ATLANTIC

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

A Partnership of ITS Communities in Europe and North America

DISCUSSION PAPER
ELECTRONIC ROAD USER CHARGING SYSTEMS AND SMART CARDS

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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 practise and research and development in Canada.

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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 2.3, Electronic Road User Charging Systems and Smart Cards, is jointly managed by Dr. Muhammad Mustafa of IBI Group (leader) and Dr. Baher Abdulhai, of the University of Toronto (rapporteur). 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 2.3 members and contributors appear in Annex A.

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1 Introduction

Work Group 2.3 'Electronic User Charging Systems and Integration with Smart Cards and Other payment Systems' is one of eight work groups of the Canadian ATLANTIC project.

In the context of the overall objectives of the Canadian ATLANTIC project, the main objectives of Work Group 2.3 are the following:

- Involve Canadian stakeholders;
- Provide description of the state-of-the-art and state-of-practice of electronic road user charging and smart cards system in Canada;
- Benefit from experience from implementations in Canada and worldwide;
- Identify issues and opportunities for future research, development and deployment in Canada.

The report is structured into two main parts; Road User charging Systems and Smart Cards. Each of these parts is presented in a summary format that summarizes the current status of technology (or state-of-the-art) and implementations of these systems in Canada (or state-of-practice). Finally the last sections of the report identify issues to be addressed in future research and opportunities to be captured in deploying such systems in Canada.

2 Electronic Road User Charging Systems

2.1 Road User Charging Technology

The electronic road user charging system is based on the principles of detecting a vehicle entering a tolled zone, facility or areas, classifying and applying respective toll rate and registering data and/or images for subsequent billing or enforcement.

There are several technologies utilized for electronic road user charging system; among others the following is a list of technologies being implemented in the world:

- Dedicated Short Range Communication (DSRC);
- Global Positioning System;
- License Plate Recognition (LPR) or Automatic Number Plate Recognition (ANPR).

The following sections provide a summary of these technologies.

2.2 Dedicated Short Range Communication

In a DSRC system, vehicles are usually equipped with a tag (e.g. transponder) and the entrance points of the system area are equipped with tag readers. When a vehicle passes by the tag reader at the entrance point, the reader reads the coded data, perform actions of identifying or charging, and the information is passed on to the roadside controller. The data is then checked for integrity and transmitted to a central computer system for processing and storage.

Sections 2.2.1 through 2.2.4 provide an overview of the DSRC technology and subsystems.

2.2.1 Vehicle Detection and Communication

The DSRC utilizes spot (or point) based charging systems. DSRC is the high-level term generally used to describe the process of direct communication between the vehicle tag and the reader. Radio Frequency ID (or RF) systems are microwave-based communications; North America communications are primarily in the 900 – 928 MHz range of the electromagnetic spectrum. There are two forms of RF communication: (1) Active RF and (2) Passive RF. Active RF systems employ microwave frequencies for communication to and from the vehicle; this system uses an active tag that requires a power source. Passive RF systems use a passive tag to communicate with the reader. The transmitter transmits a continuous signal that is intercepted by the tag and reflected to the receiver. Passive RF communication is also referred to as the 'backscatter' method. The electronic tag located in the vehicle is available in three types: (1) Read only (Type I) (2) Read/Write (Type II) (3) Smart Tags (Type III). With the use of Type I tags the information is fixed, with Type II tags the information is updateable (point of entry, date/time, etc.) and with Type III tags the reader and tag may communicate identifying information about the vehicle, customer and account balance. Examples of RFID systems are the Highway 407 Electronic Toll Route in Ontario and the Confederation Bridge in PEI. RFID technologies are currently the most widely used technology for electronic toll collection systems in North America.

Similarly to RFID, infrared systems are a form of DSRC but the communications are in the infrared range of the electromagnetic spectrum. An infrared read for roadside to vehicle communication is consistent and accurate in dense city applications with its well-focused and long operating distance. The technology is used in multilane free flow toll collection as well as stop and go traffic due to its precise, easily defined communication zone avoiding missed reads due to windshield and weather conditions or other characteristics particular to RFID. There are some examples of Infrared systems implemented in Malaysia.

2.2.2 Vehicle Classification

Some of the popular vehicle classification technologies include:

- Treadles and Weigh-In-Motion Devices;
- Light Beams and Light Curtains;
- Scanning Devices.

Treadles are pressure-sensitive devices placed in frames installed over the road surface and used to determine the number of axles, number of wheels and direction of a vehicle. Similarly, weigh-in-motion devices are pressure sensitive but are used to determine axle weight. Light beams consist of a single infrared beam that is broken as a vehicle passes through the beam providing vehicle presence and height information. Light curtains emit multiple horizontal light beams to determine vehicle presence and profile. Scanning devices generate radiation at various frequencies to detect vehicle presence and profile.

2.2.3 Vehicle Enforcement

Essentially there exist two main video enforcement technologies:

- Video Imaging;
- License Plate Recognition (LPR) or Automatic Number Plate Recognition (ANPR).

In either case the primary objective is to capture an image that is clear enough to determine the information on the vehicles license plate. Video imaging is a video based system that captures and stores digital images that are later manually examined to extract the desired information. LPR uses an automated system to extract the license plate information from digital images. The video technology can be used to register license plate information and verify status with a central system. This technology can be used as a stand-alone system or combined with infrared or RFID technologies for purposes of enforcement only. Example of this implementation is the ETR 407.

2.2.4 Central System

All filed systems for communication; classification, charging and enforcement are connected to a central system. The central system provides the following main functions:

- Transaction data and image collection, processing and storage;
- Revenue management and system auditing;
- System reporting;
- Field equipment monitoring;
- Customers account maintenance,
- Customer service.

2.3 Global Positioning System

The GPS/GSM technology allows for wide area charging systems, which includes all routes within a selected area. A vehicle o-board unit uses an autonomous positioning system such as a global positioning (GPS) system to locate itself within a charge area or network. The on-board unit will contain the appropriate charge structure as well as information concerning when the vehicle should be charged. Charges are applied at specific "virtual" locations via satellite. The charge can either be deducted directly from a smart card located in the On-Board Unit or stored for later debiting by servers that centralize all accounts. Corridors can be defined around specific zones in urban or rural areas where all vehicles (or specific categories) using the roadway will be subject to charges. This technology is being used for the truck tolling systems in Germany and Switzerland.

For enforcement purposes, the On-Board Unit may have a DSRC (Dedicated Short Range Communication) module to communicate with stationary and/or permanent enforcement system via infrared or microwave signals.

2.3.1 System Elements

The GPS-GSM tolling system includes the following elements (refer to Exhibit 2-1):

- The On-Boar Unit (OBU);
- Global Positioning System;
- GSM network, wireless system towers and repeaters;
- Central system; including servers and operators workstations;
- Enforcement system.

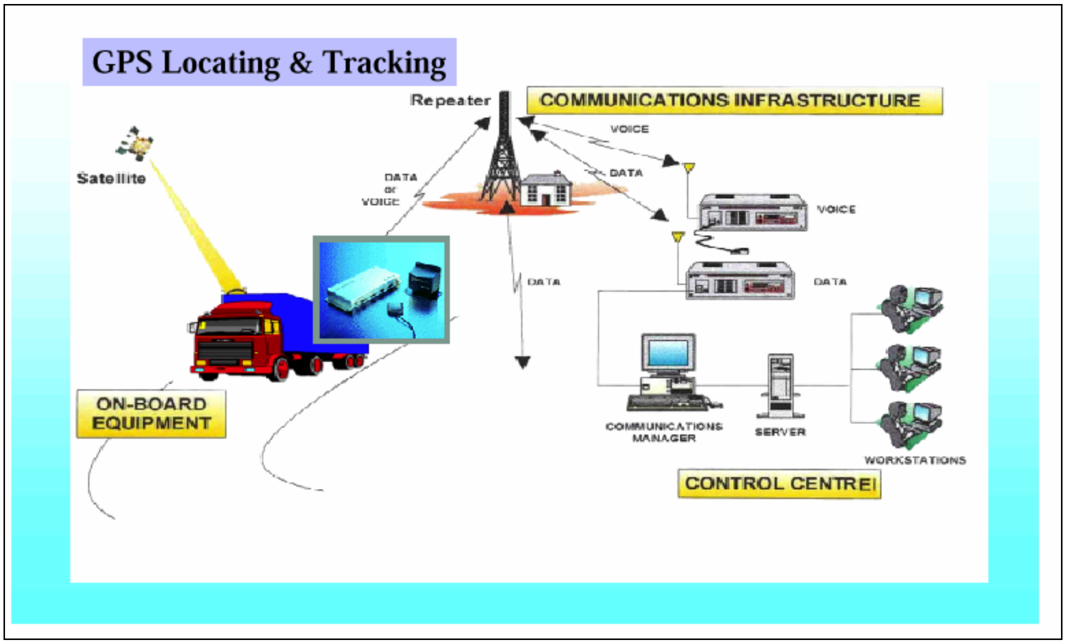


Exhibit 2-1: GPS/GSM System Components (the German Truck Tolling System)

Most GPS/GSM-based ETC systems include a mobile link that can:

- Update the stored charging system;
- Transmit charging or payment data at appropriate times and locations;
- Transmit digital "certificates" for enforcement ;
- Provide system diagnostics and a communication medium for integration of other ITS services and applications.

So far, the GPS-GSM technology has been tested in pilots and small scale implementations. The first large scale implementation was anticipated to start in August 2003 for the truck tolling in Germany. This system has experienced some technical challenges and has not started commercial operation yet.

2.3.2 Enforcement

The enforcement system is based on stationary and mobile enforcement controls. The combination of the two ensures a reasonable level of enforcement of the toll requirements and the ability to adapt the enforcement system to changing conditions.

Stationary enforcement is carried out selected locations (parking areas, rest centres, etc.). If a vehicle has not paid the required toll, the vehicle information is transmitted via radio to mobile enforcement points, which will stop the vehicle for a more detailed check. If the toll has not been paid a potential fine will be collected on the spot.

Stationary control personnel are supported by mobile toll enforcement officers deployed in control vehicles. Using DSRC communication, the officers in the enforcement vehicles determine whether passing trucks have logged on automatically and the vehicle data has been properly entered. In addition, a PC installed in the vehicle and connected to Central by GSM communication.

2.4 Automatic License Plate Recognition (ANPR)

Automatic Number Plate Recognition (ANPR) technology is based on vide imaging that records license plates and other information, process recorded information to identify the vehicle owner to collect the appropriate toll or fine.

This technology is used for the London Congestion Charging project which is briefly described in the following sections.

2.4.1 System Elements

A typical ANPR system is comprised of a video image-acquisition subsystem, a CPU for image processing and control, a hardware- or software-based character recognition engine, and storage or transmission subsystem for electronically recording plate contents and data such as date, time, and location. In specific, the following is a description of main system elements:

- Camera(s) - that take the images of the vehicle (front or rear side)
- Illumination - a controlled light that can bright up the plate, and allow day and night operation. In most cases the illumination is Infra-Red (IR) which is invisible to the driver.
- Computer - normally a PC running Windows or Linux. It runs the ANPR application which controls the system, reads the images, analyses and identifies the plate, and interfaces with other applications and systems.
- Software - the application and the recognition package.
- Hardware - various input/output boards used to interface the external world (such as control boards and networking boards)
- Database - the events are recorded on a local database or transmitted over the network.
- Central system which monitors all field equipment, receive all above information from field, process statements and analyse images which can't be processed automatically by the system.

2.4.2 Experience from London Congestion charging system

The London congestion charging system is the only example of operational systems that uses ANPR technology for road user charging purposes. The central London congestion charging scheme covers 22 square kilometres in the heart of London and was introduced in February 2003. The congestion charging scheme was implemented to achieve key transport priorities for London; namely to reduce congestion and to generate revenues and use them to improve public transport services.

2.4.2.1 Revenues and Operational Cost

Congestion charging scheme was expected to generate net revenue of £120 million in 2003/04 and £130 million in subsequent years. The latest estimates are that the revenue will be some £68 million in 2003/04 and £80 to 100 million in subsequent years. Principal reasons for the reduced levels of net revenues, compared to earlier estimates are higher than expected level of evasion and high operational cost of the system.

2.4.2.2 Enforcement

Payment levels have remained relatively constant since the second week of the scheme at an average of around 108,000 payments per day.

Failure to pay the congestion charge results in a Penalty Charge Notice (PCN) of £80 being issued to the registered keeper of the vehicle. This is reduced to £40 for prompt payment within 15 days. Failure to pay the penalty charge within 28days results in the penalty being increased to £120. In the first six months an average of 106,200 Penalty Charge Notices (PCN) has been issued per month. The rate of payment of PCNs has steadily increased since the start of the scheme. 61% of PCNs issued in August 2003 were paid by the end of September.

2.5 State-of-Practice in Canada

The Canadian Electronic Road User Charging System implementations that are discussed in this report are:

- Confederation Bridge (PEI);
- Angus Macdonald & Murray Mackay Bridges (Nova Scotia);
- Saint John Harbour Bridge (New Brunswick);
- Cobequid Pass (Nova Scotia);
- Highway 407 ETR (Ontario);
- Pearson Airport (Ontario);
- Winnipeg Airport (Manitoba);
- Nexus Border Crossing (Across Canada).

The following sections provide a description of the above implementations. A summary of basic characteristics of these systems is provided in Exhibit 2-2 and Exhibit 2-3.

2.5.1 Confederation Bridge

A part of the Trans Canada Highway network, the 12.9 kilometre Confederation Bridge is the longest bridge over ice-covered waters in the world. Officially opened on May 31, 1997, this landmark carries two lanes of traffic 24 hours a day, seven days a week. A comprehensive traffic management and toll collection system for this $1 billion bridge has been in place since opening day.

On October 28, 2002, the Confederation Bridge launched an electronic toll collection system for commercial vehicles only (trucks and buses) called StraitPass. The toll plaza is located in Borden-Carleton, P.E.I., and tolls are collected only when you depart P.E.I. The Bridge Toll Plaza has seven lanes. Five lanes are operated by toll collectors and will accept all methods of payment. The two other lanes are self-serve where one is reserved solely for commercial StraitPass users and the other is for two-axle passenger vehicles only, accepting debit and all major credit cards.

Users can use their StraitPass transponder at three other toll facilities in the Maritimes, provided they set up accounts at these facilities. The Halifax Dartmouth Bridge Commission for the Macdonald and MacKay Bridges (MacPass); the Cobequid Pass (E-Pass); and the Saint John Harbour Bridge (Bridge Pass) systems all use the same transponder as the StraitPass system.

The Confederation Bridge tolling system is based on a high rate structure with toll rates between $38.50 and $219.25. The system was designed to accommodate the peak tourist demands of the summer, while still providing a cost-effective year round service. Efficient and secure processing of tolls (cash, credit card, or debit card transactions) is facilitated by the comprehensive toll system. Finally, additional to the toll system is a sophisticated Traffic Management System enhancing motorist safety and security.

2.5.2 Angus Macdonald & Murray Mackay Bridges

The Angus Macdonald Bridge is a 1.3 kilometre suspension bridge that was opened in 1955 connecting Halifax and Dartmouth. Similarly, the Murray Mackay Bridge is a 1.2 kilometre suspension bridge that connects Halifax and Dartmouth but opened later in 1970. Each bridge uses an electronic tolling system known as MacPass. Users can traverse either bridge using cash and tokens paying full fares or with the use of a MacPass for a discounted toll payment. The MacPass system was initiated in 1998.

During 2002, the Macdonald and MacKay Bridges carried approximately 31.6 million vehicles for which approximately $23 million in revenue was generated. On a per capita basis, the Macdonald and MacKay Bridges are among the most frequently used toll bridges in North America.

The MacPass is a visible contributor to the efficient handling of traffic on the bridges. In just over four years, MacPass has gone from zero usage to representing approximately 40% of all traffic volume on both bridges. Cars and small trucks represent approximately 97% of the total traffic volume, with the remaining 3% comprised of large trucks and buses, and the traffic volume on both bridges continues to grow. On average, 44 transponders were issued per business day in 2002 and MacPass usage continues to grow. Similar to most ETC applications, the MacPass website offers online enrolment and account information.

2.5.3 Saint John Harbour Bridge

The Saint John Harbour Bridge spanning a total of 2 kilometres was opened in August of 1968 in Saint John New Brunswick. The toll bridge has a toll plaza with 10 vehicle lanes where users can pay manually with cash and tokens or electronically with the use of a Bridge Pass (transponder). Users can purchase a Bridge Pass to take advantage of the electronic mode of payment. The Bridge Pass system was initiated in 1996.

When approaching the toll plaza, Bridge Pass users go through any lane. As users approach the tollgate, their Bridge Pass number is read by a computer system that checks their account to make sure there are enough funds to pay the toll.

2.5.4 Cobequid Pass

Cobequid Pass is a 45km toll highway that follows an alignment through the Cobequid Mountains in northern Nova Scotia, Canada. Cobequid Pass was built in November of 1997 to replace an aging, congested portion of the Trans Canada Highway. The Cobequid Pass toll system uses transponder technology and manual toll operators to facilitate toll collection. Motorists have the option to purchase an E-Pass transponder to take advantage of the electronic toll system and receive a discount in toll costs.

The Cobequid Pass consists of five full interchanges with six major bridges and five large tunnels under the road for access to land parcels, snowmobile trails and wildlife passages. Toll revenues over 30 years will provide the investors a return; pay for toll operations; cover the $650,000 for annual maintenance provided by the Nova Scotia Department of Transportation and Public Works; and contribute to long-term maintenance.

Cobequid Pass has the distinction of being the first highway in Canada to include private financing. It is a example of a major benefit resulting from a public-private partnership to develop toll highways: less financial risk to taxpayers.

2.5.5 Highway 407 ETR

Highway 407 is a toll route that runs east and west just north of Toronto for a total of 108 kilometres. The toll network was officially opened on October 14, 1997.

The 407 ETR is a transportation route serving daily commuters, varied industries and geographical markets. 407 ETR is an all-electronic toll system that allows users free-flow travel. The electronic sensors located on each overhead gantry log your 407 ETR entry and exit point. On exit, a green light on the transponder and four short beeps indicate the toll transaction has been successfully completed. If users choose not to lease a transponder, their trips are logged by using a state-of-the-art, license plate recognition system.

2.5.6 Other Applications of the DSRC Technology in Canada

2.5.6.1 Pearson Airport

Canada's first airport ground transportation Vehicle Monitoring and Control System (VMCS) has automated taxi and limousine dispatching and other related operations at Lester B. Pearson International Airport. The system provides a showcase for the application of Intelligent Transportation Systems (ITS) technologies in the airport environment. The VMCS also highlights the necessary coordination and cooperation efforts between the public and private sectors. The project's goal was to undertake the deployment of an innovative information management system to enhance passenger pick-up operations for commercial vehicles, using Dedicated Short Range Communication (DSRC) technologies, developed in Canada, to track and communicate with vehicles.

The VMCS implementation at Lester B. Pearson International Airport includes DSRC/Automated Driver Identification (ADI) at entrances and exits of the Commercial Vehicle Holding Areas (CVHAs) and at the terminal curbs for identification and tracking of vehicle and driver movements, Blank-Out Signs and Variable Message Signs at the CVHAs for communication with the commercial vehicle operators, ticket printers at the exits of the CVHAs facilitating authentication of the commercial vehicles at the terminal curbs, and communication and computer subsystems.

2.5.6.2 Winnipeg Airport

Winnipeg Airports Authority Inc. (WAAI) desired additional functions not found in the Pearson Airport implementation. New functions to facilitate per-trip fees, as well as potential future dwell-time charges for commercial vehicles operating in and out of the airport, were developed and incorporated into the Ground Transportation Management System (GTMS). With funding assistance from Transport Canada's Transportation Development Centre, WAAI was able to enhance the GTMS software, an effort completed in 1997.

The goal of this project was to implement an innovative account information management system to enhance the GTMS developed for Pearson Airport. The objectives were to; implement an accurate and efficient system for revenue capture for landside commercial vehicles (i.e. taxis and limousines, as well as pre-arranged pick-up vehicles) accessing WAAI; demonstrate real-time communication capabilities between vehicles and roadside infrastructure; and establish a foundation for future expansion to create a comprehensive system for interfacing with the full range of vehicles using the airport.

The design implemented at WAAI includes the following elements and subsystems at the Commercial Vehicle Holding Area (CVHA) and terminal curb-sides:

- Automated Vehicle Identification (AVI) or Dedicated Short Range Communications (DSRC) at entrances and exits of the CVHA and at the terminal curbs for identification and tracking purposes;
- Blank-Out Signs and Variable Message Signs at the CVHA for communication with commercial vehicle operators;
- Pay-at-Point Station at the CVHA to facilitate account transactions on-site for the commercial vehicle operators; and
- Communication and computer subsystems.

2.5.6.3 Nexus Border Crossing

The NEXUS program allows pre-screened frequent travelers between the two countries to use special border crossing lanes. NEXUS identification cards are about the size of a credit card and embedded in the card are a computer chip and a tiny RFID antenna. Once in the lane, users hold the card up to an RFID reader positioned well in front of the inspection booth. The reader flashes the participant's photo and information onto a computer screen inside the booth. The inspector verifies that the photo on the screen matches the vehicle occupant and, if all checks out, authorizes the car to proceed. The clearance significantly reduces the time it takes to proceed through the standard lanes. A typical NEXUS inspection takes less then 5 seconds to complete.

NEXUS is a joint customs and immigration program for frequent travelers that both the Canadian and American governments have implemented. The NEXUS program is designed to simplify border crossings for pre-approved, low-risk travelers.

As a NEXUS member, individuals are able to use dedicated lanes at various border crossings, and may not be regularly subjected to the usual customs and immigration questioning. These lanes are provided in an effort to reduce traffic congestion and delays at bridge and land crossings while maintaining a safe and secure border.

Once approved by both Canada and U.S. as low-risk travelers, NEXUS members will enjoy a simplified entry process while traveling back and forth across the Canada/U.S. border. NEXUS enables Canadian and U.S. customs and immigration authorities to concentrate their efforts on potentially high-risk travelers and goods, thereby upholding security and protection standards at the border.

Exhibit 2-2: Canadian Implementations of Road User Charging Systems using DSRC Technology

	Confederation Bridge	Angus Macdonald & Murray Mackay Bridges	Saint John Harbour Bridge	Cobequid Pass	Highway 407 ETR
Location	Borden, Prince Edward Island (to New Brunswick)	Halifax, Nova Scotia (to Dartmouth)	St. John, New Brunswick	Highway 104, Nova Scotia	Greater Toronto Area, Ontario
Operator	Strait Crossing Bridge Limited	Halifax – Dartmouth Bridge Commission	Saint John Harbour Bridge Authority	Highway 104 Western Alignment Corporation Atlantic Highway Management Corporation	407 ETR
Commercial Name	StraitPass	MacPass	Bridge Pass	E-Pass	407 ETR
Initial ETC Operation Date	2002	1998	1996	1997	1997
Function	Transponder ID linked account & credit card for immediate charging. Initially for commercial vehicles.	Transponder ID linked to account for pre-paid charging.	Transponder ID linked to account for pre-paid charging.	Transponder ID linked to account for pre-paid charging	Transponder ID and license plate recognition, statement mailed out.
Customer Service	No billing required. Statement is available on Internet.	No billing required. Account Pre-paid in-person, by telephone or on-line.	No billing required. Account Pre-paid in-person, by telephone or on-line.	No billing required. Account Pre-paid in-person, by telephone or on-line.	Billing Required. Statement is mailed out to account holder or vehicle owner.
Plazas – Lanes	1 plaza – 7 lanes. 2 lanes have ETC.	ETC all lanes, eight exclusive lanes.	1 plaza – 10 lanes. All lanes ETC accessible, 2 lanes ETC exclusive.	ETC lanes	Free flow at all entry and exit ramps
Gates	Yes	Yes	Yes	Yes	No
Video Enforcement	No	No	No	No	Yes
Classification	Via database or toll collector and Automated check.	Via database or toll collector.	Via database or toll collector.	Via database or toll collector.	Automated
Toll Amount	$38.50 to $219.25	$0.75 to $5.25 ETC discount	$0.25 to $1.75	$3.50 to $20.00 ETC Discount	$0.1295 to $0.3885 per km

	Confederation Bridge	Angus Macdonald & Murray Mackay Bridges	Saint John Harbour Bridge	Cobequid Pass	Highway 407 ETR
Standard	RF Proprietary Backscatter	RF Proprietary Backscatter	RF Proprietary Backscatter	RF Proprietary Backscatter	RF Proprietary
Frequency	915 MHz	915 MHz	915 MHz	915 MHz	915 MHz
Transponder	Amtech	Amtech	Amtech	Amtech	Mark IV
Antenna	Overhead Amtech	Overhead Amtech	Overhead Amtech	Overhead, Amtech	Overhead, Mark IV
Interoperability – Transponder	Confederation, Macdonald, St. John, Cobequid	Confederation, Macdonald, St. John, Cobequid	Confederation, Macdonald, St. John, Cobequid	Confederation, Macdonald, St. John, Cobequid	None
Web Site	www.confederationbridge.com/	www.hdbc.ns.ca/	www.saintjohnharbourbridge.com/index.html	www.highway104.ns.ca/index.html	www.407etr.com/

Exhibit 2-3: Other Applications of the DSRC Technology

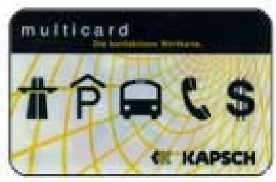
	Pearson Airport	Winnipeg Airport	Nexus Border Crossings
Location	Toronto, Ontario	Winnipeg, Manitoba	Canada & USA Border
Commercial Name	Toronto Lester B. Pearson Vehicle Monitoring and Control System	Winnipeg International Airport Ground Transportation Management System	NEXUS
Initial Operation Date	1996	1998	2003
Function	Automates the airport's dispatching and related operations for Commercial Vehicle Holding Areas and Terminal Curbs.	Automates the airport's dispatching and related operations as well as apply trip fees and dwell time charges.	The NEXUS ID cards allows pre-screened frequent travelers between the two countries to use special border crossing lanes.
Customer Service	N/A	N/A	Application process completed via mail, fax, phone or web. Approved applicants must complete process in person.
Video Enforcement	N/A	N/A	Yes
Standard	RF Proprietary	RF Proprietary	RF Proprietary
Frequency	915 MHz	915 MHz	N/A
Web Site	www.gtaa.com/	www.waa.ca/waa_what.htm	www.ccra-adrc.gc.ca/nexus/

3 Smart Card Systems

3.1 Smart Card Technology

A smart card can be defined, as a card with standard dimensions, is a portable programmable device containing an integrated circuit and stores and processes information. Smart Cards are available in three forms: (i) contact (ii) contactless and (iii) Dual Interface (combi card).

a) Contact



b) Contactless

c) Dual Interface

Contact cards commonly use a magnetic stripe to magnetically encode the required information and require the smart card to be inserted into the smart card reader. Contact cards can be seen in use for public telephone prepayment and automated banking applications. Contactless cards use RFID technology to communicate with a reader without making any physical contact. Contactless cards have been implemented throughout a variety of public transit and security access applications. A combination card combines the features of contact and contactless technologies but adds a very high level of security.

The primary use of a smart card is the storage and retrieval of information. Therefore, the fundamental component of a smart card is the memory module. The following list indicates the more commonly used memory types:

- ROM – Read Only Memory
- PROM – Programmable Read Only Memory
- EPROM – Erasable Programmable ROM
- EEPROM – Electrically Erasable PROM
- RAM – Random Access Memory

A memory module may have one or more of these memory types in order to provide the required functions of a given application. The memory module is then combined with control logic to process the required communication protocols and offer some protection of the memory against fraudulent use.

Therefore, for each form of card there exists three methods for memory storage: (i) Memory (ii) Memory with Security Logic and (iii) Memory with CPU.

Memory cards use a chip or other electronic device to store authentication information. In their most secure form, memory cards store a unique serial number and include the ability to permanently lock sections memory or allow write access only through password-protected mechanisms.

Security Logic cards have a special purpose electronic circuit designed on the chip and use a fixed method to authenticate themselves to readers, verify that readers are trusted, and encrypt communications. This is usually accomplished with some form of access code.

CPU cards implement authentication/encryption methods in software or firmware. Contactless smartcards with an embedded CPU have more sophisticated security capabilities, such as the ability to perform their own on-card security functions and interact intelligently with the card reader.

3.2 State-of-Practice in Canada

This section presents an overview of several existing smart card system implementations in Canada. As well, this section describes the progress of other cities currently considering smart card technology for transit fare collection.

The systems that are examined in this report are:

- Barrie, Ontario;
- Gatineau, Quebec;
- Burlington, Ontario;
- Edmonton, Alberta (in development);
- GTA Region, Ontario (in development);
- Montreal, Quebec (in development).

The following sections provide a summary description of the above smart card systems in Canada. Exhibit 3-1 and Exhibit 3-2 summarize the current status of smart card implementations in Canada.

3.2.1 Existing Smart Card Implementations

3.2.1.1 Barrie, Ontario

Barrie, Ontario, has a Smart Card program that dates back to 1997 when Scotiabank Canada ran a pilot program targeting merchants that deal in high volume, low value transactions. Coffee shops, grocers, sports bars, video stores and quick service restaurants were approached because of their high volume turnover and their need for speed when it comes to managing customers. In 1998, five months after the merchant program began; testing began on expanding the service to the buses in the transit system. Soon after, the transit system had one of the ten largest transaction volumes in the city, and specialized transit incentive programs were established, including monthly and weekly discount passes, semester passes for students, $5, $10 and $20 reduced fare tokens.

The smart card system supported over 350 merchants and 250 vending machines in addition to the public transit system. Merchants paid a fee averaging 1.35 percent based on the volume of their sales by smart card. Merchants were invited to design their own loyalty programs to help boost revenues that could be automatically maintained by the smart cards. There were approximately 18 loyalty programs offered by merchants and consumers could belong to all of them.

The card population in Barrie was in the neighbourhood of 50,000 cards. This is quite significant considering the city's population of 100,000. This is attributed to user acceptance of the card across all age groups, including youths and seniors.

3.2.1.2 Hull/Gatineau, Quebec

In the fall of 1998, Société de transport de l'Outaouais (STO) began issuing contactless smart cards for the purpose of fare collection on buses. In January 2002 it was rolled-out across Gatineau. Currently, the system has incorporated about 210 buses, and also is accepted on the Ottawa-Carleton Transit system with proof of validity.

The cards are re-chargeable/re-loadable, and are accessed when in proximity of the reader (i.e. they are contactless). They have memory capacity that can be used for incentive programs and for authentication/identification purposes. Stored identification data includes Name, Age, Gender and Address of the user for refund purposes.

The smart card system is integrated with the buses Automatic Vehicle Location system that allows for higher-order benefits related to planning and service development. Combining these technologies together allows planners access to smart card usage data as it occurs geographically across the network.

3.2.1.3 Burlington, Ontario

The smart card system in Burlington was first introduced for transit payment in 1995. The scope of the smart card system was then expanded as part of the Integrated Mobility Systems (IMS) Consortium; Burlington Transit implemented an on-the-ground demonstration of a multi-modal, multi-application smart card system. The demonstration was launched in October 2001, and adds on to the existing Burlington Transit ComboCard system to demonstrate:

- Multi-application use of the cards by using the ComboCard for payment at city-operated pools, as well as a loyalty program;
- Multi-modal capabilities of the cards by integrating the Adult GO Transit monthly pass with the existing ComboCard; and
- New payment options through convenient pre-authorized credit card or debit payments.

Users obtain cards for the system for $5.00 at various issuance locations through the Burlington Transit system. However, once a user has a ComboCard, they can be reloaded/replenished on all Burlington Transit buses, at the Burlington Transit Terminal, and at City pools.

Various incentive programs are offered using the ComboCard. For starters, customers can buy tickets in groups of 10, at a reduced price ($2.00 for an adult) compared to the single fare charge ($2.35). If a customer uses the ComboCard three times in one day, any subsequent trips are no longer charged (in effect, a day pass is then costs $6.00). Finally, users can pay $71.00 for their ComboCard to act as a monthly pass (31 days).

Burlington Transit has arrangements with GO Transit whereby customers pay an additional $0.50 and can travel on GO buses to and from the GO Train Service and within the Burlington Transit boundaries. The ComboCard is compatible with this service.

An alternate application that was brought into place through the demonstration was the use of the ComboCard at City Pools. Various incentive programs/pricing discounts have been tested, including free swim entrances for every 10 transit trips as well as discounted pool admission costs when purchased in bulk.

One back office function provided by this system is Pre-Authorized Payments using a credit card or directly from the user's bank account. With this feature, pre-approved customers can have any loading of $10 or more be automatically charged. The system works with automatic downloads each night of all transactions for the day to the Central Database. Once this information is processed, the system communicates with the appropriate banks to complete the requested transactions.

3.2.2 Smart Card Systems in Development

3.2.2.1 Edmonton Transit System

Edmonton Transit System (ETS) is considering implementation of a smart card system to meet policy directions set out in the City development plan, and to achieve objectives related to efficient fare collection, revenue management and control. To that end, they are currently in the process of preparing a "business case" examining issues, questions and concepts that would help Edmonton Transit determine whether the implementation of smart card technology would be of benefit for the organization, customers, and other stakeholders. The business case study is broken down into two phases:

- Phase 1: 'Definition of smart card system concept and business models', which defines business model alternatives, prepares an overall system concept, and provides initial equipment costs for an ETS-specific smart card system;
- Phase 2: 'Development of smart card business case', will update the business model and complete the business analysis, incorporating costs and benefits and concluding with implementation plan.

3.2.2.2 GTA Fare System

Presently, all 905 area code municipal transit agencies are planning to replace their fareboxes over the next few years. In addition, GO Transit is looking to replace its current paper ticket/pass fare collection system with one based on smart cards. This has resulted in a unique opportunity to deploy a single GTA Farecard. The single Farecard would allow for seamless travel within the region, allowing customers to ride on any participating transit system without having to know the fare policies of each system in advance.

The contactless smart cards would contain an electronic purse that would provide full fare payment interoperability. It would allow for increased flexibility with respect to incentive programs that could target choice riders.

Three initiatives have been completed to examine aspects of the implementation. An Operational Concept was developed that outlines the policy, functional and technological requirements of the system. Although the TTC has indicated that it would not consider implementation of the GTA Farecard in the foreseeable future, their needs/requirements were nonetheless considered when drafting the concept for the scenario that they should eventually be included in the system. The second initiative was a Business Case Analysis conducted to examine the costs and impacts of introducing a regional Farecard system. The final initiative looked at assessing various alternatives for Governance and Business models for implementing and operating the GTA Farecard system.

The GTA is now hiring a consultant to develop technical specifications of the planned multi-agency system and to assist in equipment procurement and system implementation.

3.2.2.3 Greater Montreal Area

The Société de transport de Montréal (STM), mandated by the Agence métropolitaine de transport (AMT), the Société de transport de Laval (STL), the Réseau de transport de la Capitale (RTC), the Réseau de transport de Longueuil (RTL) and the Conseil intermunicipal de transport de Sorel-Varennes, awarded major contracts relating to public transit fare collection. The partners joined forces, not only to benefit from greater buying power, but also to offer customers an integrated and efficient system. The smart card will be used in all the participating systems and will have a common appearance. It will be able to handle passes as well as all reduced fares (including intermediate fares), as it will incorporate the identity card that entitles users to these reductions. By doing so, it will provide better control and will facilitate the work of employees handling fare collection. Some transportation companies, including the STM, will also introduce a magnetic card that will support single tickets, transfers and multiple regular-fare trips. Note that cash payments will still be possible.

The fare sale and collection activities will also be automated and operated by each of the partners. In addition, vending machines will be available in the métro stations, in the commuter train stations served by the AMT, at authorized agents in the Montreal metropolitan area and at the Société des traversiers de Québec (Quebec-Lévis link) in order to ensure that fares are available at all times.

This project will be carried out in two major phases. The first phase, consisting of carrying out modifications to the system, will lead to the production and evaluation of prototypes in 2004. The second involves the installation of the system in a few buses, métro stations and commuter train stations in the spring of 2005 and its deployment starting in the fall of 2005.

The project is designed to facilitate and simplify the purchase and use of fares, provide a greater range of fares that are better adapted to customer needs, assure regional fare integration as well as reduce the loss of income resulting from fraud. In addition, the centralized information management system – to be shared among the participating networks – will promote a consolidation of procedures, which may result in significant savings.

3.2.3 Integrated Mobility Systems

The Integrated Mobility Systems (IMS) initiative was launched in 2000 and is led by Moving the Economy (MTE). The initiative brings together a consortium of service providers, public agencies, and private interests who wish to deliver integrated, sustainable multi-modal and multi-application services to end users through the use of smart card technologies.

The IMS members are:

Integrated Mobility Systems (IMS) Consortium			
Project Manager: Moving the Economy	*Technical Manager:* IBI Group	Ministry of Transportation, Ontario	Toronto Transit Commission
GO Transit	City of Burlington	City of Mississauga	Grand River Transit, Waterloo
TransLink	STO (Hull)	New City of Hamilton	Edmonton Transit System
OC Transpo	407 ETR Concession Company Ltd.	Toronto Board of Trade	Canadian Urban Transit Association
Industry Canada	AutoShare	University of Toronto ITS Centre and Testbed	Green Tourism Association
City of Toronto	EasyPark, Vancouver		

The IMS members help each other address common barriers toward smart card implementation, including:

- Uncertainty about the current day business case;
- Lack of network infrastructure for systems and communications;
- No set standard for contactless card technology;
- Costs of switching to smart cards, and upgrading the system;
- Lack of consumer education including concerns over privacy and security; and
- Institutional challenges.

To that end, the consortium undertook the following activities since the fall of 2000:

1. Study the feasibility of introducing multi-application, multi-modal smart cards in Canada for transportation, tourism and urban services, including identifying business needs, formulating a set of business rules, and identifying business models for governance.

2. Develop initial system architecture and recommended practices for implementing and integrating a range of smart card applications. The architecture was developed from an overall system concept and followed an extensive review of the ITS architecture for Canada (http://www.its-sti.gc.ca/Architecture/english/static/content.htm).

3. Demonstrate the concept of interoperability of multi-modal, multi-application smart cards through deployment in a medium size urban setting. The deployment in Burlington, detailed in Section 3.2.1.3 of this report, was the demonstration performed by the IMS consortium.

4. Analyse status of smart card industry and experience from smart card systems implemented worldwide.

Exhibit 3-1: Smart Card Systems Implemented in Canada

	Barrie	***Hull-Gatineau***	***Burlington Transit***
Location	Barrie, Ontario	Hull/Gatineau, Quebec	Burlington, Ontario
Initial Smart Card Implementation Date	1997	1998	1996
Applications	Retail Shopping and Transit Fare Collection	Transit Fare Collection and staff access control	Community Pool Entrance and Transit Fare Collection
Technology and Standards	Contact smart card	Contactless Mifare technology	Contactless Mifare technology
No. of Cards Distributed	50,000 (approximately)	58,000 (approximately)	35,000 (approximately)
Modes of Transportation	Buses	Buses	Buses

Exhibit 3-2: Examples of Smart Card Systems under Implementation

	Edmonton Transit System	***Greater Toronto Area***	***Greater Montreal Area***
Location	Edmonton, Alberta	Greater Toronto Area, Ontario	Montreal, Quebec
Initial Smart Card Implementation Date	In Development	In Development	In Development
Applications	Transit Fare Collection Student cards, parking, other	Transit agencies in the GTA	Transit agencies in the GMA

4 Issues and Challenges

Through discussions with the Work Group experts and stakeholder experience of existing electronic road user charging and smart card systems, the following issues and challenges were identified:

- Technology;
- Business case analysis;
- Business models and governance.

The following sections describe these issues and challenges which are common to both road user charging and smart card systems.

4.1 Technology

4.1.1 Standards and Specifications

With an ever-changing technological environment it is important for system standards and specifications to be established providing a simplistic approach to component and application integration. The international Organization for Standardization (ISO) has developed standards for use by multiple industries. In addition individual industries are developing proprietary versions of these standards with more detailed specifications to support their own specific system applications.

For both system types, ERUC and Smart Card, standards have been slow to develop however; both standards and interoperability are advancing. Continuing efforts by the IMS Group and Transport Canada are on-going to help set sufficient industry guidelines for issues such as technology selection, system design, multi-applications and interoperability. Current progress is evident with a Transport Canada proposal concerning the development of revenue collection standards and specifications. IMS Group members continue activities on ‘best practice’ case studies that will summarize experience in adopting existing specifications and standards.

A wide-range of standards organizations and groups are currently working towards standards and specifications for the ERUC and Smart Card system industries.

4.1.2 Integration of Systems

In the ERUC and Smart Card systems a commonality is necessary in the choice of system architecture for multiple applications. The introduction of multi-application single user accounts will reduce future implementations and enhance user applications. For example, sharing of toll collection ‘back-office’ operations could reduce costs and increase automation. Similarly, smart cards can be shared between agencies and with the private sector to expand operations. A transportation system with integrated tolling and transit systems will allow agencies to enhance existing networks and provide individuals with a more efficient approach to their daily travel.

4.1.3 Compatibility/Interoperability of systems

Compatibility and Interoperability of systems is a complex issue that can be understood very differently between business organizations. Compatibility is defined here as the ability to use different technological forms with one another. The most common example of compatibility concerns involves the use of products from multiple vendors. Interoperability is understood in this report as the capacity to provide operations between different systems. Generally, interoperability issues revolve around agreements between agencies, operators and companies involved with different revenue collection applications. Some important compatibility and interoperability points to consider include:

- How new technologies interoperate with installed physical or logical systems (i.e. backward compatible);
- How available products from multiple vendors interoperate with one another;
- How the interaction of applications is affected by the system components;
- How the applications may interact with each other;
- How agencies establish a minimum level of service; and
- How agencies determine a fair and efficient cost and revenue allocation method.

As discussed earlier, the answers to these issues need to be addressed within a set of national standards and specifications.

4.2 Business Case Analysis

A business case analysis involves the assessment of business needs and justification regarding implementation of modern revenue collection systems. A business case analysis provides insight into the potential for benefits with a particular venture. For example, Edmonton Transit wants to meet directions set out in its policy plan but would like to address any concerns or issues with the implementation of a smart card system. A business case enables agencies to review current practices and investigate improvement and growth opportunities.

4.2.1 Cost Benefit Considerations

Implementation of ERUC and Smart Card systems tend to be costly but the benefits developed commonly justify the project costs. In each system there are quantitative and qualitative benefits that can be assessed.

Quantitatively, ERUC systems commonly have associated tolls that correspond to revenue for the stakeholders involved. The number of road users plays a big role with ERUC toll system implementations since the number of users provides a direct correlation to the revenue generated by a toll network. Conversely, Access Management, Border Crossings and Smart Card implementations do not provide a new source of income but instead a more sophisticated and controlled approach to traffic management and revenue collection. The quantitative benefits are usually developed from a large reduction in vehicle delay, in the case of access management or border crossings, or a large reduction in fraud and increased ridership for smart card applications.

Qualitatively, ERUC and smart card systems enable a more organized and structured approach to revenue collection and vehicle or consumer management. When each system is implemented a new look and marketing platform is developed for the issuing agency. Businesses can enhance their public image with the implementation of a more technological approach.

4.2.2 Justification of Implementation

Agencies and businesses need to assess their current business functions or forms of vehicle management and determine if they are satisfied with their existing processes. For example, the 407 ETR involved the need to provide a fast and efficient alternative for traffic traveling the

North end of Toronto in the east-west directions. The system installed on the 407 called for a free flow approach that was acceptable in public opinion. Public opinion usually results in political pressure forcing agencies to renew or expand aging or inefficient systems. Furthermore, system modifications provide agencies additional options to users generating additional appeal and therefore consistent or increased use. Some questions to consider are:

- Will the new technology reduce operating costs, increase productivity, and/or improve security?
- What is the cost of replacing an existing system?
- What types of technologies are appropriate and cost-effective for the application?
- What level of security is required?
- Will users use/accept the new system?

4.3 Business Models

A business model is a generic approach to defining applications available and to agree on system functions. A business model also sets up roles of agencies involved in providing services in a multi-application revenue collection system.

4.3.1 Partnerships

Partnerships have been essential in the completion of major system implementations all across Canada. In a multi-application venture all stakeholders must agree on all aspects of the system design and implementation. All groups need to ensure their needs are addressed and their list of wants can be accommodated, with all being completed using a cost-effective approach. From project conception to initiation and completion each group must work together to fairly assign relevant system capabilities and components. For example, a transit and toll combination smart card project may experience cost allocation difficulties since the toll application may require an extensive central system with account maintenance functionality while the transit application may only need a small-sized central system for a pay-as-go system.

The development of National and/or International standards must address this issue in order to facilitate a fair and organized approach to multi-application partnerships.

4.3.2 Potential Applications

The potential exists for a large variety of interoperable and stand-alone systems and applications; some examples are listed below. The following lists indicate potential ERUC and Smart Card systems under Transportation and Service industry headings.

Services and Payment

- Municipal services
- Identification and access
- Tourism and "city cards"
- Campus cards
- Loyalty programs
- Retail payment and loyalty

Transportation

- Toll systems
- Car sharing and travel demand initiatives
- Regional transit fare coordination
- Parking payment
- Access Management
- Border Crossings
- Ferry Systems

It is more likely that multi-application systems will develop within one of the major industry headings, Service or Transportation, but opportunities exist for multi-application systems between each of the two groups.

4.3.3 Governance

Governance issues revolve around the role and responsibilities of the different agencies and groups involved. Some of the main points to consider for governance of multi-application systems are as follows:

- **How to share common functions of a multi-application system**. An example of a common function is issuing a multi-application smart card and load applications by each service provider. In this case, service providers need to set up and agree on procedures to issue the card to achieve acceptance at all service locations provided by the system.

- **How to operate a multi-application system and provide services.** Business rules define rights to access and update functions and interfaces of the systems. For example, how can each service provider download data from and upload data to a common processing function, such as a clearinghouse. Another example is lists of fare structure and blocked 'black listed' cards that require updating by each service provider.

- **How to access and manage services by customers**. Customers also require guidance on how and where to access services, which services are allowed on the card, how and where to manage applications on the cards (download, terminate application, etc.). An analogy in the financial system is how to manage payment services from a bank account through pre-authorized payment, Internet banking, etc.

5 Opportunities in Canada

A wide-range of opportunities exists throughout Canada for both Electronic Road User Collection and Smart Card Systems. More specifically, the following describes opportunities identified by the work group.

Multiple Applications
Agencies and private groups are increasingly forming greater interest in multi-application systems. Canadian organizations have historically kept with or gone beyond global technological standards. Furthermore, understanding that Canadian systems have not reached their potential establishes a need to expand current systems.

Involvement of Financial Industry and Other Sectors
Collaboration with financial sector members (banks, credit card companies, etc.) and vendor groups may ease implementation burdens such as cost and resources and therefore, provide additional opportunities for agencies and private groups interested in ERUC and/or Smart Card systems. Multiple application design concepts may interest a variety of potential stakeholders allowing for faster application progression. The Barrie, Ontario pilot program discussed in section 2.3.1, is an example of financial sector involvement.

Interoperability of Systems
Discussion between major groups and organizations will help in ascertaining some of the many multi-agency and multi-application opportunities available that are not being sought due to

insufficient standards and specifications with respect to interoperability. The companies and agencies that want to expand their current range of services must be prepared to work together with the needs and wants of other interested parties.

Address End User Requirements
Development of stand-alone or multi-application systems will help maintain user satisfaction and loyalty with increased system options. End user benefits may include:

- Frequent use of service discounts;
- Availability of multiple services;
- Event-based discounts and customer loyalty programs;
- Customer service.

The final goal of any system implementation is to improve service and therefore, the most important group to satisfy is the system users.

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