presents recommendations for each stakeholder for the advancement of an ITS display industry in Canada. Each recommendation is supported by candidate measures which could be undertaken in order to address the recommendation.

Industry Canada and Transport Canada

1. **Foster the development of industry alliances to facilitate turnkey system solutions in the international market.** Canada's software and integration resources should be better aligned in order to address Asian and European markets for large- and medium-scale intelligent transportation systems. These alliances would include Canadian firms in related industries and local partners overseas. Specific measures which should be considered include:

    - use the Strategis Website as a forum for exchanging information on software and integration capabilities and market opportunities;

    - represent Canada's ITS capabilities in trade missions to the Asia-Pacific region and gather information on upcoming projects and potential local partners including engineering consultancies and system integrators;

    - introduce ITS industry participants to targeted high-technology firms that are actively targeting emerging markets (e.g., Nortel);

    - encourage the alignment of SI and software firms with related ITS manufacturers to provide turnkey deployment.

2. **Provide a showcase for Canadian ITS expertise, including unique or powerful algorithms and integration capabilities.** The experience with the Ministry of Transportation of Ontario's COMPASS programme suggests that state-of-the-art ITS applications can be deployed to meet Canadian needs and also

serve as a showcase to the world market, generating significant export benefits. In the case of the COMPASS example, export revenues are estimated to be at least three times the original investment in the system deployment. The showcase, or "model deployment", is the current thrust of the U.S. programme and provides the opportunity to bring together the various ITS industry strengths and demonstrate interoperability and operational benefits. Examples in the Canadian ITS arena could include an ATMS/ATIS for Vancouver or a Canada-wide commercial vehicle pre-clearance program. Specific measures which should be considered include:

- work with targeted provincial, regional, and municipal levels of government to promote model deployment;
- provide funding for model deployment, possibly through direct assignment of fuel tax revenues or the development of an information technology infrastructure programme.

The model deployment approach brings together Canadian resources, and demonstrates how they can successfully work together. Consider the example of Highway 407 in Toronto, which initiated the Canadian Highways International Corporation (CHIC) joint venture of Canadian road construction expertise. CHIC now competes globally on large scale road construction projects.

3. **Provide incentives for ITS software research and development in Canada.** Targeted areas would be further development of vehicle scheduling and wireless data acquisition from mobiles, as well as deployment of ITS technologies to new vertical markets, such as rural transit and heavy rail.Faced with intensive levels of public and private sector R&D funding under foreign programmes, domestic programmes must focus on specific niches with demonstrated market opportunities. Specific measures would include:

   - use monetary incentives, and access to Canadian research facilities, to encourage automakers to increase their levels of research and development within Canada;
   - fund research and development and productization through NSERC programs;

- discretely identify ITS as a target area within the Technology Partnerships Canada Programme to encourage public/private partnerships for research, development and productization;

- establish a program similar to the U.S. ITS IDEA Program which encourages the transfer of technologies from related applications to the ITS arena;

- spearhead the development of a research centre of excellence along the lines of the U.S. model drawing upon the ITS expertise at University of Calgary, McMaster University, and Queen's University.

4. **Participate in foreign ITS programmes and standards initiatives in order to help facilitate access by Canadian industry.** For example, Transport Canada and the Ministry of Transportation of Ontario participate in the Enterprise consortium of U.S. state departments of transportation. This provides the opportunity for Ontario ITS firms to participate in, or have access to, Enterprise-sponsored research and development activities. Specific measures to be considered include:

   - assume a more active role in proposing, funding, and directing R&D initiatives within the Enterprise consortium;

   - use the Strategis Website as a gateway to access databases sponsored by the U.S. DOT, federal laboratories such as Turner-Fairbanks, and U.S. research centres of excellence;

   - actively participate in standards processes including U.S. national ITS architecture, U.S. DOT Joint Program Office standards for ITS, and the EU DRIVE programmes.

   It's important to emphasize that Canadian ITS product and service providers be cognizant of and compliant with emerging international standards as the industry becomes more turnkey-oriented.

5. **Update this review of technology on a regular basis.** This report identifies an array of ITS applications and related services. Some emerging applications such as expert systems for incident response are developing very rapidly. Periodic (e.g. annual)

update bulletins to amend the contents of this report will help to keep this report useful as a reference tool for Industry Canada and the Canadian industrial base.

6. **Create an ITS office within Industry Canada.** An ITS office would serve as a national ITS industry focal point in order to:

- track the progress of foreign and domestic ITS activities;
- ensure that the recommendations as set forth herein are acted upon;
- foster cooperation and information sharing among various industry participants;
- showcase Canadian ITS achievements and activities within the international community;
- represent Canadian industry/interests in international activities such as standards development;
- support the coordination of international conferences, workshops, etc.

Other Public Sector

1. **Provide the opportunity to showcase Canadian ITS capabilities.** The role of other levels of government and transit authorities would include establishment of a demonstration project scope, site and capital and operations funding. Other public sector agencies should accommodate the demonstration of advanced ITS display applications within their capital programmes. Specific measures should include:

- identification of software and overall system requirements and review of the international market with respect to products available and other agency experiences;
- provide funding for operational tests;
- increase exposure to operational tests through objective evaluation, publications, conferences, etc.

2. **Provide incentives for increased research and development.** Specific measures to be considered include the provision of

monetary incentives, access to Canadian research, and/or legislative mandates.

Industry Participants

1. **Establish a network of firms that you can partner with readily when the need arises.** Successful integrators of intelligent transportation systems have a stable of "friends", some of them sometime competitors, some of them firms in particular countries or regions or industries, that they can draw on when it comes to forming a consortium. SI firms must have a network of ITS hardware vendors in place with distributor pricing arrangements in order to be competitive on overseas, turnkey ITS projects. For example, a firm such as IBI Group might align with Ledstar (VMS), IRD (WIM), EIS (sensors), Sony (CCTV) and Impath (communications) to deliver full ITS solutions in Asia-Pacific emerging markets.

2. **Seek to bundle software applications with hardware products.** Software is much more marketable when bundled with hardware components or turnkey systems. For example, Dr. F. Hall and McMaster University could achieve worldwide distribution for their McMaster Incident Detection Algorithm through bundling with an established market leading detection system, such as Autoscope from Econolite (California) and ISS (U. of Minnesota).

3. **Seek entry into every opportunity practical, even at a low level, to gain experience and exposure.** Even a very small role leads to technology transfer from the prime and the client and the job itself; and the firm can put on its résumé that it was involved with such and such a project.

4. **In developing countries, seek a well established, reputable partner to lend local presence.** Accept the inevitable "technology transfer" that develops to the offshore firm's detriment.

Research Organizations

1. **Foster the development of enabling technologies for ITS applications, and other related applications.** Specific technologies include vehicle scheduling, incident detection, congestion management, toll system processing, value-added vehicle to roadside communications functions, and various on-

board processing functions to support navigation and collision avoidance.

2. **Strengthen links to industry in order to focus research on market needs and market products resulting from successful R&D programs.** Experience with other ITS solutions developed in academia, (such as Autoscope video vehicle detection originating from U of Minnesota) suggest that representation from the ITS industry is necessary to lend direction to research, and provide channels for productization, and international marketing, distribution and support. Universities and principal investigators must organize such that the results of their efforts can be marketed worldwide. SI firms are an obvious conduit to achieve this transition; hardware vendors are another.

Bibliography

Alling, P. Ed. (1996). *The International ITS Index 1996.* Transport Technology Publishing, London, U.K.

Douglas M. Ed. (1996). *Inside ITS.* February 1996. Volume 6. Transport Technology Publishing, New York, N.Y.

Euler, G.W. ED. (1995). *National ITS Program Plan.* First Edition DTFH61-94-R-00076, Federal Highway Administration, Washington, DC.

Industry Canada (1995). *Canada's Transportation Electronics Products and Capabilities.*

Industry Canada (1995). *Guide to Canadian Aerospace and Defence Products and Services for World Markets.*

Logden, S.Ed. (1996). *The Intelligent Highway.* March, 1996. Volume 6. Traffic Technology Publishing, New York, N.Y.

Nuttall, I. Ed. (1996). *Traffic Technology International. `96* U.K. and International Press, Surrey, U.K.

Robinson, I.B.L. and R.C. Ridley (1994). *A strategic plan for the Development of IVHS in Canada.* Transport Canada TP11885, Ottawa, Ontario.

SRI Consulting (1996). *ITS Technology and Application Evaluations.* SRI Consulting, Menlo Park, California.

The Canadian Defense Preparedness Association (1995). *Canadian Defence Almanac* Ottawa, Ontario.

APPENDIX A

SURVEY QUESTIONNAIRES

ITS TECHNOLOGY SURVEY
SYSTEM INTEGRATION

1. How long has your organization been involved in ITS system integration?

2. What other services does your organization provide? (e.g. design, project management, equipment manufacture, software development, etc.)

3. Which of the following best describes your organization:
   ___ equipment manufacturer ___ equipment supplier
   ___ system integrator ___ research and development organization
   ___ government agency ___ engineers/consultants

4. Does your organization use formal system integration standards and/or procedures in its work? If so, what are they?

5. Identify the primary system integration tools (hardware and/or software) your organization uses. Indicate whether these were developed in-house or obtained from an outside source.

6. Provide some examples of recent system integration projects, identifying the tools, standards and procedures used in them.

7. What characteristics, special talents or unique abilities of your organization are most important to its success in system integration work?

8. Do you anticipate any changes to your organization's system integration tools, procedures or standards over the next 5 years? If so, what are they?

9. How do you see ITS system integration functions in general changing over the next 5 years?

10. Identify specific barriers encountered by your organization in selling system integration services in international markets. (e.g. licensing requirements, taxes/tariffs, foreign content restrictions, language/culture, etc.) How were these overcome?

11. What are the trends in the domestic and international markets for ITS system integration services?

12. What and where are the growth areas in the markets for your organization's ITS system integration services?

13. What are your organization's current estimated shares of the domestic and international ITS system integration markets? What are the trends for your organization's market shares?

ITS TECHNOLOGY SURVEY
INTELLIGENT SOFTWARE

In the following questions, "software" refers to both complete application programs and any algorithms, subroutines, processes, etc. which are or can be incorporated into complete programs.

1. How long has your organization been involved in ITS software development?

2. Which of the following best describes your organization:

___ equipment manufacturer	___ equipment/software supplier
___ software developer	___ research and development organization
___ government agency	___ engineers/consultants

3. What are your organization's primary ITS-related software products?
   ___ Advanced Traffic Management Systems ______________________
   ___ Advanced Traveller Information Systems ______________________
   ___ Advanced Public Transit Systems (including ride-share/HOV operations)______
   ___ Commercial Vehicle Operations ______________________
   ___ Electronic Toll and Traffic Management ______________________
   ___ Advanced Vehicle Control Systems ______________________

4. What other software products does your organization produce? Where do you see opportunities for technology transfer to ITS applications?

5. Provide recent representative examples of your organization's work in ITS software.

6. Do any of your organization's software products include algorithms, subroutines, etc. from outside sources? If so, what are the main ones, and what are their sources?

7. What do you consider to be the most advanced features of your company's software (including software currently in development)?

8. What artificial intelligence (AI) features have been implemented in your organization's software (including software currently in development)?
   - What are the benefits of using AI in these applications, relative to traditional software techniques?
   - What difficulties were encountered in these AI applications?

9. What trends do you see in the development of more advanced ITS software? What new ITS software or improvements to existing software does your organization plan to develop over the next 5 years?

10. What barriers do you see as inhibiting the development of more advanced ITS software? (e.g. hardware limitations, cost, lack of demand, legal issues, standards etc.)

11. Identify specific barriers encountered by your organization in selling your software in international markets. (e.g. licensing requirements, taxes/tariffs, foreign content restrictions, language/culture, etc.) How were these overcome?

12. What are the trends in the domestic and international markets for ITS software?

13. What and where are the growth areas in the markets for your organization's ITS software?

14. What are your organization's current estimated shares of the domestic and international ITS software markets? What are the trends for your organization's market shares?

LISTING OF FIRMS CONTACTED

Allied Signal
Delcan
Delco
Gensym Corporation
Giro Enterprises
I-95 Corridor Coalition
IBI Group
Japanese Traffic Management Association
Loral Aerosys
Michel Van Aerde and Associates
Ministry of Transportation Ontario
Monenco AGRA
PB Farradyne Inc.
Siemen's Traffic Controls
SNC Lavalin
Teleride Sage
Texas A&M Research Centre of Excellence
Thomson - CSF
UK Department of Transport
University of California PATH

APPENDIX B

INDUSTRY CONTACTS

ALLIEDSIGNAL, Inc.

ADDRESS: 240 Attwell Drive
Etobicoke, Ontario
M9W 6L7

CONTACT: Peter Keyer
Tel: (416) 798-6679
Fax: (416) 798-6866

KEYWORDS: ATMS, video image processing

HISTORY: AlliedSignal is serving the automotive, aerospace and engineered materials markets. The company expanded into Canadian market with two plants located in Montreal and Toronto. Infrared sensors are produced by the AlliedSignals plant in Montreal. The Toronto office primarily manufactures aircraft cabin temperature and air flow sensors.

ITS CAPABILITY: AlliedSignal Inc. is involved in manufacturing the following ITS technologies:

- infrared image enhancement sensors adaptable for heads-up display;
- inductive loops, microwave, infrared, acoustic sensor systems;
- video surveillance, transmission, switching and display;
- traffic controllers;
- fibre optic, copper and RF/microwave communication systems;
- client-server computer systems;
- local area communication networks;
- variable message signs;
- lane control signals;
- signal system control.

ITS PERSONNEL: No data.

GROSS SALES: 1995 - $14 billion
Infrared sensors produced in Montreal generate sales of $5 million per year.

PLANT SIZE: No data.

EQUIPMENT: No data.

ITS EXPERIENCE: AlliedSignal Inc. is actively involved in ITS market and its main projects include:

- San Antonio Advanced Traffic Management Systems;
- Boston I-93 Integrated Motorist Information and Traffic Control System;
- Texas Traffic Responsive Automated Corridor ITS Operational Test;
- Intersection Collision Avoidance Research Program.

DELCAN CORPORATION

ADDRESS: 133 Wynford Drive
North York, Ontario
Canada M3C 1K1

CONTACT: Mr. Bowen Tritter, Chief Systems Engineer
Tel: (416) 391-7512
Fax: (416) 441-0226

KEYWORDS: Consultants, Intelligent Transportation Systems; ITS; Software; Systems Integration.

HISTORY: Delcan has been involved in the ITS field for over 10 years. It is a Canadian corporation.

ITS CAPABILITY: Delcan is a consulting engineering firm which provides services in a range of disciplines, including systems engineering, software development, transportation engineering, structural engineering, environmental engineering and project/program management. The firm specializes in ITS-related applications, particularly ATMS.

ITS PERSONNEL: Approximately 100 staff.

GROSS SALES: No data.

PLANT SIZE: No data.

EQUIPMENT: No data.

ITS EXPERIENCE: Clients include Canadian, U.S. and Asian government transportation agencies as well as a variety of public institutions and private sector companies. ITS projects include: ITS master plan for the Greater Vancouver Area; ATMS for Kowloon and Tseun Wan, Hong Kong; FTMS, Republic of Korea; Taipei traffic signal control system software; COMPASS FTMS software, Toronto.

GIRO ENTERPRISES Inc.

ADDRESS: 75 Port-Royal Street East, Suite 500
Montreal, Quebec
Canada H3L 3T1

CONTACT: Mr. Nigel Hamer
Tel: (514) 383-0404
Fax: (514) 383-4971

KEYWORDS: APTS; Geographical Information Systems; GIS; Software; Transit.

HISTORY: GIRO Enterprises is a Canadian company based in Montreal. It has an on-going association with the Centre for Research on Transportation at the University of Montreal.

ITS CAPABILITY: GIRO Enterprises provides specialized computer software and related consulting services for public transit and other transportation applications. The company's primary product is HASTUS, a transit vehicle and crew scheduling/management system. Other products include GIRO-ACCESS, a comprehensive trip reservation and scheduling system for paratransit operations, and GeoRoute, a geographical information system designed for advanced routing and scheduling applications.

ITS PERSONNEL: No data.

GROSS SALES: No data.

PLANT SIZE: No data.

EQUIPMENT: No data.

ITS EXPERIENCE: HASTUS has been developed over the past 15 years in collaboration with the Centre for Research in Transportation. Its is currently installed in nearly 20 countries in North America, Europe, Africa, Asia and Australia. Examples of installations include Montreal, Ottawa, Los Angeles, Boston, Seattle, Sydney, Tokyo, Barcelona, Stockholm, Edinburgh, Lyon. An example of a GIRO-ACCESS installation is the Wheel-Trans system in Toronto.

IBI GROUP

ADDRESS: 230 Richmond Street West, Fifth Floor
Toronto, Ontario
Canada M5V 1V6

CONTACT: Mr. Scott Stewart, Director
Tel: (416) 596-1930 ext.222
Fax: (416) 596-0644

KEYWORDS: Consultants; Intelligent Transportation Systems; ITS; Software; Systems Integration.

HISTORY: IBI Group was established in Toronto under its current structure in 1974. Since then it has expanded operations to 7 other offices in Canada, 4 in the U.S. and 4 overseas. IBI is a privately-owned Canadian partnership.

ITS CAPABILITY: IBI Group is a multi-disciplinary firm offering a complete range of professional consulting services for ITS projects. Services provided include feasibility studies, functional design, detail design, implementation management, systems integration and software development.
The firm develops custom software to meet clients' needs. Applications which have been developed include ATMS, ATIS, CVO and ETTM. IBI Group is also a distributor for the INTEGRATION ITS simulation package developed at Queens University.

ITS PERSONNEL: IBI Group's ITS practice includes approximately 50 engineers and programmers.

GROSS SALES: No data.

PLANT SIZE: No data.

EQUIPMENT: No data.

ITS EXPERIENCE: Clients include Canadian, U.S. and European government transportation agencies as well as a variety of public institutions and private sector companies. Projects include the full range of ITS applications (ATMS, ATIS, APTS, CVO and ETTM) as well as related applications in telecommunications, facilities and computer systems. Recent ITS projects include: commercial vehicle monitoring and control systems at Pearson and Winnipeg International Airports; Metro Toronto RESCU corridor traffic management system; CITRAC ATMS upgrade in Glasgow; Boston Central Artery/Third Harbour Tunnel traffic management system; Northumberland Strait Bridge traffic management and toll systems.

M. VAN AERDE AND ASSOCIATES Ltd.

ADDRESS: 86 Point St. Mark Drive
Kingston, Ontario
Canada K7K 6X8

CONTACT: Mr. Mike Van Aerde, President
Tel: (613) 545-6370
Fax: (613) 547-5481

KEYWORDS: Consultants; Intelligent Transportation Systems; INTEGRATION; ITS; Queens University; Simulation; Software.

HISTORY: M. Van Aerde and Associates was established in 1993 to commercialize software and services developed by faculty, staff and students at Queens University. It is a privately owned Canadian consulting firm.

ITS CAPABILITY: The company's primary products are the INTEGRATION traffic simulation software and related consulting services. INTEGRATION simulates the effects of ATMS, ATIS and ETTM technology applied to roadway networks and produces estimates of efficiency, safety and environmental benefits. The company also markets QueensOD (origin-destination), a synthetic OD generation technique based on a mixture of on-line traffic flow and probe data.

ITS PERSONNEL: 4

GROSS SALES: No data.

PLANT SIZE: No data.

EQUIPMENT: No data.

ITS EXPERIENCE: The INTEGRATION model and companion software has been applied to a wide range of traffic networks, including Miami, Orlando, Boston, Long Island, Detroit, Michigan and Los Angeles. Other recent ITS projects include: evaluation of the Toronto COMPASS freeway traffic management system; TravTek ATIS operational test safety and benefit study (subcontract to Science Applications International Corp.); U.S. National ITS Architecture Study (subcontract to MITRE Corp.).

SNC LAVALIN INC.

ADDRESS: Atria North Phase II
2235 Sheppard Avenue East
Willowdale, Ontario M2J 5A6

CONTACT: Imad Nassereddine
Tel: (416) 756-3400
Fax: (416) 756-2266

KEYWORDS: ATMS, APTS, AVCS

HISTORY: SNC Lavalin has a total staff of 5,300 in 90 countries. Involvement in ITS projects originated in 1987.

ITS CAPABILITY: Planning, detail design, system integration and turnkey delivery for traffic and transit management systems.

ITS PERSONNEL: No data.

GROSS SALES: No data.

PLANT SIZE: No data.

EQUIPMENT: No data.

ITS EXPERIENCE: MTO Freeway Traffic Management Systems, Halifax traffic signal control, Transit systems in Vancouver, Ankara, and Kuala Lumpur.

TELERIDE SAGE Ltd.

ADDRESS: 156 Front Street West, Fifth Floor
Toronto, Ontario
Canada M5J 2L6

CONTACT: Doug Baxter, Manager, Sales and Marketing
Tel: (416) 596-1940 ext. 207
Fax: (416) 595-5653

KEYWORDS: APTS; Software; Transit.

HISTORY: Teleride Sage has been a leading supplier of integrated solutions for the transit industry since 1977. It is a privately owned Canadian company.

ITS CAPABILITY: The company's primary product is its TELETRANS suite of transit software solutions. TELETRANS includes modules which support computer aided dispatch/automatic vehicle location (CAD/AVL), vehicle/crew scheduling, driver management, public information systems and fleet/inventory management. Teleride Sage also provides software and related services for other ITS applications such as emergency services dispatch, traffic signal control and ATIS.

ITS PERSONNEL: over 60 transit software specialists, 9 dedicated ITS staff

GROSS SALES: No data.

PLANT SIZE: No data.

EQUIPMENT: No data.

ITS EXPERIENCE: TELETRANS software has been successfully installed in over 80 transit organizations. Other ITS projects include a large signal control system in Toronto, and a traffic/transit real-time data acquisition/processing/dissemination system to support the Travel Guide ATIS demonstration project in Toronto.

Other Contacts (Ref. The International ITS Index, 1996)

Cartier Group
11th Floor, 2045 Stanley Street
Montreal, Quebec
H3A 2V4

Tel: (514) 499-4500
Fax: (514) 499-4515

Marshall Macklin Monaghan Ltd.
80 Commerce Valley Drive East
Thornhill, Ontario
L3T 7N4

Tel: (905) 882-1100
Fax: (905) 882-0055

Virtual Prototypes
4700 de la Savane, Suite 300
Montreal, Quebec
H4P 1T7

Tel: (514) 341-3874
Fax: (514) 341-8018

Constance Consultants Ltd.
5660 McAdam Road, Unit B-6
Mississauga, Ontario
L42 1T2

Tel: (905) 890-0798
Fax: (905) 890-6117

UMA Engineering Ltd.
1479 Buffalo Place
Winnipeg, Manitoba
R3T 1L7

Tel: (204) 284-0580
Fax: (204) 475-3646

DELCO ELECTRONICS CORPORATION

ADDRESS: One Corporate Centre, E110
Kokoma, Illinois 46904-9005

CONTACT: John McComas, Staff Engineer, ITS Technologies
Tel: (317) 451-1921
Fax: (317) 451-1340

KEYWORDS: "Forewarn" radar collision warning devices, night vision system, Telepath 100 navigation system, radio data system (RDS) receiver and electronic tolling and traffic management.

HISTORY: Delco Electronics and General Motor's sister company Hughes Aircraft (which together form the GM subsidiary Hughes Electronics) have jointly formed the HE Microwave to develop and market Forewarn radar-based object detection systems for the automotive market.

ITS CAPABILITY: DEC designs and manufactures automotive electronics, audio sound systems, air controls, air bag and anti-lock brake modules, semiconductor devices and integrated circuits, electronic engine controls, vehicle displays and instrumentation.

ITS PERSONNEL: 30,000 employees

GROSS SALES: 1994 - $5.2 billion

PLANT SIZE: No data.

EQUIPMENT: No data.

ITS EXPERIENCE: DEC was involved in the TravTek project. The Forewarn sensor system has been implemented on the Lexus L5400 and by GM on the 1996 Cadillac Seville.

GENSYM CORPORATION

ADDRESS: Corporate Headquarters
125 Cambridge Park Drive
Cambridge, Massachusetts
U.S.A. 02140

CONTACT: Jos van Trier, European Marketing Manager (The Netherlands)
Tel: +31 71 522 29 40
Fax: +31 71 521 47 53

Canadian Office (Mississauga)
Tel: (905) 677-7077
Fax: (905) 677-1606

KEYWORDS: Artificial Intelligence; Intelligent Transportation Systems; ITS; Process Control; Software.

HISTORY: Gensym was founded in Cambridge, Massachusetts in 1986. Since then, it has sold over 5,000 product licenses to more than 500 organizations in over 40 countries worldwide and has expanded operations to 14 North American and 11 overseas offices. Gensym is an American corporation, publicly traded on the NASDAQ exchange.

ITS CAPABILITY: Gensym produces object oriented artificial intelligence system development environment software. The software was originally developed for the process control industry, but is now being applied in ITS. The ITS applications are developed by partner companies using the Gensym software.
The primary product for use in ITS is G2, an expert system development/deployment environment. Other products include G2 Diagnostic Assistant, which provides a graphical interface for developing fuzzy logic systems, and NeurOn-Line for the creation of neural network applications.

ITS PERSONNEL: No data.

GROSS SALES: No data.

PLANT SIZE: No data.

EQUIPMENT: No data.

ITS EXPERIENCE: Gensym does not directly develop software for ITS applications, but provides software and technical support for partner companies which develop the applications. Recent ITS application examples include: Neuchâtel, Switzerland urban tunnel traffic incident management system, application developed by Cegelec (France); Caltrans, Orange County incident detection and traffic management application developed with UC Irvine and Knowledge Systems Design; Houston ATMS, application developed by Loral; Barcelona APTS application developed by IBM.

LORAL AEROSYS

ADDRESS: 7375 Executive Place, Suite 101
Seabrook, Maryland 20706-2257

CONTACT: Michael T. Ward, Director
Tel: 301 805-0336
Fax: 301 805-0517

KEYWORDS: ATMS, ATIS

HISTORY: Loral AeroSys is a division of Loral Corporation, a large aerospace/defence contractor. Loral is in the process of being merged into Lockheed Martin Corporation; the result of this merger will be the world's largest aerospace/defence contractor. Loral AeroSys has specialized in supporting the U.S. National Aeronautics & Space Administration, notably the Space Transportation System (shuttle) and Hubble Space Telescope programmes; hence Loral AeroSys' location, a few hundred metres from the Goddard Space Flight Center in Greenbelt, Maryland. Loral AeroSys entered the ITS market in 1992 as a result of encouragement from the U.S. government.

ITS CAPABILITY: The company's primary capability is the design of control and data-distribution systems. This started out for satellites and their scientific telemetric product, but has been adapted to the design of traffic management and control centres.

ITS PERSONNEL: about 50 software and system engineering staff; 8 dedicated to ITS

GROSS SALES: No data.

PLANT SIZE: No data.

EQUIPMENT: No data.

ITS EXPERIENCE: Loral AeroSys is one of the two successful firms at the second stage of the United States Department of Transportation's National ITS Architecture programme.

PB FARRADYNE INC.

ADDRESS: 3200 Tower Oaks Blvd.
Rockville, Maryland 20852

CONTACT: Mr. Philip Tarnoff, President
Tel: (301) 468-5568
Fax: (301) 816-1884

KEYWORDS: ATMS, ATIS, ETTM, CVO

HISTORY: Farradyne Systems was founded in 1984 and acquired by Parsons Brinckerhoff (PB) in 1992.

ITS CAPABILITY: Data modelling/analysis, software development, system integration, and transportation engineering to support all types of ITS applications.

ITS PERSONNEL: Approximately 120 people.

GROSS SALES: U.S. $15-20 million

PLANT SIZE: No data.

EQUIPMENT: No data.

ITS EXPERIENCE: Selected ITS projects include the Transmit operational test in New York/New Jersey, Travel Aid ATIS in Washington State, Travetek Orlando, and Pathfinder Los Angeles.

B2 Industry Contacts - U.S.

Other Contacts (Ref. the International ITS Index, 1996)

Ball Systems Engineering
5580 Morehouse Drive
San Diego, California 92121-1709

Tel: (619) 457-5550
Fax: (619) 457-5410

BRW Inc.
700 Third St. S.
Minneapolis, Minnesota 55415

Tel: (612) 370-0700
Fax: (612) 370-1378

Coryphaeus Software Inc.
985 University Avenue, Suite 31
Los Gatos, California 95030

Tel: (408) 395-4537
Fax: (408) 395-6351

Dunn Engineering Associates
66 Main Street
Westhampton Beach, New York 11978

Tel: (516) 288-2480
Fax: (516) 288-2544

HNTB Corporation
1201 Walnut, Suite 700
Kansas City, Missouri 64106

Tel: (816) 472-1201
Fax: (816) 472-5004

Kaman Sciences Corp.
1500 Garden of the Gods Road
P.O. Box 7463
Colorado Springs, Colorado 80933-7463

Tel: (719) 599-1631
Fax: (719) 599-1387

Battelle
505 King Avenue
Columbus, Ohio 43201

Tel: (614) 424-5189
Fax: (614) 424-5069

Computran Systems Corp.
100 First St.
Hackensack, New Jersey 07601

Tel: (201) 489-7500
Fax: (201) 487-5977

DeLeuw Cather & Co.
1133 15th St. NW
Washington, DC 20005-2701

Tel: (202) 775-3300
Fax: (202) 775-3389

Edwards & Kelcey Inc.
299 Madison Avenue
P.O. Box 1936
Morristown, New Jersey 07962-1936

Tel: (201) 267-0555
Fax: (201) 267-3555

Intergraph Corp.
One Madison Ind. Park
Huntsville, Alabama 35894-0001

Tel: (205) 730-2000
Fax: (205) 730-6750

Kimley-Horn and Associates Inc.
P.O. Box 33068
Raleigh, North Carolina 27636-3068

Tel: (919) 677-2000
Fax: (919) 677-2050

B2 Industry Contacts - U.S.

KLD Associates, Inc.
300 Broadway
Huntington Station, New York 11746

Tel: (516) 549-9803
Fax: (516) 351-7190

MITRE Corporation
7525 Colshire Dr.
McLean, Virginia 22102

Tel: (703) 883-6000
Fax: (703) 883-6809

Raytheon Company, Inc.
50 Apple Hill Dr.
Tewksbury, Massachusetts 01876-0901

Tel: (508) 858-5000
Fax: (508) 858-1021

Microwave Systems Corp.
1900 NW 114th Street
Des Moines, Iowa 50325-7077

Tel: (515) 224-1929
Fax: (515) 224-1352

Multisystems Inc.
10 Fawcett St.
Cambridge, Massachusetts 02138-1110

Tel: (617) 864-5810
Fax: (617) 864-3521

Science Applications International Corp.
1710 Goodridge Dr.
McLean, Virginia 22102

Tel: (703) 821-4468
Fax: (703) 790-5267

B3 Industry Contacts - EU

SIEMENS AG

ADDRESS: Hofmannstrasse 51
Munich
D-81359
Germany

CONTACT: Mr. Peter Wenter
Tel: 49-89-7220
Fax: 49-89-722-418-42

KEYWORDS: ATIS, APTS, Euro-Scout, Drive Program, route guidance, ATMS, SCOOT

HISTORY: Siemens Group employs 400,000 people worldwide.

ITS CAPABILITY: Chip Ticket AVI system, Euro-Scout dynamic route guidance, ATMS, parking guidance systems, detectors, VMS, SCOOT, ARTEMIS video detection.

ITS PERSONNEL: No data.

GROSS SALES: No data.

PLANT SIZE: No data.

EQUIPMENT: No data.

ITS EXPERIENCE: German ETC trials, ERTICO, various DRIVE II projects, SCOOT deployment in Toronto, Beijing, Santiago, and Sao Paulo.

B3 Industry Contacts - EU

Other Contacts (Ref. the International ITS Index, 1996)

BAeSEMA
1 Atlantic Quay
Glasgow, Scotland
UK G2 8JE

Tel: 44-141-204-2737
Fax: 44-141-221-6435

Castle Rock Consultants
Heathcoast Building
Highfields Science Park
Nottingham
UK NG7 2QJ

Tel: 44-115-943-0830
Fax: 44-115-943-0823

ENA Trafico SA
14 San Rafael
Alcobendas (Madrid)
E-28100
Spain

Tel: 34-1661-89-87
Fax: 34-1661-96-53

Groupe Decan
Telebase
6 avenue Claude Chappe
Saint Didier au Mont d'os
F-69771

Tel: 33-78-64-3100
Fax: 33-78-64-3120

JRM Software
Andil House
Court Street
Trowbridge
Wiltshire
UK BA14 8BR

Logica
Wyndham Court
74 Portsmouth Road
Cobham, Surrey
UK KT11 1HY

Tel: 44-171-637-9111
Fax: 44-1932-869-103

Memex
Via Mimbelli 5
Livorno
I 57127

Tel: 39-586-810538
Fax: 39-586-185321

MVA Group
MVA House
Victoria Way
Woking
Surrey
UK GU21 1DD

Tel: 44-1483-728-051
Fax: 44-1483-755-207

Serco Systems
Fountains Place
Guisborough
Cleveland
UK TS14 7JA

Tel: 44-1287-610310
Fax: 44-1287-610360

SODIT
2 avenue Edoward Belin
Toulouse
F 31400

Tel: 33-62-17-58-01
Fax: 33-62-17-57-91

B4 Industry Contacts - Asia Pacific

(Ref. the International ITS Index, 1996)

China Engineering Consultants
28th Floor 185 Hsin Hai Road
Sector 2 10637
Taipei, Taiwan

Tel: 886-2-736-3567
Fax: 886-2-736-3692

In Mar Tech Australia
10-12 Boundary Street
South Melbourne
Victoria 3205
Australia

Tel: 61-3696-4009
Fax: 61-3696-7449

Chodai
20-4, 1-chome
Nihanbashi-Kakigaracho
Chuo-ku
Tokyo 103
Japan

Tel: 81-3-3639-3465
Fax: 81-3-3639-4695

Kumagai Gumi
2-1 Tsukudo-cho
Shinjuku-ku
Tokyo 162
Japan

Tel: 81-3-3260-2111
Fax: 81-3-5261-9350