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ATLANTIC

A Thematic Long-term Approach to Networking for the Telematics and ITS Community

A Partnership of ITS Communities in Europe and
North America

SYNOPSIS
And Highlights of
DISCUSSION PAPER

URBAN PUBLIC TRANSIT ITS RESEARCH AND DEVELOPMENT IN CANADA

Prepared by

Work Group 1.3
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IN COLLABORATION WITH PARTICIPATING PARTNERS AND SPONSORS

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PREFACE

ATLANTIC (A Thematic Long-term Approach to Networking for the Telematics and ITS Community) is an international cooperative undertaking that aims to foster information exchange and policy debate related to the application and development of Intelligent Transport Systems (ITS). ATLANTIC originated as a project sponsored by the European Union under the 5th Research Framework with self-sustaining partners in Canada and the United States. ATLANTIC is organized into 8 work groups focused on different topics related to Telematics and ITS. This document is the product of one of the Canadian work groups to benchmark and assess the state of ITS practice and research and development in Canada.

This Synopsis report is a summary of the discussion paper prepared by Work Group 1.3 on the topic of “Urban Public Transit ITS Research and Development in Canada”. It is intended to provide readers with a brief overview of the research results of Work Group 1.3. The Synopsis follows the same structure as the discussion paper so that one can easily find the more complete discussion and treatment of subtopics in the corresponding section of the discussion paper. This is particularly true of lists of references and descriptions of projects.

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The ATLANTIC Canada network node is sponsored by Transport Canada, Ministry of Transportation Ontario and Ministère des Transports du Québec and jointly managed by the ITS Centre and Testbed, University of Toronto and the Centre de recherché sur les transports, Université de Montréal. The core team providing overall leadership for ATLANTIC Canada includes Professor Baher Abdulhai (Toronto), Professor Teodor Gabriel Crainic (Montréal) and Dr. William Johnson (Ottawa).

The Canadian Work Group 1.3 “Intermodal Collective Transport Information” is jointly managed by Professor Amer Shalaby, University of Toronto and Dr. Brendon Hemily, Hemily and Associates. They provided the intellectual leadership and writing skills to assemble and document this discussion paper with inputs and contributions from a network of Work Group members. The names of Work Group 1.3 members and contributors appear in the appendix. Special recognition is extended to Dr. Liping Fu, University of Waterloo for his extensive contribution.

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OVERVIEW OF PUBLIC TRANSPORT ITS R&D NEEDS IN CANADA

1.1 Introduction: Overview of Transit ITS and Scope of Discussion Paper

"Public Transport Services" is one of the User Service Bundles defined in the *Intelligent Transportation Systems Architecture for Canada*. It includes and defines the related User Services as follows:

Public Transportation Management (User Service 3.1)

The Public Transportation Management user service applies advanced vehicle electronic systems to various public transportation modes and uses the data generated by these modes to improve service to the public. It includes operation of vehicles and facilities, planning and scheduling, and personnel management.

En-Route Transit Information (User Service 3.2)

The En-Route Transit Information user service provides travelers with real-time transit and high-occupancy vehicle information allowing travel alternatives to be chosen once the traveller is en-route. The single sub-service of the En-Route Transit Information user service provides three major functions, which are (1) Information Receipt, (2) Information Processing, and (3) Information Distribution. This capability integrates information from different transit modes and presents it to travelers for decision making.

Demand Responsive Transit (User Service 3.3)

The Demand Responsive Transit user service involves the use of flexibly routed transit vehicles offering more convenient service to customers. These transit vehicles include small buses, taxicabs, or fixed-route transit buses that are detoured from their pre-established route to pick up or discharge passengers.

Public Travel Security (User Service 3.4)

The Public Travel Security user service supports innovative applications of technology to improve the security of public transportation. Security concerns include protecting transit patrons and employees from street crime, maintaining an environment of actual and perceived security, and developing innovative technical measures to respond to incidents.

The Canadian ITS Architecture defines *Public Transit Management* as including six sub-services:

- Transit Vehicle Tracking
- Transit Fixed-Route Operations
- Passenger and Fare management
- Transit Maintenance
- Multi-Modal Co-ordination
- Multi-Modal Connection Protection

In addition, the effective and efficient delivery of transit service may also be enhanced through the integrated deployment of several other ITS User Services defined in the ITS Architecture, including;

- Traveller Information
- Traffic Control Services
- Electronic Payment Services, and
- Archived Data Management

In simple terms, the basic components of Transit ITS include:

- Intelligent / smart vehicles, with on-board computers / data storage capability,
- Mobile communication systems,
- Location tracking system (typically using GPS),
- Transit management control centres,
- Call centres and station/stop systems for customer information,
- Maintenance garage systems, and
- Archived data from the various Transit Intelligent Transportation Systems.

These basic components are used and integrated to provide potentially a number of powerful functionalities that make fixed-route transit more effective or efficient. These include the enhancement of communications, the provision of Computer Aided Dispatch (CAD), provision of continuous Automatic Vehicle Location (AVL) monitoring, enhanced and responsive security measures, provision of continuous schedule adherence monitoring, enhanced data collection through Automatic Passenger Counting (APC), provision of Transit Signal Priority (TSP) in the traffic control system, continuous monitoring of vehicle performance data through on-board sensors, enhanced customer information (pre-trip and/or en-route), and the potential for electronic fare payment.

In addition, transit ITS offers the potential to enhance demand responsive transit services, through real-time scheduling / dispatching of paratransit vehicles or route-deviation vehicles, and the potential for dynamic rideshare matching.

The potential of Transit ITS to enhance or create the above functionalities has promoted considerable interest in the Canadian transit industry. In light of this interest, the ATLANTIC Work Group (WG) 1.3 provided a forum for exploring **Public Transportation ITS Research and Development Needs.** This forum served to:

- Identify experts interested in this issue (see the list of WG 1.3 experts in the Appendix),
- Solicit feedback on related R&D activities that are underway, or on R&D needs in the area of urban transit ITS, and
- To provide a basis for the development of a discussion paper.

The objective of this discussion paper was to build on the interactions with practitioner and research experts in order to identify R&D needs in public transport R&D in general, focusing on a limited number of higher priority areas. However, given the existing state of ITS activities in public transportation in Canada, and the modest financial resources available for support in preparing this discussion paper, the Work Group concentrated the scope of its efforts to **Urban**

Public Transit ITS Research and Development, focusing in particular on the areas of transit signal priority and demand responsive transit.

1.2 Overview of Transit ITS in Canada

The first step in the workings of Work group 1.3 was to assess the state-of-the art and of the practice in the Canadian context. The leaders of Working Group 1.3 have conducted, through interviews and a review of existing documents, a scan of Transit Intelligent Transportation Systems (ITS) Research and Development (R&D) in Canada. There is considerable interest in the Canadian transit industry in the application of ITS technologies in order to improve operational efficiency and/or the attractiveness of transit service to existing or potential customers. Interest in the potential role of Transit ITS takes several forms.

A few transit systems deployed in the 1985-1992 period multi-function Transit ITS systems, built on an Automatic Vehicle Location (AVL) system, including: Toronto, Outaouais Region, Halifax, Hamilton, and Ottawa. More recently, AVL systems have been deployed, or are being deployed, in London, St John's, Newfoundland and for the Vancouver TransLink Richmond Rapid Bus. In addition, several other transit systems have deployed stand-alone Transit ITS systems such as Automatic Passenger Counting (APC), Transit Signal Priority (TSP), etc., including: Longueil, Montreal, Quebec City Region, Victoria and Winnipeg.

There has also been considerable interest across Canada in Transport Canada's ITS deployment grant program, and several transit systems have received ITS deployment grants for transit-related initiatives. Projects include:

- Calgary-Traffic Signal Priority and Automatic Vehicle Tracking System
- Go Transit-Rail Operations Information Systems
- Ottawa-Deployment of Intelligent Transit Vehicle Subsystem
- Outaouais-Dynamic Message Signs at Bus Stops
- Peterborough-Integrated Traffic Signal Control and Bus Priority System
- Richmond-Vancouver Rapid Transit Evaluation
- St John's, Newfoundland-Metrobus GPS-based AVL System
- Toronto Integrated Mobility Systems: A Multi-Modal Multi-Application Smart Card Initiative
- Waterloo-Transportation Demand Management Initiative
- York Region-Transit Priority System Integration and deployment

Many systems are also actively planning for Transit ITS. For example, a few regional or transit systems have conducted, or are conducting, formal ITS Strategic Plans in the last 2 years (e.g. TransLink in Vancouver, Edmonton, AMT in Montreal, City of Calgary, etc). In addition, several municipal transit systems are currently exploring the range of ITS applications that use the potential offered by a common core GPS-based location system (e.g. Ottawa, Mississauga, Winnipeg, etc.). Other transit systems are evaluating individual applications of local interest, such as TSP, Customer Information systems. There is clearly much interest in ITS in the Canadian transit community. Municipalities operate in a **highly constrained fiscal environment**, and the lack of funding is the greatest challenge at the municipal level impeding

ITS deployment. It should be noted that in this context, transit systems are not surprisingly generally less interested in fundamental research, than in applied research, developments, and demonstrations that help them move closer to deployment.

1.3 Comparison of Transit ITS in Canada and Abroad

Canada was an international leader in the 1980's in the development and deployment of advanced technology in public transportation, especially in the areas of AVL, with several new systems being introduced in the late 1980's. This was highlighted during an International Conference on AVL Systems, organized by the Canadian Urban Transit Association (CUTA) in 1988 in Ottawa. Although countries such as France and Germany were slightly more advanced than Canada in the development and deployment of AVL systems, Canada was not far behind, and certainly on par with developments in the U.S.A. In fact, Canada was more advanced at the time in the deployment of schedule-based telephone customer information systems.

By 1992, the situation had totally changed. As a result of the disinvestments that started to occur as of 1992 in all public sector areas in an effort to reduce budgetary deficits, at both the federal and Provincial levels, investment in terms of both research and deployment in advanced transit technology gradually disappeared. This situation continued for a period of 6 to 8 years, and was characterized by:

- The wrapping up of all existing technology projects, such as the London AVL system, and the TSP study conducted by CUTA [O'Brien, 2000] with no new projects being initiated;
- The elimination of federal and most provincial R&D programs that could be used by the transit industry;
- The reduction or elimination of provincial capital transit subsidy programs, forcing transit systems to focus more on immediate priorities such as vehicle replacement to the detriment of Transit ITS;
- The dearth of academic research on transit technology for lack of funding; and
- The loss of Canadian manufacturing capability in the area of transit ITS for lack of domestic demand.

In contrast, during this period, massive investment in Transit ITS research and deployment were made in both Europe and the U.S.A. In Europe:

- Transit ITS has been systematically deployed in all large and medium-sized transit systems;
- Research, development, and demonstration of Transit ITS has been systematically pursued across Europe through successive European DRIVE and Telematics Framework R&D programs, with dozens of major multi-partner, multi-city R&D projects exploring all aspects of transit ITS; and
- Supplementary national programs, such as the PREDIT in France, and projects, such as the VdV project in Germany, were initiated to pursue research and deployment of Transit ITS at the national level.

And, in the U.S.A.:

- 46 transit systems have equipped 14,619 buses with AVL, and an additional 32 transit systems are planning to do so;
- 24 transit systems have equipped 3,433 buses with on-board customer information systems, and 40 other transit systems are planning to do so;
- 12 transit systems have installed APC systems on 895 buses, and 16 other transit systems are planning to do so;
- The FTA has sponsored since 1994 the production of a bi-annual comprehensive inventory of all Transit ITS-related developments and deployments in the U.S.A., entitled "*Advanced Public Transportation Systems: The State of the Art*";
- The U.S. DOT Joint Program Office sponsors a web site containing a database of all known ITS deployments by technology, including Transit ITS;
- An entire research program has been underway over the past few years in the U.S. to develop *transit-specific* ITS standards through the Transit Communications Interface Profiles (TCIP) program;
- Major research projects, involving millions of dollars, have been conducted in the U.S. on issues related to Transit ITS, by various organizations, including: the Transportation Research Board's Transit Cooperative Research Program (TCRP), ITS America, MitreTek, Battelle, the Center for Urban Transportation Research (CUTR), the California PATH Program, and the University Transportation Centers (UTC) Program; these often involve direct or indirect funding from the U.S. Federal Transit Administration; and
- The library on Transit ITS, available from the US DOT web site contains dozens of reports specifically on Transit ITS-related topics.

During this period, there has been the development of an enormous gap between Canada and Europe and the U.S., in terms of both deployment, and especially R&D related to transit ITS.

However, more recently, in particular since 2000, one is observing a slight reinvestment in transit ITS in Canada. This is illustrated by the ten or so transit systems that have benefited from the limited federal ITS deployment grant program, as well as the several Transit ITS strategic planning efforts underway, as discussed above. The investment in the ITS laboratories at the University of Toronto and the University of Montreal have opened some possibilities for Transit ITS research, but to date, participation by transit systems remains limited. Interest by the Canadian transit industry in Transit ITS will remain extremely limited until larger issues of sustainable capital funding for transit are resolved, and without the interest of the transit industry itself, the potential for synergy between academic research, supplier development, and transit industry deployment remains problematic.

1.4 Canadian Transit ITS R&D Needs

Through consultations with experts across Canada in the area of Transit ITS concerning R&D needs, the following Transit ITS R&D needs have been identified as areas of significant interest to the Canadian transit ITS community.

R&D Needs Related to Specific Applications:

- Transit Signal Priority (TSP): technical and institutional issues, and potential benefits
- Development of models and algorithms for real-time transit operations control based on AVL and APC systems
- Needs, related issues, and benefits of transit automated customer information systems, including "511"
- Institutional and technical barriers to deployment of transit contactless smart card automatic fare collection systems
- Dynamic routing and scheduling of demand responsive transit

Data-Related Issues and Applications:

- The role of Geographic Information Systems (GIS) and location-based data in Transit ITS applications
- The use of GPS-based location data from Automatic Passenger Counting (APC) and Automatic Vehicle Location (AVL) systems to enhance transit management, planning, and customer information
- Integrating ITS with standard transit planning methodologies and practice

R&D Needs Related to the Deployment of Transit ITS in General:

- Benefits and cost-effectiveness of Transit ITS applications
- Transit ITS and the Canadian ITS Architecture
- Inventory of Transit ITS deployments
- Development of transit system requirements in municipal trunk radio systems in new / reorganized municipalities

A brief discussion of each of these R&D Needs is provided in the Discussion Paper.

1.5. Conclusions

There is significant interest in the Canadian transit industry in pursuing the development and deployment of ITS systems to improve service to transit customers or to improve operational efficiency. However, the reality is that Canadian transit systems operate in one of the most financially constrained environments among the G7 countries. As a result, ITS deployment has, and will likely continue to be for the foreseeable future, piecemeal and limited. It will be guided overwhelmingly by cost-effectiveness considerations and the requirement for a strong business case.

Among the potential Transit ITS technologies and R&D topics identified above, Transit Signal Priority (TSP) represents the highest potential benefits for Canadian transit from a cost-effective point of view. For relatively minor levels of investment (and far less than other ITS technologies such as Automatic Vehicle Location or Smart Cards), TSP offers the potential to enhance service reliability and reduce transit travel times. This can translate into simultaneous cost savings and improved service to transit customers, a win-win application. However, TSP deployment has been spotty to date, and there remain a number of technical and institutional challenges that have hindered deployment. Another important transit ITS area is Intelligent Demand Responsive

Transit. Both topics have been chosen for more in-depth discussion in the next 2 sections. It should be noted that other significant areas of transit ITS are covered by other workgroups of the ATLANTIC project, such as transit customer information systems (Workgroup 1.1) and smart card systems (Workgroup 2.3)

5. TRANSIT SIGNAL PRIORITY (TSP)

2.1 Primer on TSP

TSP is a control strategy that provides preferential treatment to surface transit vehicles (buses and streetcars) operating in mixed traffic along urban corridors. The objective of TSP measures is mainly to reduce transit vehicle delays at signalized intersections through the modification of signal time settings, thus improving transit operational efficiency and level of service. TSP treatments can be classified into three types, which also roughly represent the evolution of TSP and its level of sophistication over the years. These types are described briefly below.

Passive TSP

Under Passive TSP, signal timing plans are designed off-line based on transit vehicle frequency and speed. The timing plans are then deployed at the corresponding intersections, where they are executed continuously without regard to the presence of transit vehicles. As such, no vehicle detection technology is required for Passive TSP, reducing the cost involved. Passive TSP is most effective under conditions of high transit vehicle volumes. However, they may incur unnecessarily significant delays to cross-street traffic, if transit vehicle arrivals are not highly regular and predictable (which is often the case). Passive priority may include one or more of the following treatments: (i) signal coordination based on transit travel times, (ii) phase splitting, and (iii) cycle length adjustment. Studies have shown that this is not a very effective way to provide priority to transit vehicles in the traffic stream.

Active TSP

Under this scheme, priority is only granted when transit vehicles are approaching intersections, and as such, a technology for selectively detecting transit vehicles and communicating this information to the traffic controller is necessary. Extension of the priority phase (i.e. green extension), early truncation of the non-priority phase (i.e. red truncation), and transit-exclusive phase, are common strategies of active transit signal priority. Phase omission and rotation are also sometimes used, though there is a perception among many traffic engineers that this creates confusion among motorists.

Adaptive TSP

Adaptive TSP refers to a relatively new generation of priority schemes, which attempt to achieve advanced operational objectives by means of adaptive signal control. Examples of operational objectives include improving transit headway regularity, reducing total vehicle delay in the corridor, and maximizing person throughput. Under Adaptive TSP, the traffic signal controller adapts its plan dynamically according to the criteria reflecting the desired objective. Adaptive signal control is increasingly common in Europe but has not been widely deployed yet in North America to date, but offers considerable promise for maximizing benefits for both transit vehicles and the general traffic.

2.2 Review of Recent Canadian TSP R&D Activities

The recent Canadian research efforts in the area of TSP can be classified into the following three types:

- Development of advanced TSP systems,
- Development of models/algorithms supporting advanced TSP systems (e.g. travel time prediction models and real-time bus performance measurement), and
- Development of simulation tools for evaluation of TSP systems.

In this Synopsis Paper, only the title and university sponsor is provided for each of the TSP research projects identified by Work Group 1.3 as underway in Canada. For a more complete description of the research projects, see the Discussion Paper.

2.2.1 The SPPORT Model (Signal Priority Procedure for Optimization in Real Time) – University of Waterloo

2.2.2 Integrated System of Adaptive Traffic Signal Control and TSP – University of Toronto

2.2.3 Adaptive Signal Priority for Automated Transit Headway Control – University of Toronto

2.2.4 Simulation Study of the Impacts of Environmental Parameters on the Effectiveness of Transit Signal Priority – University of British Columbia

2.2.5 Prediction Model of Bus Arrival and Departure Times Using AVL and APC Data – University of Toronto

2.2.6 A Multi-Attribute Performance Measurement Model for Advanced Public Transit Systems – Ryerson University

2.2.7 SimTransit - University of Waterloo

2.3 Overview of the Canadian State of the Practice

2.3.1 Transit Signal Priority in Toronto

The Toronto Transit Commission (TTC) was one of the first transit systems to explore the use of TSP. After a first study that assessed the potential application of passive TSP, a demonstration was conducted in 1990, involving six intersections. The findings of this first demonstration were that delay reductions of 5 to 9 seconds at each intersection were attained, contributing up to a 20% reduction in total transit travel time. Other traffic was not significantly affected. Following this success, an incremental program was undertaken to equip over 150 intersections on seven streetcar routes. This resulted in the need for 10 fewer streetcars, and saved over $1 million a year in operating costs. The payback period was less than 5 years.

In 1997, a demonstration of bus TSP was undertaken, and the results were: bus delay decreased up to 46%, auto delay decreased marginally, and cross street traffic not significantly affected. The detection system, however, caused some reliability problems. Since then, a program has equipped over 110 intersections on bus routes. The program is currently under evaluation to assess further deployment.

TSP strategies are implemented in several corridors in Toronto such as the King and St. Clair Streetcar routes. All TSP implementations are of the "Unconditional" type. They work mostly as follows. At an intersection with transit signal priority, if a streetcar has been detected at the upstream 'request' loop (approximately 80 m from the stop line), and has not yet crossed the 'cancel' loop at the stop line, the controller considers the "zone" to be "active" for this transit route direction. Two basic algorithms are used to provide signal priority for transit vehicles: transit-corridor green extension, and cross-street green truncation. In case of any disruption to the offsets (in reference to the master system clock) by the provision of signal priority an offset recovery routine is initiated.

For transit-corridor green extension, a decision point is defined. It may refer to the number of seconds before the end of the transit-corridor green (e.g. 12 seconds). Alternately, the decision point may be defined based on an interval number (e.g. react at the start of interval #3).

If either of the "zones is active" (i.e., for either transit route direction) at the time of the decision point for transit-corridor green extension, the green extension algorithm will begin with an initial fixed green time period for the transit corridor. This is followed by demand-dependant extensions (1 or 2 seconds depending on the controller type) for the transit-corridor green. The extensions are served consecutively until the zone is cleared (i.e., streetcar passes the cancel loop) or until a maximum number of extensions are provided.

An additional decision point is defined for the truncation. If the zone is active at the time of this decision point, the signal will also switch to local control. The signal timing will be altered to shorten the cross-street green time, and hasten the provision of green to the transit corridor. The amount of green time that will be subtracted from the cross street is a set value defined per intersection, ranging from 2 to 6 seconds after minimum walking time in the study area.

Those decision points for transit-corridor green extension and cross-street green truncation are defined for each intersection after pedestrian walking time and signal priority can be provided in successive cycles if the "zone" is still active.

2.3.2 Other Canadian Developments and Comparison with International Experience

There have been a few other deployments in Canada, including:

- Isolated deployments of intersection control activated by approaching buses typically for buses entering an arterial from off-street terminals or subdivision secondary streets (e.g. Eglinton Bus Station, Edmonton)
- Recent corridor deployments, involving a limited number of TSP-equipped intersections in Quebec City, Longueil, and Calgary.
- Recent or ongoing deployments of new sophisticated municipal traffic control systems that include TSP in Peterborough and York Region, both partially funded through Transport Canada ITS deployment grants.
- Deployment of TSP for the TransLink's Richmond and Granville Street Rapid Bus lines that involve the deployment of Transit ITS components in the form of real-time customer information system and TSP.

Most deployments of TSP in Canadian cities have been of the "unconditional" type, where priority is granted to any transit vehicle once detected upstream of the intersection[1]. Although many TSP deployments in the US, Europe and Japan are also of the "unconditional" type, there have been recent implementations of "conditional" TSP and "adaptive" TSP. For example, conditional TSP has been implemented at 150 intersections in Portland, Oregon, where priority is granted based on the schedule adherence of the approaching bus (i.e. give priority if bus is late). In Japan, the UTMS 21, a "next generation" adaptive traffic management system, includes PTPS (Public Transport Priority System) as one of its subsystems. The PTPS/UTMS21 system has been applied to a number of Japanese cities including Tokyo, Nagoya, Hamamatsu, and Sapporo.

Another international development is the ongoing development of the **NTCIP Signal Control Priority Standard** in the U.S. that will cover Emergency Vehicles, Transit, and Light Rail. The NTCIP Standard contents include: concept of operations, functional requirements, dialogs and sequences (interface specifications), data dictionary, and test procedure.

2.4 TSP R&D Needs

Through the consultations carried out with Canadian experts and discussions held during workshops in the U.S., a number of TSP-related R&D needs have been identified. These fall into two general categories:

- Basic research to improve the algorithms used or develop new approaches to TSP, and
- Applied research to evaluate experience to date, assess issues, and encourage further deployment.

In this Synopsis Paper, only the titles of each of the proposed TSP research projects identified by Work Group 1.3 are listed. For a more information about each research projects, see the Discussion Paper.

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[1] Some TSP systems in Canada may not provide priority to a transit vehicle if its priority request was too soon (based on some threshold value of elapsed time) since last priority request. One such system is the 98 B-Line rapid bus transit line along the Granville Street corridor in Vancouver.

2.4.1 *Basic Research To Improve The Algorithms Used Or Develop New Approaches To TSP*

- Designing TSP-Based Operational Control Strategies
- Artificial Intelligence and TSP
- Implications of Signal System Design and Traffic Parameters on TSP Request Activation Strategies
- Integrated TSP With Traffic Adaptive Signal Control Systems, Involving Optimization-Based Priority
- Corridor-Based TSP
- Technical Options for Conditional Priority: a Review of Approaches, and Technologies, and Evaluation Under Various Situations
- Development of Differential Priority Algorithms and Systems
- Hybrid Application of Unconditional and Conditional Control for TSP: Rationale, and Technical Feasibility

2.4.2 *Applied Research To Evaluate Experience To Date, Assess Issues, And Encourage Further Deployment*

- The Development of an Analytic Framework for Selecting Corridors and Intersections for TSP Treatment: Identification of Warrants and Sources of Data for Assessment
- TSP and Transit Scheduling: Best Practices for Maximizing the Benefits of TSP under Different Conditions.
- TSP and Automatic Vehicle Location (AVL): Factors Affecting the Transit Agency's Technology Development Strategy, Technical and Management Implications, and Cost-Effectiveness Considerations
- Integrating Physical and Signal Priority Measures for Transit: Inventory, Best Practices, and Issues
- Traffic Controllers and TSP: Technical Requirements for Alternative TSP Strategies and Inventory of Traffic Controllers and Technical Characteristics
- The Role of TSP in BRT System Design, and in BRT-Specific Planning Tools
- The Impact of Bus Operator Behavior on Transit Schedules Under TSP
- A Review of Major European TSP-Related Demonstration Programs, Identified Benefits, and Implications of Lessons Learned for Canadian Deployment of TSP

6. INTELLIGENT DEMAND RESPONSIVE TRANSIT[2]

3.1 Introduction to Demand Responsive Transit (DRT)

Dial-a-ride paratransit, also called demand responsive transit (DRT), is a significant component of the public transportation system. It plays a vital role in providing equitable transportation services to special groups of population such as the elderly and persons with disabilities who have difficulties to access the regular public transit system. Different from regular fixed-route transit, DRT commonly uses small to medium sized vehicles to provide shared-ride, door-to-door services with flexible routes and schedules. Due to its taxi-like service approach with a fare scheme comparable to regular transit, most paratransit systems in North America are very costly, relying heavily on subsidization. According to the Canadian Urban Transit Association (CUTA), the total operating expenses of Canadian DRT agencies in 2002 amounted to over 215 million dollars, of which less than 10% was recovered from fare revenues and the rest was subsidised. Such strikingly unfavourable cost efficiency has been mainly attributed to low vehicle productivity of paratransit services.

In order to seek cost-effective solutions, many paratransit agencies are turning to applications of advanced information technologies such as automatic vehicle location and computer aided dispatch systems (AVL/CAD), digital telecommunication and computers. Intelligent DRT is the result of integrating these information technologies into the operations and management of DRT systems. With the ability to track vehicle locations, communicate with drivers and clients, and access traffic information on a continuous basis, intelligent DRT systems are expected to operate at a significantly improved level of productivity, reliability and quality of service.

3.2 Intelligent DRT: Technology Background

Operations of DRT are substantially different from regular fixed route transit, requiring a mesh of interrelated managerial functions such as reservation, vehicle scheduling, real-time dispatching, billing and business reporting. With various ITS technologies such as microcomputers, AVL and digital communication, these functions can be automated for potentially more cost-effective operations. The objective of this overview is to provide some operational and technological background of an intelligent DRT system.

In an intelligent DRT system, the reservation system provides the connection between the operation centre and the customers, responsible for recording information on each customer's request, including pickup and delivery locations, desired time window, person to be picked up/delivered and their special requirements, and, in the case of service cancellation and change of service time, for updating request information. This procedure is traditionally performed by a reservation clerk who receives the information over the telephone and then manually enters it into the computer. Under intelligent DRT, more advanced reservation methods, such as automated telephone systems and Internet based interactive reservation systems, would be used.

Each service vehicle is equipped with an in-vehicle computer or a mobile data terminal (MDT), to which operating schedules can be uploaded from the central computer through a wireless

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[2] This section has been contributed by Dr. Liping Fu, University of Waterloo

communication channel. The MDT is integrated with an AVL system that provides the dispatch centre with real-time location information. Several alternative AVL technologies are available, different by positioning accuracy and updating frequency. The most popular technology is the Global Positioning System (GPS) which relies on radio signals from satellites to locate the vehicles. The location information is used for real-time monitoring and vehicle dispatching.

All related information is managed by a central database management system (DBMS) and a geographical information system (GIS) for effective data support to all associated functions. There commonly exist two categories of data that need to be treated differently. The first category of data, called static data, consists of those that are relatively stable and need not be updated frequently. Examples include road network topology, customer addresses, and fleet and driver information. The second category includes data such as vehicle location, traffic conditions, new requests and cancellation, which often change during the time of day and need to be updated on a continuous basis.

The scheduling component provides both off-line and on-line scheduling capabilities. The off-line scheduling function is used to assign the trips that are requested in advance and known before operation starts. The on-line scheduling component is essential to a computer-aided dispatch system (CAD) responsible for assigning the requests that arrive in real time and need to be serviced immediately.

The dispatcher monitors continuously any operational changes in the system such as vehicle breakdowns, service cancellations and new requests. These changes may justify modification of existing vehicle schedules such as diverting en-route an on-road vehicle to service a new request in the vicinity or re-assigning trips from one vehicle to another. Once a change is verified, the modified schedules are sent to the drivers and displayed in their in-vehicle computers or mobile data terminals (MDT).

3.3 Review of Recent Canadian R&D Activities on Intelligent DRT

Canada has played a leading role in providing software solutions for DRT. Examples include the two world renowned transit software solution providers: Trapeze Inc. of Mississauga, Ontario (www.trapezesoftware.com) and GIRO Inc. of Montreal, Quebec (www.giro.ca). Trapeze Inc. has developed a range of software solutions for the planning, scheduling and dispatching of DRT. GIRO is the developer of the scheduling software system GIRO/ACCES which has been successfully applied to the TTC's WheelTrans.

Recent development in technology is generating interest in developing new methodologies and optimization/evaluation tools that can be used to deploy Intelligent DRT. This section provides a list of recent Canadian R&D in this area.

In this Synopsis Paper, only the title and university sponsor is provided for each of the Intelligent DRT research projects identified by Work Group 1.3 as recently underway in Canada. For a more complete description of the research projects, see the Discussion Paper.

3.3.1 *The SimParatransit Model – University of Waterloo*
3.3.2 *Development and Evaluation of Dynamic Scheduling Algorithms – University of Montreal*
3.3.3 *Planning and Scheduling of Advanced Flex-route Transit – University of Waterloo*

3.4 R&D Needs for Intelligent DRT

Intelligent DRT systems have presented a unique opportunity for public transit agencies to improve the productivity, reliability and quality of their paratransit services. However, many issues need to be addressed before such technologically advanced systems can attain their full potential and gain broad acceptance by public transit agencies. This section summarizes future R&D needs related to intelligent DRT, including both basic and applied research.

In this Synopsis Paper, only the title and university sponsor is provided for each of the Intelligent DRT research projects identified by Work Group 1.3 as recently underway in Canada. For a more complete description of the research projects, see the Discussion Paper.

- Development of Dynamic Scheduling Algorithms for Intelligent DRT
- Planning under Uncertainty and Real-time Information
- Exploration of Distributed Computation Platform for Intelligent DRT
- Development of Data Fusion and Estimation Algorithms
- Development of Scheduling Algorithms for Integration of Fixed Route Transit and DRT
- Planning and Scheduling of Advanced Flex-Route Transit
- Intelligent DRT: Inventory, Best Practices, and Issues
- Development of an Operations Manual for Intelligent DRT
- Planning Tools for Intelligent DRT
- A Review of International Programs on Intelligent DRT, Identified Benefits, and Implications of Lessons Learned for Canadian Deployment

7. SUMMARY AND CONCLUSIONS

This discussion paper provides an overview of transit ITS in Canada and identifies research and development needs for several transit ITS areas. The paper focuses on two key areas, namely, TSP (Transit Signal Priority) and Intelligent DRT (Demand Responsive Transit), and elaborates on their R&D needs[3].

Numerous deployments of TSP systems have been made across Canada since the early nineties. For example, in Toronto alone, TSP has been implemented at 150 intersections on seven streetcar routes and at 110 intersections on several bus routes. Other Canadian cities that have deployed, or plan to deploy, TSP systems include Vancouver, Edmonton, Calgary, York Region, Peterborough, Ottawa and Quebec City. Most deployments of TSP in those cities have been of the "unconditional" type, where priority is granted to any transit vehicle once detected upstream of the intersection. The most common TSP strategies of those systems include green extension and/or red truncation, with offset transitioning implemented after the transit vehicle clears the intersection in order to recover signal coordination and to compensate the non-priority phases. Although many TSP deployments in the US, Europe and Japan are also of the "unconditional" type, there have been recent successful implementations of "conditional" TSP (e.g. 150 intersections in Portland, Oregon) and "adaptive" TSP (e.g. PTPS/UTMS21 system in 4 Japanese cities). Advancements of TSP deployments in those countries create a gap for Canada that requires serious attention and higher investments to fill.

On the research side, the paper shows that advanced research has been undertaken in Canada on various aspects of TSP. Examples include the development of advanced control algorithms (e.g. adaptive TSP) and models (e.g. prediction and performance models), the development of simulation tools for TSP evaluation (e.g. SimTransit) and the assessment of TSP systems. These research efforts are very important and vital to keep Canada on par with other countries in the area of TSP. In order to further the leading-edge TSP research already carried out and to improve the chances of deploying advanced TSP systems in Canada, a number of significant R&D needs have been identified. They fall into two categories:

- Basic research to improve the algorithms used or develop new approaches to TSP, and
- Applied research to evaluate experience to date, assess issues, and encourage further deployment

The first category includes the following topics: (1) Designing TSP-Based Operational Control Strategies, (2) Artificial Intelligence-Based TSP, (3) Implications of Signal System Design and Traffic Parameters on TSP Request Activation Strategies, (4) Integrated TSP With Traffic Adaptive Signal Control Systems, Involving Optimization-Based Priority, (5) Corridor-Based TSP, (6) Technical Options for Conditional Priority, (7) Development of Differential Priority Algorithms and Systems, and (8) Hybrid Application of Unconditional and Conditional Control for TSP.

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[3] Another two significant areas of transit ITS are addressed by other workgroups of the ATLANTIC project, namely transit customer information systems (Workgroup 1.1) and smart card systems (Workgroup 2.3)

The second category includes the following topics: (1) Development of an Analytic Framework for Selecting Corridors and Intersections for TSP Treatment, (2) TSP and Transit Scheduling: Best Practices for Maximizing the Benefits of TSP under Different Conditions, (3) TSP and Automatic Vehicle Location (AVL): Factors Affecting the Transit Agency's Technology Development Strategy, Technical and Management Implications, and Cost-Effectiveness Considerations, (4) Integrating Physical and Signal Priority Measures for Transit: Inventory, Best Practices, and Issues, (5) Traffic Controllers and TSP: Technical Requirements for Alternative TSP Strategies and Inventory of Traffic Controllers and Technical Characteristics, (6) The Role of TSP in BRT System Design, and in BRT-Specific Planning Tools, (7) Impact of Bus Operator Behavior on Transit Schedules Under TSP, (8) Review of Major European TSP-Related Demonstration Programs, Identified Benefits, and Implications of Lessons Learned for Canadian Deployment of TSP

Intelligent DRT (Demand Responsive Transit) is the second transit ITS area on which this paper focused. Paratransit agencies in Canada are increasingly turning to applications of advanced information technologies such as automatic vehicle location and computer aided dispatch systems (AVL/CAD), and digital telecommunications in order to improve the cost effectiveness of their operations. Intelligent DRT is the result of integrating these information technologies into the operations and management of DRT systems. With the ability to track vehicle locations, communicate with drivers and clients, and access traffic information on a continuous basis, intelligent DRT systems are expected to operate at a significantly improved level of productivity, reliability and quality of service.

Canada is a world leader in Intelligent DRT software, providing two world-renowned system providers, namely Trapeze Inc. of Mississauga, Ontario and GIRO Inc. of Montreal, Quebec. Both provide software solutions for planning, scheduling and dispatching of DRT operations. Also, advanced research has been undertaken including the development of dynamic scheduling algorithms and models, the development of simulation tools for the evaluation of intelligent DRT (SimParatransit) and the planning/scheduling of advanced flex-route transit.

In order to maintain Canada's leading position in this ITS area, ten R&D needs have been identified. These include: (1) Development of Dynamic Scheduling Algorithms for Intelligent DRT, (2) Planning under Uncertainty and Real-time Information, (3) Exploration of Distributed Computation Platform for Intelligent DRT, (4) Development of Data Fusion and Estimation Algorithms, (5) Development of Scheduling Algorithms for Integration of Fixed Route Transit and DRT, (6) Planning and Scheduling of Advanced Flex-route Transit, (7) Intelligent DRT: Inventory, Best Practices, and Issues, (8) Development of Operations Manual for Intelligent DRT, (9) Planning Tools for Intelligent DRT, and (10) A Review of International Programs on Intelligent DRT, Identified Benefits, and Implications of Lessons Learned for Canadian Deployment.

8. REFERENCES

See Discussion Paper for details.

Appendix – Work Group 1.3 List of Experts

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