Benefit/Cost Assessment

of

Intelligent Transportation Systems (ITS)

Implementation in Canada

Technical Memorandum

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Transportation Development Centre

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

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EXECUTIVE SUMMARY

Background

This report presents the findings of a preliminary Benefits -Cost evaluation of selected Intelligent Transportation Systems applications in Canada.

Intelligent Transportation Systems (ITS) is the term used to describe the application of appropriate combinations of communications, electronic detection, navigation and information technologies to the field of surface transportation. Through the application of ITS, the interfaces between driver, vehicle and the roadway are undergoing a revolutionary change as they become dynamic, adaptive and interactive.

The objectives of ITS technologies is to: promote more efficient use of existing road systems, increase service levels, increase safety and mobility and decrease the environmental impact of road transportation through reduced fuel consumption. Intelligent Transportation Systems are regarded by many transportation agencies as an essential component of any sustainable infrastructure transportation. ITS allows the capacity of the existing infrastructure to be upgraded at a fraction, some estimates show less than 30%, of the cost of new highways of equivalent capacity. Furthermore ITS allows the increased capacity to be distributed over a wide area, rather than restricted to the area serviced by additional roads or lanes on existing roads, thereby allowing it to be responsive to traffic conditions at any location.

Already problems of congestion and safety problems are significant. In 1991, 3,700 people died in traffic accidents, and 248,000 were injured. The value of this loss alone is estimated to be in excess of $14 Billion. In Canada, the number of licensed drivers and registered vehicles continue to rise resulting in increased travel demand, congestion and reduced efficiency of our transportation system. These forces bear consequences for productivity, national competitiveness, energy use and environment.

Road infrastructure expansion is now very difficult to accommodate in many urban settings. As a result, Canadian agencies are now turning to new technologies, such as the ones embraced under ITS, to help use the capacity we have more effectively. ITS makes it feasible to provide a whole range of road transportation services and policies that were previously not technically or economically possible: road pricing, regulatory compliance, broadcasting of safety bulletins, on-board navigation, traffic flow monitoring, and environmental impact monitoring.

ITS offers many potential advantages to its different users and stakeholders:

- To the population as a whole ITS will improve the safety of our roadways resulting in fewer human tragedies and less demand on the medical system.
- To the commercial user ITS provides a direct savings in travel time and vehicle operating cost that can be easily shown to provide a high economic payback. Commercial users are expected to be the first major user of ITS and, through the improved economics of their operations, will sustain and improve the competitive position of Canadian Products in world markets.
- To the taxpayer ITS provides long term savings in the cost of road building and maintenance, which by itself could justify investment in ITS.
- To the Canadian electronic industry ITS provides a major new market opportunity with positive inputs to the Canadian economy and employment.
- To the consumer ITS can provide less stress and shorter travel times particularly in the heavy traffic commuting period.
- ITS will contribute to lower fuel consumption and lower air pollution.

Scope and Objectives

The Policy and Coordination Group of Transport Canada commissioned this Benefit-Cost Study to report on the economic and social benefits that selected Intelligent Transportation Systems offer Canadians relative to their costs of deployment. An understanding of the magnitude of the potential benefits and the associated cost of ITS implementation is essential for the various ITS applications. The objective of this report is to quantify these potential benefits through an exploratory analysis of the economic payoffs achievable through implementation of selected Intelligent Transportation Systems applications in Canada.

A major difficulty with the quantification of the benefits is the absence of empirical data demonstrating the cause and effects of ITS in the transportation sector. Few ITS projects have been completed in North America to allow for a detailed cause and effect analysis. Complicating the analysis further is the fact that unlike other Transport Canada Benefit-Cost studies routinely conducted for other transportation systems, in which the analysis of incremental changes in demand and supply provides 'hard engineering numbers', a similar exercise for ITS is far more difficult. While engineering is an 'exact science, the analysis governing changes in travel behaviour, made possible through the intervention of ITS, relies much more on the 'behavioural sciences' where professional expertise is required to allow analysts to make informed assumptions about anticipated causal effects.

As a result, the decision was made by the Steering Committee of the study to engage three individual transportation consultants with an expertise in transportation and ITS to undertaken an analysis of anticipated benefits and costs focusing on three of the seven ITS application areas namely:-

1. Inter-Urban Freight;
2. Advanced Rural Transportation Systems; and
3. Advanced Urban Transportation Systems.

The study team identified 38 opportunities in which the individual ITS applications may be applicable in Canada. From these a smaller set of applications likely to be of higher priority in Canada was selected for the benefit/cost analysis. The criteria for selection included: implementation costs; monetary benefits; other benefits; likelihood of implementation; program necessity; compatibility; technology availability; and coverage. The process filtered down the list to the 8 ITS applications identified below. The selection process and the resultant ranking of the identified ITS applications are described in the relevant sections of this report.

ITS Applications Selected for Benefit-Cost Analysis

Inter-Urban Freight 6 Opportunities Screened	**Rural Transportation** 20 Opportunities Screened	**Urban Transportation** 12 Opportunities Screened
Electronic Clearance Automated Roadside Safety Inspection	Traveler Information Electronic Transactions Rural Safety	Traffic Management Information Services Demand Management

Interurban Freight

i) ***ELECTRONIC CLEARANCE*** will facilitate the electronic check of safety, driver / passenger / vehicle / cargo credentials, and size and weight data for Dedicated Short Range Communications (DSRC)-equipped vehicles before they reach an inspection site. Illegal or potentially unsafe vehicles can then be identified and stopped for inspection. Legal and safe vehicles will be allowed to travel at mainline speeds past inspection sites and without stopping for compliance checks at ports-of-entry. Electronic clearance focuses on delays at border crossings and other inspection stations to avoid congested traffic conditions. It is targeted at all trucks, particularly those involved in daily repeat crossings. It is expected to be implemented at many border crossings between CANADA - U.S. and U.S. - MEXICO, at road-side stationary and mobile inspection using 2-way DSRC to equipped vehicles only.

ii) ***AUTOMATED ROADSIDE SAFETY INSPECTION*** systems will provide for roadside detection of an abnormal safety status indicator in vehicles approaching the inspection station at main line speeds, with much faster and more reliable inspections of vehicles called in, and effective follow-up with carriers and drivers on violations identified. This module focuses on effectiveness of safety inspections at stationary and mobile roadside stations with congested (commercial) traffic conditions. It is targeted at all commercial vehicles, particularly those with safety-related problems.

Rural Transportation

iii) ***RURAL TRAVELER INFORMATION*** systems provide information to motorists of adverse travel conditions (e.g. weather, construction, incidents, as well as other hazardous situations such as rock slides etc.) before they are encountered by allowing travelers to avoid hazardous situations or be prepared to encounter them thereby reducing the number and severity of accidents and other incidents. Also to provide travelers with real-time schedule/ operations information for rail, air, marine and bus services; to provide guidance and information/schedules for local tourist attractions thereby allowing travelers to plan trips, avoid delays and minimize overall travel time; and to distribute information on weather conditions to motorists, maintenance crews, emergency response personnel, etc. In all cases, information can be provided pre-trip or en-route in the vehicle.

Data would be collected from road surface condition sensors, weather condition sensors, road users (by cellular phone, CB radio, etc.), road maintenance and police patrols, closed circuit television cameras or special sensors (e.g. avalanche/rock slide detectors) for critical areas, transportation system and tourist attraction operators. Data from these sources would be processed into reports for dissemination, either locally or at a central facility.

iv) ***RURAL VEHICLE ELECTRONIC TRANSACTION*** systems are comprised of two modules; Electronic Toll Collection and Border Crossing Clearance. In the Electronic Toll Collection component of Rural Vehicle Electronic Transaction Systems the toll levy is transacted electronically (e.g. using Automatic Vehicle Identification/ classification and Vehicle-Roadside Communications Technologies) which permits time savings for highway users and reduces the toll collection cost for the operating agency. Electronic Toll Collection could be implemented at rural sites, bridges and tunnels connecting the United States and Canada, various other major bridges and tunnels as well as ferries.

Border Crossing Clearance Systems allow declaration of travelers and goods prior to reaching the border and pass them electronically to border inspectors. The electronic transfer of information may use technologies such as automatic vehicle identification and thereby permit travelers to reduce time and stoppages currently typical at border crossings and allow governments to minimize the cost and maximize the efficiency of border clearance systems.

Both modules involve the application of DSRC to exchange information between the vehicle and roadside equipment.

v) ***RURAL SAFETY*** systems are comprised of two modules; Portable Construction Zone Traffic Management System (TMS) and Intersection/Railway Crossing Collision Avoidance.

The Portable Construction Zone Traffic Management System provides monitoring of construction zone conditions and informs motorists of lane restrictions, delays, queue locations, etc. before they are encountered.

Intersection/Railway Crossing Collision Avoidance provides motorists with consistent advance warning of conflicting traffic at roadway intersections and railway grade crossings. Detectors placed on the intersecting facility detect the speed and direction of approaching vehicles or trains. As a DSRC-equipped vehicle approaches the intersection / crossing, its speed is measured and a local processor calculates whether a collision is possible. The driver of the DSRC-equipped vehicle is given an audible/visual warning, as a supplement to existing traffic control devices, if a collision could occur. They could be implemented at rural highway sections with a history of intersection and/or grade crossing collisions to reduce the frequency and severity of accidents and other incidents.

Urban Transportation

TRAFFIC MGMT, OPERATIONS AND CONTROL (TMOC) PACKAGE is comprised of Incident Management and Traffic Control modules.

vii) vi) Incident Management provides a capability for detecting and responding to incidents. It will help safety officials to quickly and accurately identify incidents and to implement a set of actions to minimize the effects of these incidents on the movement of goods and people. It would be installed along all major roadway links with main emphasis on the freeway network in metropolitan regions and medium/ large urban areas.

Incident response involves automatic selection from pre-planned responses including; emergency dispatch, inter-agency coordination (police, emergency services, tow trucks) and, driver advisory (diversionary routes).

Traffic control maximizes utilization of available freeway and arterial network capacity through the use of real-time information and coordinated traffic management and control strategies and equipment. It would be implemented along all road network links with main emphasis on freeway and arterial networks. It uses a number of advanced technologies and software for the detection and classification of vehicles.

TRAVEL AND TRAFFIC INFORMATION SERVICES (TTIS) PACKAGE provides travel related information to drivers after their trips have begun. It is composed mainly of two sub-services Route Guidance and Traveler Services Information:

viii) Route Guidance provides travelers with instructions/directions on downstream traffic/transit maneuvers and how to best reach their destinations. It relies on real-time information which is used to derive a suggested route that is displayed on an in-vehicle/personal display device. This module focuses on maximizing the use of the transportation system capacity and improving travel conditions.

ix) Traveler Services Information provides traveler with access to information regarding a variety of travel-related services and facilities. This information will be accessible to the traveler at home, in the office and while en-route either in a vehicle or at public facilities and transit terminals. It provides real time information where available but otherwise can use scheduled information.

TRANSPORTATION DEMAND MANAGEMENT the major objective of TDM is to modify transportation demand to more closely match existing capacity rather than moderate or otherwise reduce transportation demand. The modification to the transportation demand by TDM primarily effects the vehicle trips taken and not the person trips taken.

The Transportation Demand Management (TDM) application package, consists of two primary modules - *Road User Pricing* and *HOV Preferential Treatments* -

- *Road User Pricing*: Introduces a road user pricing mechanism which facilitates the setting of user charges and price differentials based on time, location and distance of travel and based on vehicle type.
- *HOV Preferential Treatment*: Introduces preferential treatment of High Occupancy Vehicles (HOVs) / Multiple Occupancy Vehicles (MOVs) which offer priority and exclusive access and rates to car / van / bus pools, taxis with passengers, and public transit, all equipped with AVI-POOL tags, over all Single Occupancy Vehicles (SOVs) / Low Occupancy Vehicles (LOVs) and trucks at critical locations within the urban expressway / arterial / street and parking systems.

The two modules are highly complementary as they provide both *incentives* (faster / cheaper / more convenient travel and parking for people in pool vehicles & faster / more reliable transit service) and *disincentives* (additional charge during the most severe congestion periods).

Methodology for the Benefit /Cost Evaluation

Given the limits of the existing empirical data base, and the resources available for this project which precluded the development of a more comprehensive data base, this analysis relied on the 'sketch planning method' to explore causes and effects that link benefits and costs. The sketch planning method lays out the associated benefits and costs of an ITS application, and traces and measures their impact to achieve a benefit-cost ratio.

Using the sketch planning method, baseline values for the overall benefits and service provider costs for each of individual applications were calculated for existing localized sections of the highway infrastructure. Where available the sketch planning method uses current traffic statistics applicable to specific sections of highway. The baseline results were then extended to the national level using appropriate multipliers.

Long term, 10 year, projections of stable ITS market penetration levels were used as a basis for estimating the aggregate user cost of implementation. The penetration levels range from 25% to 55% in an urban environment and 12% to 33% in a rural environment. The actual penetration values used in the analysis reflect the distribution of vehicle types and the expected usage by these different vehicle types. These values reflect a voluntary implementation by vehicle owners. Whether an economic argument can be made for mandatory fitting of ITS equipment in vehicles was beyond the scope of this analysis.

The baseline values for Inter-Urban Freight were determined for the St. Clair & Detroit River border crossing from a previously conducted study of this crossing. Automated Roadside Safety Inspection analysis was based on the provincial level distribution of existing weigh stations.

Baseline Rural Benefit-Cost were evaluated for three different sites: a 302 km section of the Trans-Canada highway from Sault Ste. Marie to Sudbury (Rural Traveler Information Systems); toll facilities at the Peace Bridge and along a 38 km. section from the QEW to Fort-Erie (Rural Vehicle Electronic Transaction Systems); and a 205 km. section of the Trans-Canada highway from Revelstoke and Kamloops in British Columbia.

Baseline Urban Benefit-Cost were evaluated for three sites all within Greater Toronto: a 34.8 km. stretch along the Highway 403/QEW corridor in Mississauga (Traffic Management); a 144.8 km. Section along Highway 403/QEW corridor in Mississauga (Information Services); and the entire region of Greater Toronto Demand Management was also based on the Toronto Metropolitan area and extrapolated to other metropolitan areas.

Summary of Findings

National Implementation

The following table, shows in detail, the benefits and costs of the selected 8 ITS applications at the National level. The table distinguishes ITS service provider costs from ITS in-vehicle costs. While Total Benefits aggregate user and service provider and society benefits, two additional benefit-cost ratios are provided to distinguish Benefit-Cost ratios for transportation users and for the service provider manager. Italicized values for both costs and benefits apply to travelers only. Time savings were categorized as traveler benefits. All benefits and costs are annualized. Capital costs are discounted using an annual rate of 10 percent over 10 years. Operating and maintenance cost are added to give the total annual costs. Annualized benefits were estimated in the final 10th year of operation. Traffic growth was estimated to increase by 1% per annum. No transitional costs or benefits were considered.

Table 1- ITS Benefit-Cost Results Canada-Wide Implementation

	Inter-Urban Freight		Rural Transportation			Urban Transportation		
	Electronic Clearance	Roadside Safety Inspection	Traveler Information	Electronic Transactions	Rural Safety	Traffic Management	Information Services	Demand Management
Annualized Costs (in $millions)								
Service Provider Costs								
Capital	3.3	1.6	22.3	7.7	45.5	212.2	51.6	38.4
O&M	2.0	1.3	13.7	5.8	10.4	147.4	58.3	51.3
Sub-total	5.3	2.8	36.1	13.5	55.9	359.6	109.9	89.7
Vehicle Costs								
Capital	4.3	123.9		1.7			369.6	23.1
O&M		7.6						0.0
Sub-total	4.3	131.5	0.0	1.7	0.0	0.0	369.6	23.1
Total Costs	9.6	134.3	36.1	15.2	55.9	359.6	479.5	112.8
Annualized Benefits (in $ millions)								
Time Savings	13.0	36.3	58.5	3.1	3.8	2050	630	39.6
VOC	0.06	5.7	5.8	0.6	0.8	63	13	13.8
Safety		53	1.0		58.3	81.	54	14.4
Other		7.7	26.0	15.8	0.4	128	27	156
Total Benefits	13.0	102.7	91.2	19.5	63.3	2322.0	724.0	223.8
Benefit-Cost Ratios								
Overall B/C Ratio	1.35	0.76	2.66	1.27	1.12	6.46	1.51	1.98
Service provider and society B/C Ratio	1.26	23	0.77	1.18	1.05	0.4	0.6	0.31
User B/C Ratio	1.51	0.27	N/A	1.82	N/A	N/A	1.78	8.4

The results of the benefit/cost assessment at the national are shown for individual ITS applications in graphical form in Figures 1and 2 below. Figure 1 shows the Benefit/Cost ratios applicable to each application and Figure 2 shows the benefits and costs in monetary terms. In Figure 1 the conservative values reflect the lower values obtained from the sensitivity analysis and the optimistic value the highest values obtained from in the sensitivity analysis. For clarity only the baseline values are shown in Figure 2.

Figure 3 illustrates the actual benefits in terms of travel time reduction reported for a number of ITS implementations in North America. A similar range of values is reported for other ITS performance measures such as accident reduction and productivity. The performance values used in the assessment of benefit/cost in Canada have used values in the lower range of reported values as shown in Figure 3. These values are more likely to be appropriate to a national level implementation as considered in this report and presented in Figure 1. For a more selective implementation, performance values towards the upper range of values shown in Figure 3 could be anticipated. This would result in benefit/cost ratios approximately 2:1 greater than those presented in the report.

Figure 1 Benefit /Cost ratios for selected Canada wide ITS Applications

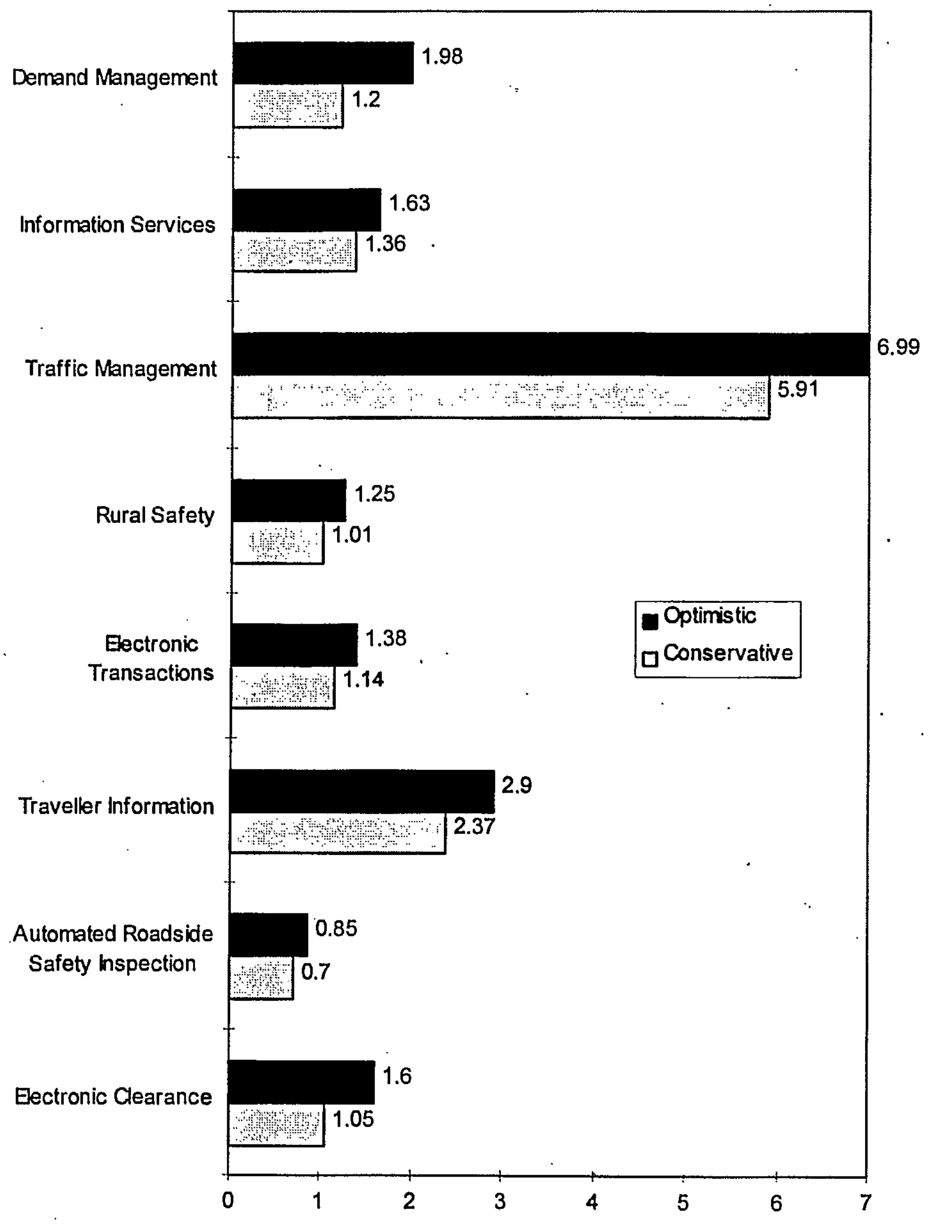


Figure 2 - Monetary Value of Benefits and Costs

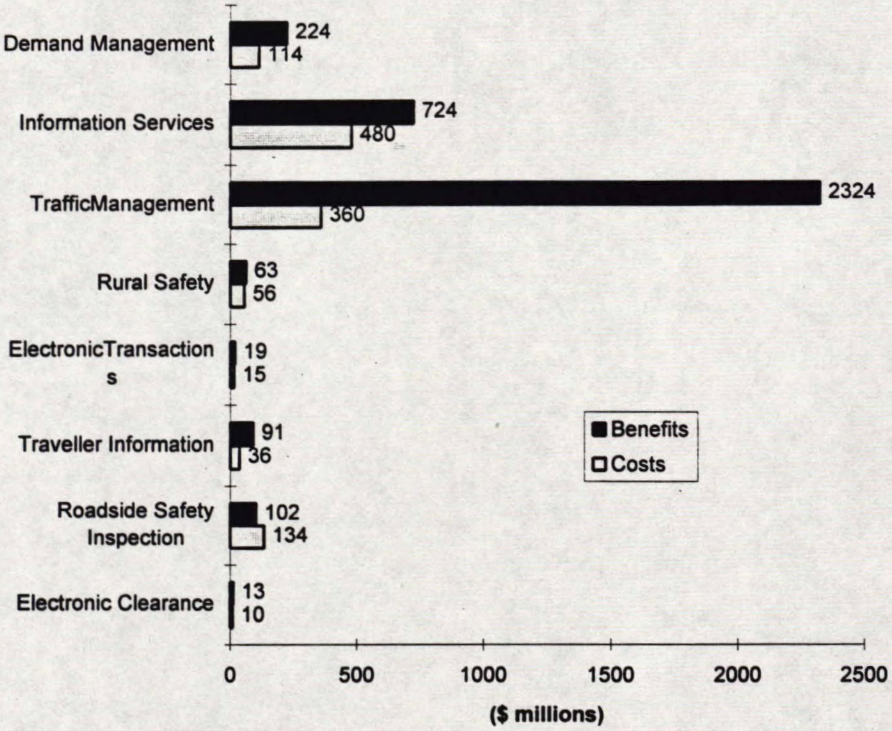
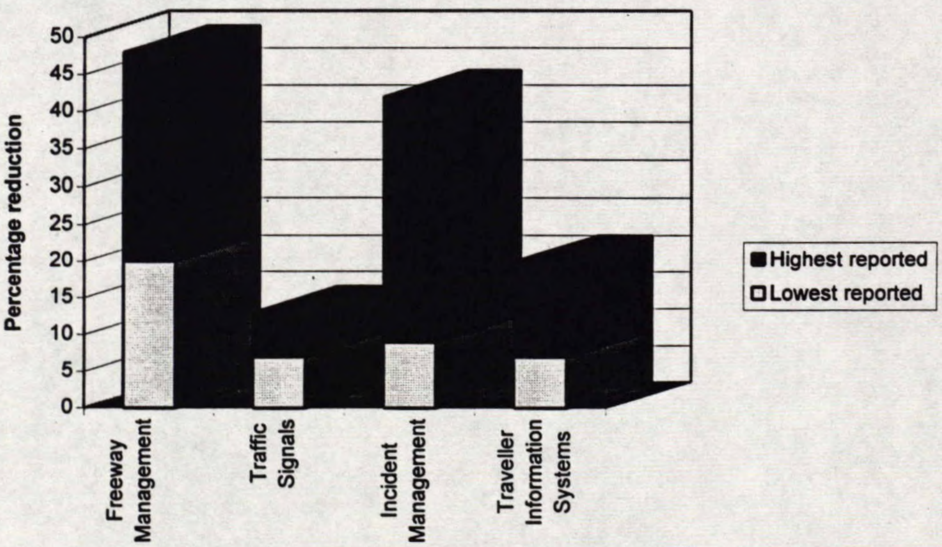


Figure 3 Reported Travel Time Reduction



The reader is cautioned that placing too much emphasis on the absolute values presented above could lead to a misleading interpretation that many of the applications represent marginal promise. This is due to the fact that the benefit-cost ratios as calculated represent only those benefit factors that can be reasonably estimated or extrapolated from other data. The benefits are therefore considered to be conservatively estimated since they do not include other potential benefits the value of which cannot quantified with any degree of confidence at this time. Furthermore, while the costs are based on current values, the cost of several of the electronic elements is expected to follow current trends and decline by the time of widespread implementation. In almost all cases the anticipated cost reduction of 50% results in a corresponding increase of the benefit cost ratio.

According to the findings shown above, Urban Transportation (Traffic Management) offers the greatest promise for Canadian applications with a benefit cost ratio of 6.5:1. The benefit cost ratio for this application was not found to be particularly sensitive to any one input parameter. Traveler Information, Electronic Clearance and Roadside Safety Inspection were also found to have significant benefit /cost ratios in excess of 2.3:1 even under the most conservative assumptions. The analysis also shows that Demand Management can provide a high benefit/cost ratio but in this case the benefit /cost ratio achieved is highly dependent on the pricing policy adopted and can be varied over a significant range. The high value of 1.98:1, shown above, represents a fairly aggressive policy while the low value of 1.2 :1 was achieved when a more moderate pricing policy was assumed.

In seven of the applications, those that used local corridors for the assessment of cost and benefits, the benefit/cost ratio on the local corridor exceeded the national level benefit/cost ratio by a factor of 1,1 to 1.5. This clearly illustrates the advantage to be gained from selective implementation.

Synergistic Cost Savings

Another consideration is the manner in which costs for the application areas were assigned. In the initial analysis all applications were considered on a stand alone basis. In practice however much of the in -vehicle and roadside equipment is multifunctional and would be shared between several ITS applications. The impact on the benefit/cost ratios from cost savings due to a few of these synergistic combinations is shown below.

Potential synergistic cost savings can occur when more than one ITS application is implemented in the same coverage area. Based on the applications analyzed in this cost benefit study a number of applications were considered to have potential synergistic cost savings primarily due to the use of common equipment either at the roadside or in the vehicle. The potential impact due to these cost savings were assessed by examining the overall benefit cost ratios due to a simple summation and due to a synergistic combination for the following combinations of ITS applications:

- Interurban freight Electronic Clearance with Interurban freight Roadside Safety Inspection due to the vehicle use of a common in-vehicle transponder for Dedicated Short Range Communications.
- Interurban freight Electronic Clearance with Rural Electronic Transactions due to common service provider equipment at border crossings and toll booths.
- Urban Traffic Management with Urban Traveler Information and Urban Traffic Demand Management due to the common use of traffic surveillance and monitoring equipment.
- Rural Electronic Transactions with Rural safety systems due the common use of in-vehicle transponder for Dedicated Short Range Communications.

The results are summarized in Table 2 and indicate that, of the groupings considered, only the synergistic combination of the three urban ITS applications results in significant improvement in the benefit/cost ratio.

Table 2 - Benefit Cost Ratios With and Without Synergistic Cost Savings

Applications	Summed Benefit /Cost Ratio	Synergistic Benefit Cost Ratio
Electronic Clearance with Interurban Freight - Roadside Safety Inspection	**0.82**	**0.85**
Electronic Clearance with Rural Electronic Transactions	**1.31**	**1.66**
Urban Traffic Management with Urban Traveler Information and Urban Traffic Demand Management	**3.6**	**4.0**
Rural Electronic Transactions with Rural Safety	**1.13**	**1.16**

NOTE : Due to the difference in quantities, the values shown should not be compared directly with the benefit cost ratios for the individual applications

Discussion of Results.

Inter-Urban Freight Transportation

Two ITS applications were investigated: Electronic Clearance and Roadside Safety Inspection.

- Electronic Clearance

  This report examined and quantified time savings as direct savings in operating costs for freight carriers, toll operators and customs departments. At 1.36 the benefit cost ratio to the freight carriers should encourage investment in this application even considering that it does not take into consideration the time value of transported goods. Similarly the positive benefit cost ratio of 1.21 achieved by toll and customs departments should encourage investment particularly as the roadside equipment can be used to process equipped private vehicles as well as commercial vehicles.

- Roadside Safety Inspection

  At a national scale, the benefit-cost ratio for Roadside Safety Inspection was 0.76:1. Time savings and improved safety accounted for 35% and 52% respectively of the total benefits. Future success of Roadside Safety Inspection will be driven by the ability of ITS promoters to induce commercial truckers to equip their vehicles with Roadside Safety Inspection equipment as more than 95% of the total annualized cost will be borne by the truckers. (The study estimated that in-vehicle costs for commercial trucking would be $1,690). If user and service provider and society benefits and cost were allocated against user and service provider, the user benefit-cost ratio would be marginal at 0.76:1 while the service provider and society benefit-cost ratio would be very substantial at 23:1

One major difference between these two applications is that the future success of Roadside Safety Inspection will depend on the ability of ITS promoters to induce vehicle owners to equip themselves with in-vehicle technologies. For both applications evaluated, the deployment of ITS technologies in Inter-Urban Freight applications represent significant benefits to freight carriers, shippers and as well, to other highway vehicles.

These finding indicates the need for Transport Canada to consider two initiatives:

1. Monitor the future cost of in-vehicle Roadside Safety Inspection equipment; and
2. Given the very large service provider and society benefit-cost ratio, explore means of inducing, or if necessary enforcing, commercial trucking firms to fit their vehicles with electronic roadside inspection equipment.

Rural Transportation

Three ITS applications were investigated:

- Traveler Information

  In contrast to other rural applications, the implementation costs of the Traveler Information application represent very low capital and operating costs and yet reach a very large group of motorists. This is reflected in the positive benefit-cost ratio of 2.66

  The most significant benefits derived from Traveler Information applications in rural Canada, is a net reduction in travel time and reduced fuel consumption. Together, these account for virtually all of the benefits (97%). While the service provider investment accounts for all of the costs, service provider and society benefits through improved safety and reduced emissions are marginal. An allocation of benefit-cost ratio to users cannot be determined since no costs for this particular Traveler Information package have been assigned to users.

  Due to the different nature of the applications investigated in the urban and rural areas a direct comparison of benefit /cost ratios between rural and urban areas is only possible for the Traveler Information systems. In this case rural application provides an aggregate benefit/cost ratio of 2.66:1 compared with urban benefit/cost ratio of 1.5 :1.0

- Electronic Transactions

  At a national scale, the benefit-cost ratio for Electronic Transactions is 1.27:1. 22% of the benefits accrue to individual travelers through travel time reductions and fuel savings Customs and Immigration benefits through productivity gains represent 75% of total benefits. Reduced emissions round out the benefits (3%).

This benefit-cost ratio calculation was derived by extrapolating a benefit-cost assessment at a specific site and then applying the findings to a national level. It is noteworthy that the benefit-cost assessment calculated for the study site, (appendix 2, part 2) shows a total annual benefit of $1.22 million versus an annualized cost estimate of $0.54 million representing a potential benefit-cost ratio of 2.3. This is a good example of how greater benefits may be obtained through selective implementation

At a national scale, aggregate user benefits from travel time reductions are impressive ($3.1M) and compared to the individual annualized cost($1.7M), the benefit cost ratio is 1.8:1. Whether this benefit-cost ratio is large enough to persuade individual travelers to equip their vehicles with in vehicle transponders units is difficult to determine because public perception of the value of time may differ substantially from the standard values used in this study.

- Rural Safety Systems

  At a national scale, the benefit-cost ratio for Rural Safety Systems is limited to 1.1:1. The benefit-cost ratio for this particular ITS application will improve significantly in response to future capital cost reductions for Rural Safety Systems technologies.

Overall the benefit-cost ratios for rural ITS implementation were marginal compared to the urban and inter-urban transportation application areas. Service provider costs in rural Canada generate smaller gain given the low vehicle miles traveled in these sparsely populated regions. There is strong agreement however, that improved benefit-cost ratios can be achieved at particular sites having higher than average rural traffic volumes and/or incidents. It is concluded that "site specific" benefit-cost assessments should be the first step in implementing any rural ITS application.

The Terms of Reference for this study assumed full implementation of ITS at a national scale, ignoring transitional effects. It is very evident from this exercise that future ITS implementation in rural Canada, will not be nation wide but site specific.

However, the anticipated unit cost of vehicular equipment of $700, which reflects current technology, is likely an over estimate and in time, the actual cost will decline in real terms. A 50% reduction in in-vehicle costs would increase the benefit-cost ratio to 3.5:1.

Societal level benefits due to Traveler Information Services will only accrue if a sufficient number of the general public use the service to modify their travel and hence reduce traffic congestion. Consumer driven ITS technologies such as Traveler Information Services are however more likely to be affected by perceived consumer values rather than any rigorous benefit cost analysis. The Benefit-Cost analyses are based on the standard monetary values society assigns to these benefits. Whether these values are reflective of individual traveler preferences is unclear. As a result, one cannot accurately forecast the consumer response to the cost and benefits of in-vehicle equipment and determine, with any certainty, whether private benefits would be sufficient to induce sufficient vehicle owners to equip themselves with Information Services. As only the level of public response will determine whether the societal benefits due to Information Services are achieved, (i.e. congestion reduction with the attendant benefits of travel time savings, averted or deferred infrastructure capital investments, reduced emissions, and decreased fuel consumption) it is desirable that a campaign be conducted to increase public awareness of these benefits.

- Travel Demand Management

Of all the ITS applications, the Travel Demand Management package is the most sensitive to fluctuations in benefit-cost ratios because it relies on road pricing to effect changes in travel behavior. The objective of this application is not however to generate revenues, or reduce demand for transportation, but to effect changes in travel behavior and reduce the dependence on the automobile for transportation by increasing the attractiveness of alternative modes and /or times of making transportation trips.

The benefit-cost ratio of TDM is between 1.8 to 2.9:1 for the study area Toronto which reduces to 1.2 and 1.98 respectively when expanded to the national level. Such ratios can be adjusted seemingly at will, by increasing or decreasing the tolls imposed by the metropolitan region.

The nation level reduction in emissions produces an annualized benefit of $39.8 million and is one of the most important benefits attributable to Transportation Demand Management

Demand Management can also reduce or postpone the need for highway capacity expansion. However, the options considered in this study , did not allow this linkage to be considered. As a result, the benefits from demand management are shown as the consequences avoided from deteriorated levels of service not as a reduction in the costs incurred to maintain levels of service

BENEFIT/COST ASSESSMENT OF

INTELLIGENT TRANSPORTATION SYSTEMS

IMPLEMENTATION IN CANADA

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ABBREVIATIONS

AM/FM Amplitude Modulated/Frequency Modulated
ARSI Automated Road-Side Safety Inspection
AVI Automatic Vehicle Location

B/C Benefit / Cost

CVO Commercial Vehicle operations
CRT Cathode Ray Tube
C & I Customs and Immigration

DSRC Dedicated Short Range Communications

EMI Electromagnetic Interference
EC Electronic Clearance
ETA Estimated Time of arrival

FHWA, Federal Highways Administration

GPS, Global Positioning System

HOV High Occupancy Vehicles
HAR Highway Advisory Radio

ITS Intelligent Transportation Systems

LED Light Emitting diode
LOV Low Occupancy Vehicles

MOV Multiple Occupancy Vehicles

O & M Operation and Maintenance

RDS Radio Data System

SOV Single Occupancy Vehicles

TMS Traffic Management System
TMOC traffic Management, Operations and Control
TDM Transportation Demand Management
TTIS Travel and Traffic Information Services

VOC Volatile Organic Compounds

1.0 INTRODUCTION

In many parts of the world, traffic congestion is a frequent problem that is experienced on a large number of the urban and interurban roads. The economy's dependence on transportation, restrictions on land use and the lack of funds necessary for significant expansion of the road network has led many governments to consider other means by which surface transportation can be made more efficient. The use of Intelligent Transportation Systems(ITS) is regarded by many transportation authorities as an essential component of any sustainable infrastructure capable of satisfying future transportation needs. In a number of countries, including Canada , ITS technologies are now considered to be of strategic importance.

In the U.S., it has been estimated that ITS allows the capacity of the existing infrastructure to be upgraded at a fraction, some estimates indicate less than 30%, of the cost of new highways of equivalent capacity. Furthermore ITS allows the increased capacity to be distributed over a wide area, rather than restricted to the area serviced by new roads or additional lanes on existing roads, thereby allowing it to be responsive to traffic conditions at any location.

While the level of current Canadian ITS activities does not proportionately match that of the major ITS players, there is nonetheless a solid body of work which is underway at the present time. These activities are taking place at various levels of government and in the private sector. One hundred and sixty seven active ITS projects were reported in a recent Canadian survey.(Parvianen & Associates)

To date those ITS functions that have been implemented in Canada have been implemented to help solve specific problems for which the benefits versus cost could be readily demonstrated. It is predicted that the potential economic benefits of ITS will be greatly enhanced through the synergistic combination of many of the 30 identified ITS functions and their expansion to the national level.

The objective of this study is to provide an exploratory assessment of the net economic payoffs associated with the implementation of key Intelligent Transportation Systems applications across Canada. Furthermore, important public policy and regulatory issues that need to be addressed in order to facilitate deployment of ITS, will be identified.

The study was undertaken as part of Transport Canada's program to undertake research, development and demonstration projects in surface transportation that provide input to the process of developing transportation policies. Further, this study complements the objectives of the Transportation Development Centre to investigate system innovations that will improve mobility and increase the efficiency of road transportation, particularly through the application of electronics, computers and communications technologies.

A chart showing the flow of main activities within the study is presented in Figure 1 (note that, the chart presents the main activities for the Urban Sector).

For purposes of this study, ITS applications have been broken down into three broad groups:

- **Interurban Freight,** movements by truck, including intermodal linkages;
- **Rural Transportation,** including intercity travel by road and intermodal passenger linkages;
- **Urban Transportation,** including both non-business and commercial users of the transportation infrastructure

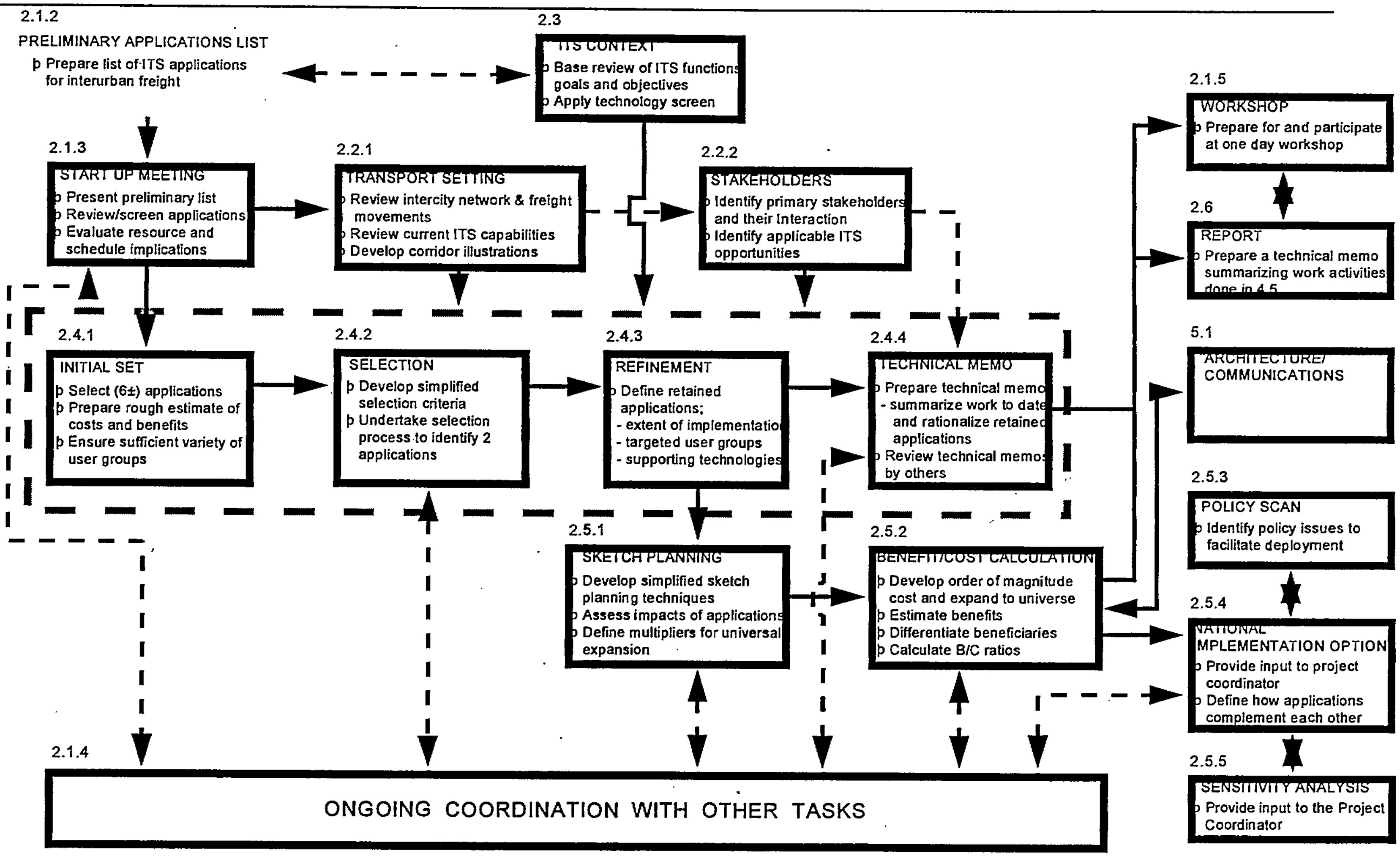
This document provides background to the initial list of application areas investigated, within the above grouping, and defines the features of each of the applications. The main objectives of the ITS applications are also summarized and the functions of each are identified.

The document reports on the screening process utilized to screen applications from further consideration and the results of the benefit/cost assessment of the most promising applications selected through the screening process.

As with any new technology, or a new application of an existing technology, there is a great deal of uncertainty as to the degree of success that will be achieved in the open market place. We lack the knowledge about the willingness of people to purchase the ITS equipment and/or services, and the manner in which people may use them. For the applications considered, it has been necessary to make assumptions which reflect just one possible course of development. Perhaps the most difficult assumption to justify relates to the public acceptability of some of the applications and the limitations they place on people. In the case of ITS we lack empirical data for models through which a detailed behavioural analysis could be performed. In light of the above uncertainties and the lack of suitable data applicable to ITS; a simplified Sketch Planning Technique was used.

As presented in this report the results of this sketch planning technique appear to have a high precision. The reader is cautioned that this apparent high precision is due only to the analytical tools used. In practice the accuracy of the assumptions and the input data allow the absolute values for the benefits and costs to be assessed only as a rough order of magnitude. However, since many of the same assumptions and data are used for a number of the applications examined, the relative assessments are considered to be accurate to within 25% or better.

ITS BENEFIT/COST ASSESSMENT-INTER-URBAN FREIGHT - 9/24/96



2.0 STUDY APPROACH

2.1 Sketch Planning

The unifying characteristic in sketch planning methods is that they are quick-response, cost and time-saving ways of assessing impacts of transportation proposals. They are particularly well-suited for illustrating travel behavior changes and their benefit/cost consequences when innovative applications of new technologies are being considered.

By using simple-to-follow work-sheets, sketch planning methods allow readers to follow the logic flow and repeat mathematical exercises that reflect and measure incremental changes in travel behavior as a direct result of new technology applications. There are no hidden 'algorithms' based on 'calibrated past relationships' with or without 'correction factors', churning out results within computer programs that then would be untraceable. The method emphasizes the professional and personal judgment of experienced planners and researchers about the likely, order-of-magnitude consequences of ITS applications.

The ITS benefit-cost assessment models were developed to permit others to 'revisit' the analysis when the assumptions about travel behavior can be modified to reflect the experience gained from deployed ITS applications

For each of the ITS application groups, a simplified sketch planning process was applied to estimate benefit/cost ratios for nationwide implementation. The general steps in the process were:

- generate a preliminary list of ITS applications relevant to the application group;
- identify criteria for screening the preliminary list in order to obtain a smaller group of applications for benefit/cost assessment (list of criteria and their interpretation is shown in Table 2.1, see page 8);
- apply the screening criteria to the preliminary applications list, ensuring that the retained applications represent all major ITS goals and the most critical relevant objectives, while providing for a sufficient number of user groups and travel purposes;
- refine the definition of the retained applications sufficiently to enable benefit/cost assessment;
- select a representative study site for the retained applications;

- develop a sketch planning technique as a basis for B/C estimation;
- estimate benefits and costs of implementation of each ITS application for its representative study site;
- scale up the study site benefits and costs to provide an illustrative, order of magnitude estimate for implementation of the complete ITS application group on a national scale.
- calculate benefit/cost ratios for implementation of each of the ITS application groups nation wide;

Following completion of this process, a sensitivity of the benefit/cost ratios to changes in key variables was investigated.

Since the study is intended to be only an "exploratory assessment" of ITS benefits and costs, a number of simplifying assumptions were made as the sketch planning process was carried out. The major assumptions were:

- study sites represent average conditions for ITS implementation in terms of benefits and costs;
- benefit/cost ratios provide a 'snap shot' of conditions 10 years in the future, assuming 1 % growth in traffic per year over the intervening years;
- benefits and costs are assessed using current road and traffic conditions as the base case (i.e. no geometric, capacity or traffic condition improvements made prior to or in conjunction with the ITS implementation);
- benefit/cost assessment is based on full implementation of all ITS applications;
- transition effects are ignored.
- A 1% annual growth rate was applied over 10 years to the estimated national benefits to take into consideration background growth in traffic volumes.
- The capital costs were estimated for each of the modules within each urban ITS application group on a sample corridor basis.
- For fixed equipment the total capital cost was annualized based on a 10% discount rate applied over a 10 year period. For in vehicle equipment the discount rate applied over a 7 year period.

- The annual operating and maintenance cost was calculated for each module within each ITS application group. Where available, separate O

& M costs were used, otherwise annual O & M cost were assumed to be 10% of the capital cost.

- All costs were calculated in constant 1996 dollars and were not adjusted to account for inflation. B/C ratios are reported for both base year and year 10.
- The benefits due to reduction in emission are converted to equivalent monetary units using the values \$ 33 / tonne for carbon dioxide, \$1000/tonne for carbon dioxide and \$5000/ tonne for VOC and NOx .

Note: The estimates of societal cost due to automotive emissions differ widely, the values used in this study are therefore representative values based on guidelines provided by Environment Canada

In addition, data used as input to the sketch planning process was obtained only from existing literature and the professional experience of the project personnel. No new benefit/cost data was generated for the purposes of the study. Base data on highway network mileage, AADT's, total travel (vehicle-km), etc. was obtained from available sources such as: a spreadsheet prepared by Transport Canada for a national O-D study, MTO's Traffic Volume Annual Report

Input data and assumptions specific to individual ITS application groups are detailed in the corresponding sections of this report.

2.2 Screening

In North America 29(recently increased to 30) ITS applications are generally recognized. Some of these have been implemented while others are undergoing research and testing, and some are still in the conceptual stage.

In developing the ITS applications for this Study, the application selection was oriented towards those applications that have been implemented or undergoing testing in all parts of the world with most happening in the USA and Canada.

An initial list of potential applications for ITS were identified and presented to the steering committee at which time they were discussed and screened in preparation for a more detailed screening process as documented in the relevant sections of the report.

Each of the application areas was investigated and detailed in relation to a number of factors. These factors included the following:

1. Main objectives related to the specific ITS application;
2. The applicable conditions and road environments for each application;
3. The primary users and stakeholders involved in the urban passenger and goods movements;
4. Typical functions within each of the application areas;
5. The different ITS features and potential technologies to be utilized in each application; and
6. Areas where the proposed application could be implemented.

The criteria shown in table 2.1 were used to select those ITS applications best suited for Benefit /cost analysis in Canada at this time. In all cases the criteria were given equal importance and the total score for each application is a simple, unweighted, sum of the individual scores.

TABLE 2.1 SCREENING CRITERIA

CRITERIA	INTERPRETATION
Implementation Costs	Relative ranking of overall costs • installation + operation + maintenance
Monetary Benefits	Relative ranking of overall savings • operating + maintenance cost savings for direct and indirect users • savings due to deferral in construction of new conventional facilities
Other Benefits	• Road user safety improvements (direct users + others) • Compatibility with environmental goals: reduced emission & spills • Favourable industrial impacts: Canadian product opportunities
Likelihood of Implementation	Probability of realisation of this package in its "full glory" • proper implementation, including required marketing activities, etc. to secure acceptance and safe adaptation
National Program Necessity	Importance of a national ITS program for overcoming institutional constraints/barriers • organizational mandates, bureaucratic inertia & politics likely to prevent/delay implementation of this package
Compatibility	• Compatibility with ITS demos and anticipated follow-up in U.S. • Complementary with other likely winner applications
Availability of Technology	Is it already mature enough for full implementation within the 10-year time frame
Coverage	Application range, fairness and equity in reaching/capturing/engaging majority of road users (e.g. freight commodities & carrier types & service types affected)

The application of the criteria shown in Table 2.1 to each of the ITS applications under the three broad ITS groups (Interurban Freight, Rural Transportation and Urban Transportation) is covered in the relevant sections of the report.

2.3 Future Penetration

2.3.1 Penetration by Vehicle Category

The accrual of benefits for most ITS applications is contingent on vehicle owners equipping their vehicles with specialized equipment. To ensure that the evaluation of all ITS applications is based on a consistent view of the future, assumed future penetration rates of all ITS equipment were developed for the year 2005. They are all based on the assumption that ITS would be made on a voluntary basis; in other words, ITS equipment would not be mandatory for vehicles. These assumed penetration rates were broken down by vehicle type, level of functionality and highway operating environment. The assumed ITS equipment penetration rates reflect the collective wisdom of the three consultants. It should be understood that they are subject to significant uncertainty, as it is always difficult to predict with accuracy the long term market response to new services.

The size of each of the vehicle classes was estimated (as indicated below) as a percent of the total private /commercial categories of users. These percentages were estimated based on a number of general information sources as outlined in Appendix D.

The automobile category (89% of all vehicles) breaks down into the following classes of automobiles:

1- taxis and Limousines (5%)

2- rental cars (3%)

3- company leased cars (15%)

4- luxury cars - excluding a, b & c above (15%)

5- all other automobiles (62%)

For the purpose of calculating the value of time due to traffic delays the use of private vehicles was further sub divided between the time used for business (54%) and the time used for non business(46%).

The commercial user category (11% of all vehicles) breaks down into of the following classes of registered vehicles:

1- school buses (1%)
2- other buses (1%)
3- emergency vehicles - ambulance, fire, tow trucks, etc. (0.5%)
4- municipal fleets - hydro, bell, gas trucks & vans included (1%)
5- light trucks - small trucks, couriers, commercial vans, pickups, etc. (78.5%)
6- medium trucks - 2 axles, dual rear tires (8.0%)
7- heavy trucks - 3 or more axles (10%)

Medium/heavy trucks categories represent all trucks with a gross weight greater than 4.5 tons.

2.3.2 Penetration By Functionality

Table 2.2 summarizes the expected penetration for each of the in-vehicle equipment categories for the year 2005.

The in-vehicle equipment assumed to be used by all users was divided into four categories according to their level of functionality:

Level 1 Functionality.

2-way communication DSRC module (e.g. TAG-type 2+, RDS unit). This provides the minimum capabilities for a vehicle to use electronic tolling and to receive audio announcements concerning information related to road and traffic conditions.

Level 2 Functionality.

Simple display device (e.g. single line LED, multi-colour LED, simple audio). In addition to the functions provided by level 1 this provides a minimal capability for display of information in alpha-numeric format

Level 3 Functionality.

Enhanced display device (e.g. CRT arrows, audio from text, heads-up display). In addition to the functions provided by level 2 this provides a graphical display for display of maps or route guidance directions.

Level 4 Functionality.

Data entry/recording & sending device (e.g. keypad/Function keys, on board sensors, card swipe). In addition to the functions provided by level 3 this provides for vehicle based entry of data for electronic clearance, automated safety inspection or for use as a vehicle traffic probe.

TABLE 2.2 ASSUMED PENETRATION FOR VARIOUS CLASSES OF IN-VEHICLE EQUIPMENT(SNAP SHOT VISION FOR YEAR 2005)

FUNCTIONAL LEVEL & EQUIPMENT DESCRIPTION	ASSUMED AVG. COST	URBAN		RURAL	
		COMM	AUTO	COMM	AUTO
1. 2-way communication DSRC module	$50	70%	55%	60%	33%
2. Level 1 plus a simple display device	$250	55%	40%	45%	25%
3. Level 1 plus an enhanced display device	$350	25%	25%	15%	10%
4. Level 3 plus data entry/recording and sending device	$1700	30%	25%	25%	12%

2.3.3 Penetration By Operating Region

Penetration rates for in-vehicle equipment were assumed for two highway operating environments - urban and rural sectors - in order to facilitate the estimation of benefits and costs associated with the implementation of ITS in Canada. These percentages are outlined in Table 2.3.

TABLE 2.3 PERCENT OF VEHICLES USING IN-VEHICLE (SNAP SHOT VISION FOR YEAR 2005)

% of Total	Vehicle Category	Percent of Vehicles Using In-Vehicle Equipment							
		Function Level (1)		Function Level (2)		Function Level (3)		Function Level (4)	
		Urban	Rural	Urban	Rural	Urban	Rural	Urban	Rural
	Automobiles (89%)								
5%	1. Taxis & limousines	100	50	100	50	100	20	100	50
3%	2. Rental cars	50	50	25	40	20	20	20	20
15%	3. Company leased cars	80	50	50	20	20	20	20	20
15%	4. Luxury cars	80	80	80	75	60	20	60	20
62%	5. All other autos	40	15	25	10	12	5	12	5
100%	Rounded total penetration	55%	33%	40%	25%	25%	10%	25%	12%
	Commercial Vehicles (11%)								
1%	1. Buses (school)	100	100	50	50	50	50	-	-
1%		100	100	50	50	50	50	-	-
0.5%	2. Buses (others)	100	100	100	100	50	50	50	-
1%	3. Emergency vehicles	50	50	50	50	50	50	50	50
78.5%		65	55	50	40	20	20	30	25
8.0%	4. Municipal fleets	90	80	70	70	40	30	40	30
10%	5. Light trucks/vans	90	80	70	70	40	30	40	30
100%	Rounded total penetration	70%	60%	55%	45%	25%	15%	30%	25%

2.4 *Pricing Trends*

To the extent possible pricing information used in this study reflects the prices currently quoted for similar equipment or systems. These prices may be subject to change as the technologies evolve and the market expands. Projection of long term costs are therefore subject to uncertainty.

For in-vehicle equipment, many observers predict that prices will drop dramatically. These predictions are based on comparison with equipments such as hand carried Cellular and GPS equipment. It should be noted however that the price reductions applicable to Cellular and GPS have been partly facilitated by the write off of R&D costs against service revenues and the development of other related applications. Technologically similar products such as Special Mobile Radio(SMR) radios have not been subject to the price reductions experienced by cellular radio.

For the somewhat more diverse requirements of ITS, the severe operating environment of vehicular equipment, packaging, electromagnetic interference (EMI) protection and thermal design are likely contribute as much to cost as that of the electronics. It is therefore unlikely that the cost reduction for ITS electronics will be as substantial as has been possible in cellular radio and GPS. The prices used in this benefit cost analysis reflect these pricing constraints and are therefore closely based on currently estimated prices as determined from the U.S. National Architecture Study and make only modest allowance for price reduction .

For the fixed infrastructure, much of the cost is driven by system design, system integration and equipment installation rather than equipment costs. These are all manpower intensive and are therefore likely to increase with time. This price increase will be partially offset by decreases in the cost of the electronic equipment. However the fixed items of equipment are not built in the extremely high numbers found for the in-vehicle equipment and hence price reductions can be expected to follow a more modest trend. A price fluctuation of around plus or minus 20% with respect to current prices is not unreasonable but prices outside of this range do not seem likely.

2.5 Communications Cost

For successful operation most ITS applications are dependent on some form of communications. The modes most likely to be used in the applications considered in this report are;

- Fixed (Wireline) communications between fixed elements of the architecture;
- Dedicated short range communications (DSRC) between the vehicle and the roadside elements of the architecture;
- Extended range two-way communications between the vehicle and the architecture; and
- Extended range one-way communications (Broadcast) from the architecture to the vehicle

A study, conducted under the guidance of the ITS Canada Communications Working Group, investigated specific requirements for communications against each of the ITS applications and the cost of the communications components. From a technical perspective the main cost driver was found to be the Fixed (Wireline) communications between fixed elements of the architecture. This was due to the high capacity required by the use of TV cameras for surveillance of the road network. Except for traffic management the applications selected for the study do not require the wide bandwidth of TV and the remaining costs of the fixed communication elements have been calculated assuming use of leased services from within the existing wireline infrastructure. Typically costs are $5,580 per year for a 9.6 kbps dedicated end-to-end datapac service. In an urban area cost are not sensitive to distance but in a rural area cost are 25% greater than in an urban area. Where applicable, the annual costs of leased communications services are included as part of the operating and maintenance cost of the infrastructure.

Depending on the location and the existing infrastructure at that location, either fibre optics, microwave or a combination of both can provide the most economical solution for wideband applications. In the long term it expected that , as has been found feasible in a number of U.S. installations, that communications capacity can be obtained on a near zero cost basis in exchange for the granting of longitudinal right of way along the roadway. Previously the right of way has been denied on the basis of safety considerations and traffic disruption during installation and maintenance. The cost of these wideband communications has therefore been assumed to be in line with dedicated copper wire facilities as provided by telecommunications service providers and is also included within the O&M cost of the infrastructure.

For Broadcast and DSCR communications the cost of the fixed stations can be shared between all of the many users and the effective airtime cost is estimated as $0.91 per month for private vehicles and $1.82 per month for commercial vehicles when considering all of the 29 ITS applications combined. It would be less for the ITS applications selected for the benefit /cost assessment . It is speculated that the airtime cost would be covered by advertising revenues or from a one time fee buried in the cost of the in-vehicle equipment. The primary cost for these modes of communications is therefore that due to the in-vehicle receivers, in the case of Broadcast and in-vehicle transponders (TAGS) in the case of DSRC. These cost have been included in the analysis of user equipment cost.

Extended range two way communications are most likely to be used in advanced traveler information applications in which a vehicle request specific information. This mode of operation is expected to be provided by means of existing mobile communications systems, either Cellular for public access systems or privately operated dispatch radio. The latter is expected to be used by many high value users such as emergency vehicles, local truck fleets and transit vehicles who already own and operate dispatch radio and would therefore not encumber additional airtime cost. For analogue systems they would however need to add a baseband modem in order to pass information in a digital form. Cellular based services would be subject to airtime charges. Based on expected maximum frequency of use this is estimated to cost less than $2.13 per month for private vehicles and less than $4.26 per month for commercial vehicles.

For the applications considered in this study extended range two way communications are not essential although they may be used by high value users who would also use the extended range two way communications for other communication purposes. For this reason they are not considered as a cost item within the benefit /cost analysis and only the cost of the basic DSRC and RDS broadcast receivers are used.

3.0 INTERURBAN FREIGHT

3.1 Development of Initial Set of ITS Applications

Interurban Freight is a specific application of the more generic ITS application of Commercial Vehicle operations (CVO). The National ITS Program Plan (US DOT & ITS America) defines CVO in six categories, all applicable to Interurban Freight, as follows:

- ELECTRONIC CLEARANCE , this service will allow enforcement personnel to electronically check safety, credential, and size and weight data for transponder-equipped vehicles before they reach an inspection site and then select only illegal or potentially unsafe vehicles for an inspection. Safe and legal vehicles will be able to travel without stopping for compliance checks at weigh stations, ports-of-entry and other inspection sites.
- AUTOMATED ROAD-SIDE SAFETY INSPECTION, this service will use safety data provided by the Electronic Clearance service combined with state-of-the-art technology to allow for more selective and rapid inspections. Through the use of sensors and diagnostics, inspectors will eventually be able to check vehicle systems and driver requirements and ultimately driver alertness and fitness for duty.
- ON-BOARD SAFETY MONITORING, this service will non-intrusively monitor the driver, vehicle and cargo and notify the driver and carrier - and, possibly, enforcement personnel - if an unsafe situation arises during operation of the vehicle. [e.g.: driver fatigue, vehicle systems, cargo shift]
- ADMINISTRATIVE PROCESSES, this service will allow freight carriers to exchange credentials and collect and report fuel and mileage tax information electronically. Through automation, this service should provide to carriers and States a significant reduction in paper work burden and has the potential for simplifying compliance operations.
- HAZARDOUS MATERIALS INCIDENT RESPONSE, this system will provide emergency personnel at the scene of a hazardous materials incident immediate information on the types and quantities of hazardous materials present in order to facilitate a quick and appropriate response.
- FREIGHT MOBILITY, this service will provide information links between drivers, dispatchers and intermodal transportation providers - enabling carriers to take advantage of real-time traffic information, as well as vehicle and load location information, to increase productivity.

3.2 Application Screening

The results of the screening process are presented in Table 3.1 The two packages retained for further development and the B / C assessment are *Electronic Clearance* (EC) and *Automated Road-Side Safety Inspection* (ARSI) - with total scores of 32 and 31 respectively.

TABLE 3.1 - INTERURBAN FREIGHT, SCORING OF APPLICATIONS USING SIMPLIFIED SCREENING CRITERIA

APPLICATION	DESCRIPTION (PURPOSE & ENABLING TECHNOLOGIES)	Implementation Costs	Monetary Benefits	Other Benefits	Implementation Likely-Hood	Program Necessity	Compatibility	Technology Availability	Coverage	Total Score
1.ELECTRONIC CLEARANCE	Screen commercial vehicles for size/weight/safet compliance while they are moving at mainline speeds and provide electronic customs/immigration at transparent borders to reduce delays. [electronic tags / readers & WIM & database access & EDI]	2	5	2	5	5	5	4	4	32
2.AUTOMATED ROAD-SIDE SAFETY INSPECTION	Automate safety inspection activities in order to reduce inspection time and increase consistency o results. [diagnostic equipment & on-board recording devices & systems reader]	3	3	3	5	4	4	4	5	31
3. ADMINIS-TRATIVE PROCESSES	Provide motor carrier administrative functions electronically, i.e.: licensing, registrations, permits, fuel tax reporting, audits (via one-stop shopping). (electronic data and funds transfer & on-board comuters & vehicle/driver/cargo tracking)	4	2	1	5	4	3	5	4	28
4. ON-BOARD SAFETY MONITORING	Provide real-time monitoring of driver performance vehicle systems and loads to provide warnings to drivers of unsafe conditions. (driver/vehicle monitors & cargo condition monitors & collision warning systems)	4	2	4	3	3	4	2	3	25
5.HAZARDOUS MATERIALS INCIDENT RESPONSE	Provide incident response teams rapid access to information about hazardous cargo (class/dangers /handling) to enhance emergency response mgt. [automatic vehicle/cargo i.d. & carrier resident database & emergency mgt. network]	3	1	3	4	4	2	4	2	23
6.FREIGHT MOBILITY	Provide information links between drivers, dispatchers, intermodal terminals, freight consolidators, shippers/receivers, traffic mgt. centres to increase productivity. [mobile comm & vehicle tracking & computer-aided dispatch & in-veh displays]	3	3	2	2	2	2	3	5	22

3.3 Description of Retained ITS Applications

The ITS application packages of Electronic Clearance (EC) and Automated Road-Side Safety Inspection (ARSI), were selected for interurban freight sector as a result of the screening process. These two applications are briefly described below . Summaries of their main objectives, applicable conditions, primary users, functions, ITS features, and areas of applicability are provided in Tables 3.2a and 3.2b respectively. For ease of comparison they a more detailed breakdown is also presented in side by side tabular format in appendix 1A .

3.3.1 Electronic Clearance Package

This module focuses on reducing delays at border crossings and other inspection stations due to congested traffic conditions. This ITS service will implement and expand clearance mechanisms by allowing enforcement personnel to electronically check safety, driver / passenger / vehicle / cargo credentials, and size and weight data for DSRC-equipped vehicles before they reach an inspection site. Only illegal or potentially unsafe vehicles would then be stopped for inspection at ports-of-entry. Legal and safe vehicles will be able to travel at mainline speeds past inspection sites without stopping for compliance checks (or be entitled to expedited checks). Random checks would be maintained for enforcement integrity.

It is targeted at all trucks, particularly those involved in daily repeat crossings (e.g. 'just -in -time' and 'local' plant-to-plant shipments), long distance shipments (e.g. loads suitable for advance clearance via EDI) with a special road safety-related focus on main-line back-up (e.g. on freeways / bridges) plus abrupt maneuvers at entrances and plazas.

It is expected to be implemented at many boarder crossings between CANADA - U.S. and U.S. - MEXICO, at road-side stationary and mobile inspection stations using 2-way DSRC and some means of storing ,and electronically updating ,accreditation data. The accreditation data may be input via the DSRC, functionality level 1. Alternatively , if the vehicle hardware is upgraded to include displays, keyboards or swipecards, functionality level 4, it may be shared with other applications within INTERURBAN & URBAN freight transportation. This could include;

- access control at restricted facilities (terminals / yards, urban streets),
- ARSI (automated road-side safety inspection),
- on-board safety monitoring (of driver / vehicle / cargo condition and performance),
- administrative processes (credentials purchase and fuel / km reporting),
- hazardous materials incident response (vehicle itself & other incidents), and

- freight mobility package (real-time vehicle location and traffic information).

The vehicular equipment may also be used in the rural applications of;

- traveler information and assistance (road & weather & tourist & mayday),
- electronic transactions (border crossings & toll facilities) and
- safety (at grade crossings & construction zones).

Other urban applications include:

- travel / traffic information services,
- traffic management operations and control, and
- transportation demand management package:

3.3.2 Automated Roadside Safety Inspection Package

This module focuses on effectiveness of safety inspections at stationary and mobile roadside stations. This ITS service would allow enforcement personnel to obtain, and act on, real-time safety information about carriers, drivers, vehicles and cargo in an effective manner. These systems will provide for roadside detection at main line speeds of an abnormal safety status indicators in vehicles approaching the inspection station.. Where there is a large volume of commercial vehicles it will overcome the limitations of cumbersome manual inspection which is slow an unreliable. ARSI will provide for fast and reliable inspections of vehicles called in and will facilitate effective follow-up with carriers and drivers on violations identified. It is targeted at all commercial vehicles, particularly those with the appearance of having safety-related problems (to ensure thorough checks on all) or those with active out-of-service rulings or past violations (to catch and monitor poor performers and to ensure that remedial actions are taken)

It is expected to be implemented at roadside stationary and mobile inspection stations and share the same synergies as the **Electronic Clearance Package** discussed in paragraph 3.3.1.

TABLE 3.2 a - ELECTRONIC CLEARANCE (EC) - DESCRIPTION OF FEATURES

APPLICA-TION CATEGORY	MAIN OBJECTIVES	APPLICABLE CONDITIONS	PRIMARY USERS	FUNCTIONS	ITS FEATURES	AREAS OF APPLICABILITY
ELECTRONIC CLEARANCE	• Improve safety: check safety/credential/ size/weight data (reduce frequency of accidents) • Improve service level (increase throughput capacity of facilities) • Reduce energy/environmental impact (reduce stop&go and idling) • Enhance productivity (reduce travel times & operating costs) • Reduce stress (improve predictability of estimated Time of Arrival (ETA)	• Congested clearance fa-cilities & their access systems, with - processing delays - abrupt maneuvers - main-line back-up • JIT operations through border crossings and other inspection sites • freight logistics within NAFTA	• freight carriers (for-hire and private)) • Other road users (affected by faster /smoother processing of trucks) • Freight consolidators/for-warders & warehouses • Intermodal terminals • Customs agents/brokers • Shippers & receivers • Customs & immigration • Transport departments	• Maint. of databases • 1- and 2- way communications • information processing • vehicle & cargo/driver surveillance • Control & enforcement	• On-board computer (OBC) and smartcard • Vehicle-mounted transponder: AV/D/CI tag Vehicle-mounted transponder: AV/D/CI tag • Road side/facility interrogator unit (facilitating 2-way DSRC via inductive loop/RF/microwave/optical/infrared/surface-acoustic wave (SAW)/laser • Computer systems at border crossing plaza, broker, carrieer • Peripheral equipment: changeable message signs, video monitors, etc • ARSI (automatic road-side safety inspection equipment)	• Ports -of -entry (border crossings) • restricted access facilities • Other inspection sites (e.g. weigh stations)

TABLE 3.2 b - AUTOMATED ROADSIDE SAFETY INSPECTION (ARSI) - DESCRIPTION OF FEATURES

APPLICATION CATEGORY	MAIN OBJECTIVES	APPLICABLE CONDITIONS	PRIMARY USERS	FUNCTIONS	ITS FEATURES	AREAS OF APPLICABILITY
AUTOMATED ROADSIDE SAFETY INSPECTION	• Improve safety: check vehicle systems and driver requirements (reduce frequency of accidents) • Reduce energy/ environmental impact (identify pollution sources) • Enhance productivity:- reduce travel times & operating costs for carriers in compliance - inspect more vehicles & drivers • Reduce driver/owner stress (secured compliance with regulations through more effective enforcement)	• Congested inspection stations & their access systems • Special road safety cam-paigns (mobile insp. stations)	• Freight carriers (for-hire and private) • All other road users (affected by improved compliance with regulations by road freight carriers) • Transport departments • Emergency response teams	• Maint. of databases Maint. of databases • Control & enforcement • and 2-way communications • Information processing • Vehicle & driver surveil-lance/monitoring Control & enforcement	• In-vehicle sensors & on-board computer (OBC) (tie-in with on-board safety monitoring) • Vehicle-mounted transponder: • Road-side interrogator unit (facilitating 2-way DSRC via inductive loop/RF/microwave/optical/infra red /surf-acstc-wave(SAW)/laser) • WIM scales • Computer systems at inspection sites and on-board mobile units (tie-in with electronic clearance) • Peripheral equipment: vehicle classifiers, changeable message signs, video monitors, etc.	• Border crossings • National & provincial highways • Secondary highways

3.4 Benefit / Cost Assessment of Electronic Clearance

3.4.1 Introduction

This section summarizes the results of the detailed benefit/cost assessments for the implementation of *Electronic Clearance* capabilities in Canada and is presented in four sections as follows:

- Section 3.4.2: Toll Operations & Customs and Immigration (C&I) assesses the costs and benefits attributable to the crossing (toll) operator and to Customs and Immigration (C&I) due to installation of a transparent borders system
- Section 3.4.3: Truck Operations assesses the costs and benefits attributable to truck operators
- Section 3.4.4: B / C Performance combines the costs and benefits to arrive at an overall B / C ratio
- Section 3.4.5: Sensitivity Analysis reassesses the B / C ratio in light of possible Low and High values of selected variables.

For Electronic Clearance, the B / C assessment of the sample corridor was conducted using data applicable to the St. Clair & Detroit River crossings as provided in the Marshall Macklin Monaghan (et al) report of May 1994 (Ref 1). From this, the cost savings due to different volumes of truck traffic have been derived and the results used to scale up to the national level.

Since this case study considers the economic benefits to Canada. It is based on one-way crossings only and it assumes that the U.S. will be responsible for implementation, and will derive the equivalent benefits therefrom, for electronic crossings systems operating in the opposite direction. The U.S. and Mexico would be expected to implement a compatible system along their border, thereby extending similar benefits to long distance (Canada & Mexico) trucking operations at those crossings.

Among the stated goals (Table 3.2 a), this assessment will address the expected impacts either directly (i) or indirectly (ii) - within the limits of the selected sketch planning techniques - as follows:

a) Enhance productivity by reducing travel times and operating costs; extend operating radius within safe working hours.

b) Improve over-all freight logistics within / between NAFTA states
c) Improve service level by increasing throughput capacity of border and other inspection facilities.
d) Reduce energy / environmental impact by reducing stop & go and idling.
e) Improve road safety by checking driver hours / credentials / weight data to reduce frequency of accidents.
f) Reduce maintenance and rehabilitation cost of road infrastructure by enforcing weight limits.
h) Reduce driver / shipper / receiver stress by improving predictability of Estimated-Time-of-Arrival.

3.4.2 Toll Operations and Customs and Immigration (C&I)

(a) Impact of Truck Volumes and EC Penetration

For purposes of the following analyses it is assumed that a number of lanes are reserved for the handling of trucks. This reflects the current situation at most international borders. In time it is anticipated that electronic clearance lanes will allow a mix of truck and automobile traffic in which case the number of lanes would be adjusted to reflect the overall volume of traffic. However the total number of lanes required would be less than the sum of that required for the two (truck & automobile) requirements separately. T his allows some synergistic saving in implementation and operating cost.

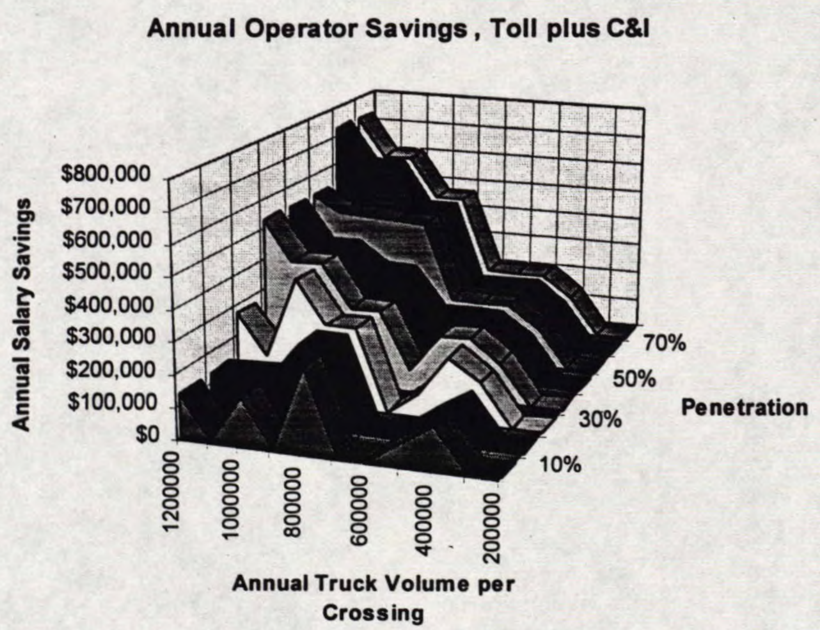
For the purposes of this analysis the total volume of two-way truck trips at a crossing was allocated to three eight hour periods in the day to reflect peak volumes of traffic
(60 %), medium volumes of traffic (30 %) and low volumes of traffic (10 %). It is further assumed that the majority of truck crossings occur during weekdays and that, as a result of the low volume of trucks, there would be no savings during weekends. From this the number of lanes required to handle the average peak hour truck traffic is calculated for both the toll operation and the C&I operation separately. This is based on the current manual operation and the average time required to process a truck at each booth.

A similar computation was then made assuming that a minimum of two manual lanes would be retained under Electronic Clearance[1]. The difference in the number of lanes required reflects the manpower savings. The daily manpower savings are calculated by summing the savings in each period.

The results of the analysis are shown in graphical form for various traffic volumes and EC-related (truck) equipment penetrations in Figure 3.4 a. From this it can be seen that at low penetrations the savings behave erratically with traffic volume. This is due to the fact that a minimum two lanes, one in each direction, would be manned. As the penetration level increases the savings tend to reflect a more linear relationship to traffic volume. Also it should be noted that as the penetration level increases above about 60 % there is very little increase in savings.

The analysis indicated that savings during periods of low volume such as would occur at night and during weekends would be insignificant. The annual savings were therefore based on savings during weekday operation only. The estimated savings assume annual salary for toll booth operators of $ 35 000 and for C&I inspectors $ 65 000. These salaries were multiplied by 1.2 to reflect overall cost to the operator.

FIGURE 3.4 a - ANNUAL SAVINGS IN OPERATOR COST: TOLL + C&I



[1]) Manual lanes, or at least the equivalent manual processing on some automated lanes, will be required for the foreseeable future (not all vehicles will be equipped, neither trucks nor automobiles).

(b) Implementation Cost

The annualized cost of implementation and operation was calculated assuming an annual maintenance cost of 10 %, a discount rate of 10 % and an economic life of 10 years

TABLE 3.3 b - ELECTRONIC CLEARANCE IMPLEMENTATION COSTS AND 'AGENCY' B / C RATIOS

# of Electronic Lanes per Site	Implementation Cost	Annualized Cost	Salary Savings	'Agency' B / C Ratio
2 Lane Site	**$ 1,098,030**	**$ 288, 502**	**$161,561**	**0.56 : 1**
4 Lane Site	**$ 1,424,650**	**$ 374,320**	**$456,670**	**1.22 : 1**
6 Lane Site	**$ 1,742,274**	**$ 457,774**	**$553,906**	**1.21 : 1**

B / C ratios derived from the annual manpower savings (from Figure 3.4 a) are shown in column 5 of Table 3.3 b. Although these ratios (0.56 : 1 1.22 : 1 1.21 : 1) for 2 - 4 - and 6 - lane systems do not yet incorporate in-vehicle equipment costs (nor corresponding trucker benefits), they are useful in presenting a possible agency perspective for transparent border installations.

(c) Expansion to National Level

There are 13 interstate level crossings along the border between Canada and the U.S. Of these, it is assumed, 6 crossings handle one-way truck volumes in excess of 900,000 annually and require (6 electronic + 2 manual) lane operation and 7 handle truck volumes of 500,000 to 900,000 annually and require (4 electronic + 2 manual) lane operation. Nine of these crossings are associated with bridges or tunnels and typify the types of location at which toll collection is most frequently applied.

There are 21 crossings on principle highways that could handle truck volumes of 200 000 to 500 000 and require (2 electronic + 2 manual) - lane operation in peak hours. However, since these are shown to have a B / C ratio of less than 1, they are unlikely to be implemented and are not included in the analysis. Further, since it is unlikely that completely unmanned operation will be allowed, it is considered that the 59 rural crossings will be too small to justify the implementation of Electronic Clearance.

The total annualized cost of implementation of Electronic Clearance, Toll plus C&I on the 13 primary crossings is $ 5,367,000. The total annual manpower savings becomes $ 6,504,000 - resulting in a national 'agency' B / C ratio of 1.21 : 1.

3.4.3 Truck Operator Costs & Benefits

(a) Implementation Cost

It is assumed that trucks making frequent crossings (50%)will install equipment for functionality level 4 without the enhanced display at a cost of $1350. The remaining trucks will install equipment at functionality level 1 or 2. the average installation cost is therefore approximately $800. The annualized cost over a 7 year period is $164.00 . no allowance is made for maintenance as at this price it would be cheaper to throw away and replace. This is reflected in the 7 year discount period.

(b) Time Savings per Truck

The St. Clair and Detroit River crossings together handle nearly 25 % of the cross border truck traffic. The average saving in processing time was estimated at 90 seconds per crossing for trucks using EC.

A further saving in time stems from the reduction in queuing delays. Current queue delays were calculated based on the traffic volume at the bridge crossings to give an average queuing delay per crossing of 1.12 minutes. It is estimated that queuing delays would be reduced by 25 % to 50 %. The overall savings in time is therefore on average 106 to 123 seconds per vehicle per one-way crossing.

It should be noted that the average savings in time are used only for computational purposes as the real benefits of a savings of typically two minutes per one-way trip are probably not significant. What is significant is the savings that occur due to reduction in the frequency of long delays. A study of the distribution of delay and its impact on cost of trucking operations is outside the scope of this study.

(c) Cost Savings

The cost of truck operations - i.e. fuel cost plus the time related to the driver and the truck amortization - is $ 38.00 Canadian per hour (no allowance is made in this study for the value of the goods in shipment). This gives a total annual saving of $1.5 to $1.8 million for time savings of 106 and 123 seconds respectively.

The EC-related savings per truck are $(346 - 401) per year for trucks making daily crossings, $(77 - 89) per year for trucks making weekly crossings, and $ (18.50 - 21.50) per year for trucks making quarterly crossings..

Truck Fuel & Emissions - The fuel consumption reduction due to reduced idling and stop-and-go cycles is 454 ,075 L /year. The equivalent monetary value of fuel saved is already incorporated through the above $ 38 / h time rate of the fuel/driver / truck. The equivalent monetary value of the reduced emissions as a result of this fuel savings is $57,779 per year at the sample site.

Accidents - Because of the enhanced ability to check driver hours and credentials, and as a result of the reduction in driver stress (more predictable ETA), it is expected that there will be a reduction in accidents involving trucks (and other vehicles). However, since no reliable information was available to the study team to substantiate the expected benefits, they were not included in the benefit assessment.

Road Maintenance and Rehabilitation - Because of the enhanced ability to check truck weight data and to track carrier compliance information in general, there will be a reduction in the damage done to roads by over-weight trucks. However, for the purposes of this B / C assessment no estimate is prepared, nor benefits included.

Time Value of Goods - Although many Canadian companies rely on "just- in -time" and "continuous replenishment" concepts, the lack of empirical data related to the value of goods in transit precluded an assessment of the benefits due to a reduction in transportation delays arising from the use of EC

(d) Expansion to National Level

The study site carries approximately 25 % of all border crossing truck traffic. By assuming 95 % of the total traffic to be at crossings equipped with EC, the national savings were calculated by the use of a simple multiplier of (4 x 0.95) applied to the savings at the sample site. The national savings over all one-way truck crossings are therefore between $ 6.1 M and $ 7.1 M (average $ 6.6 M).

3.4.4 B/C Performance of EC

The overall costs and benefits that accrue at the national level due to the implementation of Electronic Clearance incorporate service provider and truck operations and are, together with corresponding B / C ratios, presented in Table 3.4. See appendix A2 for details.

TABLE 3.4 d - B / C PERFORMANCE OF ELECTRONIC CLEARANCE

	ANNUALIZED COST ($)	ANNUAL SAVINGS ($)	B/C RATIO
Toll Operations and C&I	5,367,000	6,504, 000	1.21
Truck Operations	4,780,000	6,500,000	1.36
Overall total	10,147,000	13,004,000	1.28

3.4.5 Sensitivity Analysis

The B / C ratio for EC implementation is sensitive to changes in several parameters:

- penetration rates for in-vehicle equipment (% trucks equipped)
- cost of in-vehicle equipment
- time values assumed for the driver, carrier and truck (tractor & trailer)
- cost of Electronic Clearance infrastructure.

The most uncertain factor in the B / C assessment of Electronic Clearance is the annual operator cost (toll and C & I) - as it changes with truck volumes and penetration rates (as illustrated in Figure 3.4). For the baseline assessment a penetration level of 60 % was assumed, see Table 2.2., Note that this level also represented the lowest stable level for which savings increase in unison with annual truck volumes; at this level, service provider cost savings appeared largely independent of penetration rate.

The sensitivity of the B / C assessment results to variations of plus and minus 20% in the values of selected parameters, is presented in Table 3.5.

TABLE 3.5 - SUMMARY OF SENSITIVITY ANALYSIS

PARAMETER	BASE VALUE	B / C AT - 20%	B / C AT BASE	B / C AT + 20%
Penetration Rate (in-vehicle equipment)	60%	1.05	1.28	1.47
Service provider & In-Vehicle Equipment Cost	various	1.60	1.28	1.07
Values for Time (trucking	$38/h	1.14	1.28	1.40

operations)				

3.5 Benefit / Cost Assessment of Automated Roadside Safety Inspection

3.5.1 Introduction

This B / C assessment summarizes the B/C assessment shown in detail in Appendix A for the implementation of *Automated Roadside Safety Inspection* capabilities in Canada. It is presented in four sections as follows:.

- Costs Section 3.5.2.
- Benefits Section 3.5.3.
- B / C Performance Section 3.5.4
- Sensitivity Analysis Section 3.5.5

Since this case study considers economic benefits to Canada, it is based on cost savings accruing to the operators of Canadian ARSI sites and to the Canadian freight carriers only. The U.S. is in the process of evaluating and implementing similar sites along major freeway corridors - which, in due course, will benefit Canadian freight carriers operating long distance trucking routes and having the required on-board equipment. These cost-savings are not included in this assessment.

Among the stated goals (Table A1 of appendix A) this assessment will address the expected impacts either directly or indirectly - within the limits of the selected sketch planning techniques - as follows:

- enhance productivity of carriers in compliance,
- reduce travel times and operating costs as a result of quicker inspections,
- extend operating radius while maintaining safe driver hours by allowing inspection by-pass for *Premier Carriers,*
- Improve road safety for commercial and other vehicles by reducing frequency of accidents,
- improve traffic safety law enforcement,
- simplify complex inspection tasks allowing inspection of more vehicles/drivers & increasing the detection rate for unsafe vehicles,

- provide real-time safety information about carriers, drivers, vehicles and cargo,
- improve on-board vehicle system monitoring,
- reduce energy / environmental impact due to:
- reduce energy consumption and harmful emissions,
- improve pollution source identification and ensure follow-up on remedial measures, and
- reduce number and severity of hazardous materials incidents.

3.5.2 Costs: Capital / Operating / Maintenance

(a) Service provider Costs (roadside installations)

Automated Roadside Safety Inspection is made up of many components. A representative list, presented in Table A2-4 of appendix A, is based on the components associated with roadside safety inspection in the U.S. National Architecture Study (Cost Analysis / Projections, April 96). Software and integration costs ($ 252,000) would apply to the first system only, dropping substantially thereafter; to illustrate this, $ 70,000 per system has been assumed. These components are likely to vary from site to site so as to reflect specific safety concerns applicable to the region. To reflect the lesser number of installations anticipated for Canada a conservative value for equipment cost has been used.

Expansion to National Level - For the purposes of assessing the national level cost it was assumed that installations would be made at an equivalent number of sites as are currently used for permanent weigh stations. The number of weigh stations installed in Canada (184) was obtained from the provincial data shown in Appendix 1.0 Table A2-5. (Source: Telephone survey, 15.2.96).

The cost of installation and operation will vary based on the complexity of each system. For purposes of this benefit-cost analysis a mix of system installations - allowing one quarter of each type - was assumed. This resulted in installation (I) and *operating (O)* costs as presented in Appendix 1.0 Table A2-7. The over all capital cost of roadside systems across Canada was assessed as $ 10,796,200. The replacement life varies between 10 and 20 years. Assuming an average of 12 years under Canadian conditions, the annualized cost (using 10 % discount rate) is $1,584,486 plus an annual operating cost of $1,079,620 for a total of $2,853,166.

(b) Vehicular Cost

Vehicle equipment required for operation compatible with roadside safety inspection includes on-board trip and cargo monitoring modules. Estimates for installed costs are based on the U.S. Architecture Study cost analysis (April 1996):

On-Board Trip Monitoring (per vehicle)

DSRC Tag	$100
Onboard cargo monitoring sensors and computer	$1,200
Mileage and Fuel Reporting Sensors	$250
Trip computer	$140
---------------------------	----------
Total	**$ 1,690**

Expansion to National Level - The application of greatest concern is heavy trucks of which there are estimated to be 500 000 operating in Canada. Assuming that 90% of all heavy trucks (see table 2.2) are fitted with trip and cargo monitoring, the total capital cost is: $ **760,500,000**.

Based on a 10-year replacement life, the annualized cost were calculated as $123,901,670. Annual operating costs for this equipment, expected to be low, were estimated at $**7,605,000**, or 1% of the capital cost. The overall annualized implementation costs of vehicular equipment is therefore $131,506,000.

3.5.3 Benefits

Benefits from the use of Automated Roadside Safety Inspection are expected to arise from:

- reduced delays for trucks
- reduced fuel consumption and (CO + NOx + VOC) emissions for trucks
- reduced costs for road maintenance and rehabilitation
- lower accident rates due to more effective inspections and the parallel safety / compliance campaign
- lower staffing cost for roadside inspection stations.

(a) Reduced Truck Delays

Reduced truck delays would accrue due to the greater efficiency of electronic inspection. No definitive figures are available for truck delays at inspection / weigh stations. The following numbers, although considered reasonable, are therefore provided more as an illustration of what may be possible:

- assume average truck delay reduced, conservatively, by 3 minutes per inspection (note: during congested periods, complete by-pass by premier carriers would save significantly more)
- total length of freeways and significant truck corridors is 24 000 km. Based on a map analysis it was estimated that 50% of inspection stations are located to these freeways and truck corridors therefore the average separation of inspection / weigh stations is 260 km
- annual average distance traveled by trucks is 44 448 km. (Ref.: Royal Commission Report, Vol. 4 / Table 4.1)
- average (avoidable) weigh station stops per year 42.5
- annual delays are 125.5 min. per truck, at a saving of $82.75 per truck

The total annual saving to all trucks using the major freeways is $36,337,500. Additional savings to trucks at inspections stations on other roads will be incurred but were not evaluated within the scope of this study.

(b) Truck Fuel & Emissions

The equivalent monetary value of the reduction in total annual truck fuel consumption is already incorporated through the $38 / h allocated for fuel/drivers time / truck amortization.

The equivalent monetary value of reduced emissions is $11,367,000 savings per year, see Appendix A.

(c) Accidents

Heavy trucks were estimated to be involved in 30 000 accidents including 3 % of serious accidents which cause 9 % of fatalities. Assuming that 10% of these truck accidents were caused by safety infractions and that 50% of the safety related accidents were eliminated, the total annual value of injuries and fatalities in truck related road accidents would be reduced by: $53,000,000.

(d) *Other Cost Savings*

Inspection Costs - For the purposes of this assessment, it was assumed that Automated Roadside Safety Inspection would result in a saving of one person year per station. The annual savings over 184 stations was $7,728,000.

Road Maintenance and Rehabilitation - Because of the enhanced ability to check truck weight and condition, there is expected to be a reduction in the damage done to roads by trucks with excess weight and worn-out / broken suspensions. However, for the purposes of this B / C assessment no estimate was prepared, nor benefits included.

(e) Total Benefits

A summary of the annual benefits due to the implementation of ARSI follows:

reduced truck delays (incl. reduced fuel consumption)	$36,337,500.
reduced truck emissions	$5,683,500
reduced accidents	$53,000,000
reduced staff cost for inspection stations	$7,728,000
T o t a l (salary+benefits)	***$102,700,000***

3.5.4 B/C Performance of ARSI

The value of direct benefits of *$102,700,000*, as calculated using the assumptions above, results in a benefit /cost ratio of 0.76:1

3.5.5 Sensitivity Analysis

The B / C ratio for ARSI implementation is sensitive to changes in several parameters, i.e.:

- cost of ARSI service provider
- in-vehicle equipment cost
- penetration rates for in-vehicle equipment (% trucks equipped)
- average annual distance traveled by trucks
- proportion of inspection stops considered avoidable
- time value assumed for trucking operations
- proportion and types of accidents eliminated
- discount rate adopted & life-cycles assumed.

The most uncertain factor in the B/ C assessment of Automated Roadside Safety Inspection is the reduction in the number and type of accidents that can be credited to improved inspections, tracking and enforcement of carrier performance on safety related matters, and the complementary road-safety / compliance campaign. As a baseline for the assessment, 10% of truck accidents were assumed to be safety related. It was then assumed that a 50% reduction in safety related accidents to give a net reduction of 5% in truck related accidents.

The sensitivity of the B / C assessment results to variations of plus and minus 20% in the values of selected parameters, is presented in Table 3.6.

TABLE 3.6 - SUMMARY OF SENSITIVITY ANALYSIS

PARAMETER	BASE VALUE	B / C AT - 20%	B / C AT BASE	B / C AT + 20%
Penetration Rate (in-vehicle equipment)	90%	0.76	0.76	0.75
Accident reduction assumed	5%	0.66	0.76	0.85
Values for Time (trucking operations)	$38/h	0.7	0.76	0.82

Penetration Rate - With ± 20 %, the penetration rate of 90 % changes to 72 % and '108 %'. The latter, although incorrect per se, is utilized to illustrate the effect of a modest penetration beyond the 1 / 2 M heavy trucks (i.e. some light trucks also being so equipped).

3.6 Discussion of Results

Two ITS applications were investigated: Electronic Clearance and Roadside Safety Inspection. The comparative results are shown in table 3.7

Table 3.7 Summary of Results for Inter-Urban Freight

	Costs and Benefits ($ millions)	
	Electronic Clearance	Roadside Safety Inspection
Service Provider Costs		
Capital	3.3	1.6
O&M	2.0	1.3
Sub-total	5.3	2.8
Vehicle Costs		
Capital	4.3	123.9
O&M		7.6
Sub-total	4.3	131.5
Total Costs	9.6	134.3
Annualized Benefits		
Time Savings	$6.5+$6.5	36.3
VOC	0.06	5.7
Safety		53
Other		7.7
Total Benefits	13.0	102.7
Overall Benefit-Cost Ratio	1.35	0.76
Service Provider. B/C Ratio	1.26	23
User B/C/ Ratio	1.51	0.27

- Electronic Clearance

  This report examined and quantified time savings as direct savings in operating costs for freight carriers, toll operators and customs departments. At 1.53 the benefit cost ratio to the freight carriers should encourage investment in this application even considering that it does not take into consideration the time value of transported goods. Similarly the positive benefit cost ratio of 1.33 achieved by toll and customs departments should encourage investment particularly as the roadside equipment can be used to process equipped private vehicles as well as commercial vehicles.

- Roadside Safety Inspection

  At a national scale, the benefit-cost ratio for Roadside Safety Inspection was only 0.76. Travel time reductions attributed 58% of total benefits and improved safety contributed 39% of total benefits. Automatic Roadside Safety Inspection shows a high benefit in terms of reduced accidents and, if this results in commensurate reductions in insurance premiums, the benefits to truck operators would be comparable to their cost. Unless vehicle equipment prices decline, more than 95% of the total annualized cost will be borne by the truckers and not the transportation service provider. (The study estimated that in-vehicle costs for commercial trucking would be $1,690). When the safety benefits are allocated to society rather than the truck operator , the societal benefit-cost ratio would be very substantial at 23:1. This finding indicates the need for Transport Canada to commit to two initiatives:

  1. Monitor the future cost of in-vehicle Roadside Safety Inspection equipment;
  2. Given the very large service provider benefit-cost ratio, explore means of inducing, or if necessary enforcing, commercial trucking firms to equip their vehicles.

4.0 RURAL TRANSPORTATION

4.1 Development of Initial Set of Rural ITS Applications

The set of 29 ITS applications, see Ref. 5 of Appendix D, was reviewed to identify a preliminary list (20) of the ITS applications potentially useful in the rural environment (see Table 4.1). An initial investigation of each of the applications identified was carried out to obtain information on the following points:

- primary and secondary ITS user services provided by the application
- targeted user groups;
- goals and objectives of application implementation
- key ITS functions and technologies which would be incorporated into the application;
- rural areas where the application could potentially be implemented;
- existing similar initiatives in Canada or the United States.

The results of the investigation are summarized in Table B1 of Appendix B.

TABLE 4.1 - PRELIMINARY APPLICATIONS LIST - RURAL

Application Description	Potential Applications	Existing Similar Initiatives
Hazardous Road Condition Warnings	Ont. Hwy 400, Transcanada Highway Sections (variations Pre-Trip/In-Vehicle)	• BC Avalanche Warning System • TRAVEL-AID, Washington State
Intermodal Traveller Information Systems	Rail, Air, Marine Terminals e.g. Victoria Ferry (variations Pre-Trip/In-Vehicle)	• PROMISE, Europe
Road Availability/Accessibility in Arctic	Seasonal Roads in North	
Tourist Information Kiosks	Gas Stations, Rest Areas, Community Centres on Transcanada Highway (variations Pre-Trip/In-Vehicle)	
Park Traveller Information Systems	Visitor Guide, Traffic Advisory, Reservation System for Banff	• Yosemite, California
Collision Avoidance @ Intersections/Railway Crossings	At-Grade Crossings On Transcanada Highway, Remote Intersections	• Smart Signal System, NJ
Animal Crossing Warning System	Along Transcanada Highway sections prone to migratory patterns of large animals	
Remote Incident Detection	Located on known, accident prone sections of heavily travelled rural roads e.g. Highway 400.	• TRANSMIT, Washington, D.C. • Reach-75
Portable Construction Zone Traffic Management System	Bridge reconstruction/rehabilitation on Transcanada Highway	• Intelligent Work Zone TMS, Minn.
Border Crossing Pre-Clearance System	Key U.S./Can. border crossing points e.g. Peace Bridge	• operational tests on U.S. Boarder • NITEC
Road Weather Information System	Sections of Transcanada Highway prone to adverse weather	• Arizona, Wyoming, Idaho, I-75 Fog Warning, RWIS, Minn.
Ridesharing/Ride Match ing Program	Large rural employers	
Ferry Electronic Payment and Reservation System	Manitoulin Island Ferry	
Transit/Emergency/Maintenance Vehicle Monitoring/Scheduling	Emergency/Maintenance Vehicle Monitoring on Transcanada Highway Sections	• ARTIC, Minn. • Smart Bus
Rural Taxi Monitoring and Control System	Air/Rail Terminal Access	• Pearson • Winnipeg
Electronic Toll and Traffic Management	Highway 407, PEI Fixed Link	
SmartCard Tech. for Rural Transit	Rural transit operators	• Ajax • Mississauga
Call Box Systems	Heavily Travelled Transcanada Highway Sections	• Many Interstate Sections
Intercity Bus with On-Board Safety/Advisory Systems	New vehicle components	• VORAD, Voyageur IVSAWS

4.2 Application Screening

The results of the screening process are presented in Table 4.2 The 'total score' for each application package is a simple, unweighted, sum of the individual scores. A total of 9 rural ITS applications were retained following the screening process. These applications were grouped into three categories:

- Rural Traveler Information Systems:
  - Hazardous Road Condition Warnings
  - Intermodal Traveler Information
  - Tourist Information Kiosks
  - Road Weather Information Systems
- Rural Vehicle Electronic Transaction Systems:
  - Electronic Toll Collection
  - Border Crossing Pre-Clearance System
- Rural Safety Systems:
  - Portable Construction Zone Traffic Management System
  - Intersection/Railway Crossing Collision Avoidance

TABLE 4.2 RESULTS OF SCREENING RURAL APPLICATIONS

Application	Implementation Costs	Monetary Benefits	Other Benefits	Likelihood of Implementation	National Program Necessity	Compatibility	Availability of Technology	Coverage	Total Score
Hazardous Road Condition Warnings	3	2	5	4	3	5	5	5	32
Portable Construction Zone Traffic Management System	4	3	4	4	2	5	5	5	32
Border Crossing Pre-Clearance System	2	3	4	4	5	5	5	4	32
Intermodal Traveller Information Systems	4	3	3	5	3	5	5	3	31
Tourist Information Kiosks	5	2	3	3	3	5	5	5	31
Road Weather Information System	3	2	5	4	2	5	5	5	31
Electronic Toll & Traffic Management	3	3	3	4	4	5	5	4	31
Intersection/Railway Crossing Collision Avoidance	2	2	5	3	3	5	4	5	29
Park Traveller Information Systems	2	2	2	4	3	4	5	3	25
Ridesharing/Ride MatchingProgram	4	3	3	3	2	3	5	2	25
Ferry Electronic Payment & Reservation System	3	3	2	4	2	5	5	1	25

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Application	Implementation Costs	Monetary Benefits	Other Benefits	Likelihood of Implementation	National Program Necessity	Compatibility	Availability of Technology	Coverage	Total Score
Transit/Emergency/Maintenance Vehicle Monitoring/Scheduling	3	3	3	3	2	4	5	2	25
Mayday/Emergency Request System	1	2	4	3	2	5	3	5	25
Call Box Systems	2	1	4	3	1	4	5	5	25
Remote Seasonal Road Availability/ Accessibility	1	2	3	3	2	4	4	5	24
Remote Incident Detection	1	2	4	3	1	5	3	5	24
Intercity Bus with On-Board Safety/Advisory Systems	3	2	3	3	2	5	5	1	24
Rural Taxi Monitoring and Control System	4	3	2	3	1	4	5	1	23
Animal Crossing Warning System	2	2	4	2	2	3	2	5	22
Smart Card Technology for Rural Transit	3	3	2	2	1	4	5	1	21

4.3 Description of Retained ITS Applications

Brief narrative descriptions of the application groups retained are presented in the following pages. For ease of comparison they are also presented in a side by side tabular format in Appendix B .

4.3.1 Rural Traveler Information Systems

Rural Traveler Information Systems provide information to motorists, emergency response teams and maintenance crews of adverse travel conditions (e.g. weather, construction, incidents, rock slides etc.) before they are encountered. This allows travelers to avoid hazardous situations, or be prepared to encounter hazardous situations before arriving at them, thereby reducing the number and severity of accidents and other incidents. Also, they provide travelers with route guidance, real-time schedule/operations information for local tourist attractions, rail, air, marine, and bus services , thereby allowing travelers to plan trips, avoid delays and minimize overall travel time. In all cases, information can be provided pre-trip or in-vehicle.

Data would be collected from road surface condition sensors, weather condition sensors, road users (by cellular phone, CB radio, etc.), road maintenance and police patrols, closed circuit television or special sensors (e.g. avalanche/rock slide detectors) for critical areas, transportation system and tourist attraction operators. Data from these sources would be processed into reports for dissemination, either locally or at a central facility. Information would be distributed through some or all of the following channels:

- commercial television or radio (pre-trip);
- highway advisory radio (HAR) or commercial radio (in-vehicle voice only);
- in-vehicle display devices (not included for B/C assessment);
- road-side computerized information kiosks;
- changeable message signs at entrances to monitored roadway segments (road and weather condition advisories only).

The service provider and vehicle equipment implemented for Rural Traveler Information Systems can be used synergistically to provide benefits in other ITS applications in the following manner.

- DSRC and in-vehicle display useful for other applications within Rural Transportation as well as a variety of Interurban Freight, Urban and Other ITS applications;
- Communications system could be used for Rural Safety Systems, Interurban Freight and other ITS applications;
- Changeable message signs, HAR and kiosks can be used by Rural Safety Systems;
- Information from Urban Traveler Information Systems can be provided to rural travelers destined for urban areas, and information from Rural Traveler Information Systems can be provided to urban travelers destined for rural areas;
- Data collected for Rural Safety Systems can be used for Hazardous Road Conditions Warnings;
- Rural Traveler Information Systems improve conditions for efficient interurban freight transportation.

Assumptions

Key assumptions applicable to Electronic Tolling as used in the B/C assessment include:

- The base case for Electronic Tolling is full manual tolling. In other words, the evaluation assumes that the decision to implement tolling on the baseline highway has already been made.
- For the purposes of this evaluation, it has been assumed that pre trip information would be used and, except for HAR, in-vehicle data would only be used in combination with other ITS applications.
- All vehicles are equipped with an AM/FM radio and hence can receive voice messages via HAR broadcasts.
- Intercity AADT and total travel (vehicle-km) data provided by Transport Canada include only vehicles traveling end to end over a roadway segment; effects of local traffic are represented by a 50% increase applied to the base numbers.

- Other assumptions (e.g. percentage of travelers using a service) are detailed in the B/C assessment input data included in Appendix B.
- For the Hazardous Road Condition module, construction work is assumed to be representative of other, more difficult to quantify, hazardous road conditions;

4.3.2 Rural Vehicle Electronic Transaction Systems

Rural Vehicle Electronic Transaction Systems are comprised of two modules; **Electronic Toll Collection** and **Border Crossing Clearance.**

In the Electronic Toll Collection component of Rural Vehicle Electronic Transaction Systems the toll levy is transacted electronically (e.g. using Automatic Vehicle Identification / Vehicle-Roadside Communications Technology) which permits time savings for highway users and reduces the toll collection cost for the operating agency. Electronic Toll Collection could be implemented at rural sites throughout Canada, including the Northumberland Strait Bridge, Highway 407 in Ontario, bridges and tunnels connecting the United States and Canada, various other major bridges and tunnels as well as ferries.

Border Crossing Clearance Systems allow declarations of travelers and goods prior to reaching the border and pass them electronically to border inspectors. The electronic transfer of information may use technologies such as automatic vehicle identification and thereby permit travelers to reduce time and stoppages currently typical at border crossings and allow federal governments to minimize the cost and maximize the efficiency of border clearance systems. Border Crossing Clearance Systems could be implemented at more than 20 major border crossing sites between Canada and the United States. The B/C assessment was conducted using the Peace Bridge toll and border crossing operation connecting Fort Erie, Ontario with Buffalo, New York.

Both modules involve the application of Vehicle to Roadside Communications (DSRC) to exchange information between the vehicle and roadside equipment. For electronic toll collection: highway operators fund the implementation of roadside equipment (e.g. AVI card readers) communications systems and a central system (hardware and software) to facilitate electronic funds transfer. This may also require the involvement of the financial community, to act as credit providers and fund holders, integrated with the various other financial instruments and accounts to which travelers would have access. In the case of the border crossing systems federal departments (occasionally coupled with bridge/tunnel commissions) would be responsible for the implementation of highway/roadside infrastructure, communications and central systems. Central systems requires interfaces with customs and immigration systems and with other federally supported systems such as truck safety, commercial vehicle registration, etc.

On-Board Vehicles Automatic Vehicle Identification / Vehicle-Roadside Communications transponder tags, Type II+ (read-write capability with three-colour LED display) would be required to support these modules. Other on-board equipment could include smartcard readers for tracking revenue (for toll collection) or personal identification (for border crossing). The simple display of the Type II+ transponder or other in-vehicle audio capabilities may be used in the vehicle to advise motorists of transaction difficulties in respect to toll collection or electronic clearance in the border crossing application. Roadside license plate reader systems are typically required by for both modules for enforcement purposes. Communications systems are required to communicate both video and data from field equipment to a central location. At the control centre both hardware and customized software are required for each application. Monitors, communication switching equipment and communications equipment for links with external information sources would also be required.

The service provider and vehicle equipment implemented for Rural Vehicle Electronic Transaction Systems can be used synergistically to provide benefits in other ITS applications in the following manner.

- This group of applications could provide the in-vehicle equipment necessary to provide traveler information to the drivers.
- Border crossing handling of commercial vehicle shipments may overlap in terms of information exchange and on-board technology with inter-urban freight applications. Under the rural applications the benefits and cost evaluation is applicable to non-trucking vehicles. The application to trucking is covered in section 3 of this report and the synergistic benefits and savings are considered in section 6.
- Vehicles equipped with DSRC equipment could be used as probes to collect traffic data for traffic management applications in both urban and rural settings.
- The presence of AVI equipment on-board vehicles could permit synergistic efforts with private sector for such initiatives as:
    - non-stop access to parking facilities;
    - provision of private sector information such as advertising en-route;
    - traveler and vehicle identification for security access for large employers.

Assumptions

Key general assumptions applicable to Electronic Border Clearance as used in the B/C assessment include:

- 60% of commercial vehicles and 33% of private vehicles using an equipped toll or border crossing facility will be equipped with Type II+ DSRC transponder tag;
- Existing Canada Customs staff will be used to operate the border crossing pre-clearance system, so there is no staff cost increase as a result of the implementation of this application;
- Costs and benefits for the border crossing system will be shared between U.S. and Canada Customs, but only those relevant to Canada Customs will be considered in the analysis.
- Other assumptions are detailed in the B/C assessment input data included in Appendix B.

4.3.3 Rural Safety Systems

Rural Safety Systems are comprised of two modules; Portable Construction Zone Traffic Management System (TMS) and Intersection/Railway Crossing Collision Avoidance.

The Portable Construction Zone Traffic Management System provides monitoring of construction zone conditions and informs motorists of lane restrictions, delays, queue locations, etc. before they are encountered. As required for each location the construction contractor or highway agency deploys CCTV cameras, portable TMS, temporary vehicle detectors, HAR and DSRC in the construction zone in addition to the regular traffic control devices and radio communications system. Field equipment is connected to a computer in an on-site "control centre" where conditions are monitored and appropriate response messages generated. A portable TMS could be implemented at major construction zones on rural roadway sections with moderate to heavy traffic, particularly in locations with restricted cross section/geometry and/or sight distances.

Intersection/Railway Crossing Collision Avoidance provides motorists with consistent advance warning of conflicting traffic at roadway intersections and railway grade crossings. Detectors placed on the intersecting facility detect the speed and direction of approaching vehicles or trains. As a DSRC-equipped vehicle approaches the intersection / crossing, its speed is measured and a local processor calculates whether a collision is possible. As a supplement to existing traffic control , the driver of the DSRC-equipped vehicle is given an audible/visual warning, using a built in alarm annunciation, if there is a risk of a collision. They could be implemented at rural highway sections with a history of intersection and/or grade crossing collisions to reduce the frequency and severity of accidents and other incidents.

The service provider and vehicle equipment implemented for Rural Vehicle Electronic Transaction Systems can be used synergistically to provide benefits in other ITS applications in the following manner.

- DSRC service provider and in-vehicle display useful for other applications within Rural Transportation as well as a variety of Interurban Freight, Urban and Other ITS applications;
- Data from Construction Zone TMS can be used in Hazardous Road Condition Warnings;
- Rural Safety Systems can be used to improve conditions for safe and efficient interurban freight transportation.

Assumptions

Key general assumptions applicable to rural safety as used in the B/C assessment include:

- 45% of commercial vehicles and 25% of private vehicles will be equipped with DSRC and a simple display device;
- The in-vehicle equipment required is pre-existing, installed for other ITS applications (e.g. electronic toll collection or border crossing clearance systems);
- All vehicles are equipped with an AM/FM radio which can receive voice messages via HAR broadcasts;
- Other assumptions are detailed in the B/C assessment input data included in Appendix B.

4.4 Benefit/Cost Assessment of Rural ITS Applications

The B/C assessment for Electronic tolling and border clearance was carried out on the section of the Trans-Canada Highway (Hwy. 17) between Sudbury and Sault Ste. Marie in northern Ontario. This isolated section of highway includes several towns and villages providing traveler/tourist services and has intermodal transfer points for bus, rail, air and marine (ferry) modes.

The section of the Trans Canada Highway (Hwy. 1/97) through the Rockies between Revelstoke and Kamloops in British Columbia was used for the B/C assessment of rural safety applications. This section includes 7 major intersections, but no railway grade crossings. All B/C calculations for the railway grade crossing collision avoidance application were done at the national level.

Detailed calculation of the benefits and cost are provided in Appendix B.

Appendix B contains three parts:

(1) details on the derivation of the input data used in the spreadsheet;
(2) an explanation of the estimation of delay resulting from an incident;
(3) the benefit/cost assessment for each of the three rural ITS application groups.

The following subsections provide additional information and discussion of the results of the benefit /cost analysis provided in the appendix.

4.4.1 Input Data

As indicated in Section 2 of this report, only existing data was used in the benefit/cost assessment. Much of the data for estimation of benefits was provided by Transport Canada through published material and figures from other sources forwarded by members of the Project Advisory Committee. Other sources of input data included provincial ministries of transportation, transportation industry sources and previous work carried out by IBI Group.

An emphasis was placed on providing accurate cost estimates for use in the analysis. Capital costs for the Traveler Information Systems and Safety Systems were estimated by IBI Group on the basis of costs encountered for similar equipment in recent projects. Capital cost estimates for the Electronic Transactions Systems were derived from a Transport Canada report. The accuracy of these estimates is within the 25% to 50% range, suitable for the level of analysis being carried out.

Except for in-vehicle equipment the cost estimates assumed that each of the three ITS application groups was implemented individually. Synergies among the groups would result in some cost savings in actual applications.

In some cases, needed data was not readily available, so values had to be estimated. In these cases, conservative and realistic estimates were developed, drawing on IBI Group staff expertise and professional experience.

The sources used for individual values are indicated in the documentation of the input data provided in Appendix B.

4.4.2 Assessment Methodology

The benefit/cost assessment was not intended to be a rigorous analysis. Its intent was to identify the order of magnitude of the benefits and costs resulting from implementation of the rural ITS applications nation-wide. In keeping with this level of analysis, simple approaches were used in the conversion of benefits to monetary values and the scaling up of costs and benefits to the national level. The approaches, described below, assume uniform characteristics across the country for the valuation of benefits and the scaling of costs.

For all rural ITS applications except the Railway Grade Crossing Collision Avoidance System, benefits and costs were calculated for the study site, as identified in Section 4.3, then scaled up to the national level. All calculations for the Railway Crossing Collision Avoidance System were done at the national level, since national data was more readily available than data for specific sites.

Using the input data discussed above, benefits of system implementation were first estimated in physical non -monetary terms (e.g. accident reduction, litres of fuel, vehicle-hr). These calculations are included in the documentation of the input data (Appendix B). Most of the absolute benefits were then converted to monetary values. Monetary values of benefits at each study site were totaled, then scaled up to the national level. Scaling factors used for the benefits assessment were:

- ratio of national intercity highway network total travel (vehicle-km) to study site total travel for traveler information and safety systems;
- ratio of study site toll/customs transactions to national intercity highway network estimated total toll/customs transactions for Electronic Transaction Systems time and fuel savings;
- number of equipped toll/customs facilities nation-wide for Electronic Transaction Systems operating cost savings.

Total capital costs were estimated for each study site or individual installation as appropriate. An annual value for fixed equipment capital costs was calculated using a 10% discount rate applied over a 10 year period. A 7 year discount period was used for vehicle equipment.

The annual operating and maintenance costs were calculated as a percentage of the capital costs, 10% for applications with an operations component and 2% for applications which run unattended, requiring only maintenance. All costs were summed for each study site or individual installation, and the totals were then scaled up to the national level.

Scaling factors used for cost assessment were:

- ratio of national intercity highway network km to study site km for Traveler Information Systems, Portable Construction Zone Traffic Management System and Intersection Collision Avoidance System (based on study site);
- number of installations nation-wide for Electronic Transaction Systems and Railway Crossing Collision Avoidance System (based on individual installations).

All categories of costs were considered together for benefit/cost assessment purposes. Most costs are application-specific, borne by the agency implementing/operating the ITS application. The only exception is DSRC transponders, which are bought by vehicle owners/system users.

Total national benefits for the base year were factored up to account for 1% growth in traffic/transaction volume per year over ten years. Costs were not factored up to account for inflation, because all calculations were done in constant 1996 dollars. Benefit/cost ratios were calculated for both the base year and year 10.

4.4.3 Assessment Results

The benefit/cost ratios for the three rural ITS application groups are summarized in Table 4.3.

TABLE 4.3 - SUMMARY OF BENEFIT/COST RATIOS

Rural ITS Application Group	Benefit/Cost Ratios	
	Base Year	Year 10
Traveller Information Systems	2.41	2.66
Electronic Transaction Systems	1.14	1.27
Safety Systems	1.01	1.12

In practice implementation decisions by local authorities and individual users will be based upon the benefit/cost ratio applicable to either the local authority or the end user. It is therefore useful to examine the corresponding B/C results that may affect implementation decisions. These are shown in Table 4.4 The table distinguishes ITS service provider costs from ITS in-vehicle costs. Time savings were categorized as traveler benefits.

Table 4.4 Service provider /User Breakdown of Benefit /Cost

	Rural Transportation		
	Traveler Information	Electronic Transactions	Rural Safety
Annualized Costs			
Service Provider			
Capital	22.3	7.7	45.5
O&M	13.7	5.8	10.4
Sub-total	36.1	13.5	55.9
Vehicle(User) Costs			
Capital		1.7	
O&M			
Sub-total	0.0	1.7	0.0
Total Costs	36.1	15.2	55.9
Annualized Benefits			
Time Savings (user)	58.5	3.1	3.8
VOC	5.8	0.6	0.8
Safety	1.0		58.3
Other	26.0	15.8	0.4
Total Benefits	91.2	19.5	63.3
Benefit-Cost Ratio			
Overall B/C Ratio	2.66	1.27	1.12
Service provider B/C Ratio	0.77	1.18	1.05
User B/C/ Ratio	N/A	1.82	N/A

4.4.4 Sensitivity Analysis

Because the benefit/cost assessment relied on a number of assumptions, a limited sensitivity analysis was carried out to determine the effects on the B/C ratios of changing certain key variables. The effects of a ±10% change in the value of each variable were determined. The results of the sensitivity analysis are summarized in Table 4.5. The percentage change ("Δ") in B/C ratio shown in the table was calculated by subtracting the original B/C ratio (shown in Table 4.3) from the new one, dividing the difference by the original ratio and multiplying by 100.

Table 4.5 clearly shows that out of all the individual factors examined, capital cost has the greatest impact on benefit/cost ratio. This highlights the importance of factors which can reduce capital costs, such as standardization, regulatory streamlining and sharing of infrastructure among multiple ITS applications.

On the benefits side, cost of fuel had a very small effect compared to the value placed on time. Other factors had varying effects for the different ITS application groups. The assumed time savings per passenger produced by the Intermodal Traveler Information System were a significant component of the overall benefits of the Traveler Information Systems. The percentage of vehicles equipped with DSRC was a significant factor in the Safety Systems because of the large benefits resulting from accident prevention and the assumption of a pre-existing DSRC-equipped fleet. It was not a factor in the Electronic Transaction Systems because the time/fuel savings were offset by the cost of the DSRC transponders.

TABLE 4.5 - SENSITIVITY ANALYSIS

Variable	Traveler Information Systems				Electronic Transaction Systems				Safety Systems			
	+10%		-10%		+10%		-10%		+10%		-10%	
	B/C	Δ (%)	B/C	Δ (%)	B/C	Δ (%)	B/C	Δ (%)	B/C	Δ (%)	B/C	Δ (%)
Capital Cost	2.37	-9.28	2.90	10.97	1.13	-8.87	1.38	11.29	1.02	-8.93	1.25	11.61
Cost of Fuel	2.63	0.84	2.59	-0.84	1.24	0.00	1.24	0.00	1.12	0.00	1.12	0.00
Value of Time	2.79	6.75	2.43	-6.75	1.26	1.61	1.22	-1.61	1.13	0.89	1.11	-0.89
Incident Reduction Rate	2.64	1.27	2.58	-1.27	-	-	-	-	-	-	-	-
Intermodal Transfer Time Savings	2.47	3.80	2.51	-3.80	-	-	-	-	-	-	-	-
# of Transactions	-	-	-	-	1.22	-1.61	1.26	1.61	-	-	-	-
% of Vehicles Equipped with DSRC	-	-	-	-	1.24	0.00	1.24	0.00	1.23	9.82	1.01	-9.82
Transaction & Queue Time Savings	-	-	-	-	1.26	1.61	1.22	-1.61	-	-	-	-

4.5. Discussion of results

Three individual rural ITS applications were evaluated: Information Services, Electronic Transaction and Safety Systems.

The B/C ratios for the three rural ITS application groups reflect their different characteristics in terms of the number of vehicles benefiting versus implementation costs. The Traveler Information Systems provide generally small individual benefits, but reach a very large group of motorists. Implementation costs are relatively low, since the small amount of field and central equipment required can be shared by all applications in the group.

Benefits from the Electronic Transaction Systems are experienced only by suitably equipped vehicles. Non equipped vehicles continue to use manual lanes and are expected to incur the same delays as currently experienced..

For the collision avoidance systems, individual benefits are relatively large, but they are only applicable to vehicles equipped with DSRC. Implementation costs are high because of extensive field equipment requirements at a large number of sites. The Portable Construction Zone TMS also has intensive equipment requirements, but the benefits are applicable to all vehicles at a site where it is installed.

The Terms of Reference for this study assumed full implementation of ITS at a national scale, ignoring transitional effects.. Because of these characteristics, benefit/cost ratios for nation-wide implementation of Rural Vehicle Electronic Transaction Systems and Rural Safety Systems are marginal. There is no question, however, that better ratios could be achieved at particular sites having higher than average traffic volumes, accident rates, etc. Site-specific benefit cost assessment should be the first step in implementing any of the rural ITS applications. Focusing implementation on those sites with the highest potential benefits results in the most efficient use of resources. It could be possible, for example, to achieve 80% of the benefits of a nation-wide system implementation by equipped only the busiest 20% of all potential sites. It is very evident from this exercise that future ITS implementation in rural Canada, will not be nation but will occur only at specific sites

Due to the different nature of the applications investigated in the urban and rural areas a direct comparison of benefit /cost ratios between rural and urban areas is only possible for the Traveler Information systems. In this case the rural applications provides an aggregate benefit/cost ratio of 2.66:1 compared with the urban application benefit/cost ratio of 1.5 :1.

4.5.1 Traveler Information

In contrast to its other rural applications, the implementation costs of the Traveler Information application represent very low capital and operating costs yet reaches a very large group of motorists. This is reflected in the positive bas year benefit-cost ratio of 2.4 which increases to 2.66 in year 10.

The most significant benefits derived from Traveler Information applications in rural Canada, is a net reduction in travel time and reduced fuel consumption. Together, these account for virtually all of the benefits (97%). While the service provider investment accounts for all of the costs, service provider benefits, through improved safety and reduced emissions, are marginal. A benefit-cost ratio for travelers is not shown since no costs for this particular Traveler Information package have been assigned to the users.

Some enhanced implementations of traveler information, such as route guidance, could also be considered and these would therefore incur direct cost to the users. The use of route guidance systems would however generate further benefits as discussed in section 5 paragraph 5.5.5.2.

As with urban systems, the use of traveler information services is expected to show greatest benefit /cost ratios if selectively implemented in the busier locations. In many of the busier locations the building of new roads and/or additional lanes is often undertaken to relieve congestion and reduce accidents. Where alternative, albeit longer, routes already exist ITS could result in the deferral of new road/lane construction in these areas as traffic is safely diverted to the longer route before it is caught in the high density traffic area. A rigorous analysis of this cost deferral was not possible within the scope of the study, however it is interesting to note that at a cost of $250,000 per km, the deferral of only 120 km of new road building would pay for the entire national Traveler Information ITS infrastructure.

Direct comparison with analytical or empirical results from other administrations is not possible at this time since ITS in rural areas is generally considered as a low priority, except for safety related applications, and no empirical data is known to be available.

Considering that most benefits accrue in selected smaller areas it is recommended that benefit/cost analyses be conducted at a number of rural sites in which periodic high levels of congestion are known to occur. Those sites with the highest benefit/cost ratio should be selected for implementation of demonstration systems which can be monitored to obtain empirical verification of the benefits. This information is considered essential to establishing guidelines that could be applicable to the implementation of ITS at a large number of potential rural sites.

4.5.2 Electronic Transactions

At a national scale, the benefit-cost ratio for Electronic Transactions is limited to 1.2:1. 22% of the benefits accrue to individual travelers through travel time reductions (15%) and fuel savings (7%). Customs and Immigration benefits, through productivity gains, represent 75% of total benefits. Reduced emissions round out the benefits (3%). For most applications the benefit/cost ratio will actually be higher since the cost of the infrastructure component will be shared by inter-urban freight vehicles. By assuming that one third of the infrastructure cost is attributable to Inter-urban freight the Benefit cost ratio increases to 1.9 :1

At a national scale the user benefit/ cost ratio is 1.8:1. Whether this benefit/cost ratio is large enough to persuade individual travelers to equip their vehicles with DSRC units is difficult to determine. Public acceptance of DSRC in-vehicle equipment will be largely driven by consumer perception and the individual's tolerance to traffic delays rather than economic evidence. It is worth noting however that, in the U.S., public reaction to electronic payment systems is generally very high in areas in which it replaces manual toll booths. Less information is available concerning public acceptance of electronic transactions on routes that were not previously subject to tolls.

4.5.3 Rural Safety Systems

At a national scale, the benefit-cost ratio for Rural Safety Systems is limited to 1.1:1. Although the benefits are large for individual users the high costs that would be required for implementation across Canada are equally substantial. The benefit-cost ratio for this particular ITS application could improve significantly in response to future capital cost reductions for Rural Safety Systems technologies.

5.0 URBAN TRANSPORTATION

5.1 Development of Initial Set of Urban ITS Applications

In developing the Urban ITS applications for this Study, the application selection was oriented towards those applications that have been implemented, or are undergoing testing, in all parts of the world with most happening in the USA and Canada.

Table 5.1 presents the initial list of potential ITS applications identified for the Urban Transportation Sector.

TABLE 5.1- Potential ITS APPLICATIONS in URBAN TRANSPORTATION

ITS APPLICATION CATEGORY	DESCRIPTION OF APPLICATION
Traffic Management and Control	Manages and controls the movement of traffic on streets and highways.
Route Guidance	Provides travellers with instructions on turns and other movements to reach their destinations.
Incident Management	Enhances existing capabilities for detecting incidents and taking the appropriate actions in response.
En-route Driver Information	Provides travel-related information to travellers after their trips have begun.
Automated Highway Systems	A fully automated vehicle roadway system that will improve the safety and efficiency of highway travel.
Pre-trip Travel Information	Provides travellers with information prior to their departure and before a route choice decision is made.
En-route Transit Information	Provides information to transit riders after their trips have begun.
Personalised Public Transit	Involves the use of flexibility routed transit vehicles offering more convenient service to customers.
Collision Avoidance	Augments the driver's ability to avoid collision.
Transportation Demand Management	Reduces vehicle demands on the roadway by developing and encouraging modes other than single occupancy vehicles.
Traveller Services Information	Provides the travellers with access to information regarding a variety of travel-related services and facilitles.
Electronic Payment Services	Allows travellers to pay for transportation with electronic cards or tags.

5.2 Application Screening

The results of the screening process are presented in Table 5.2 . The three packages retained for further development and the B / C assessment are ;

- Traffic Management, Operations and Control (TMOC) Package which includes :
    - Incident management (37) &
    - Traffic Control (37)
- Travel and Traffic Information Services (TTIS) Package which includes:
    - En-route driver Information(29),
    - Route Guidance(31) &
    - Traveler Services Information (26)
- Transportation Demand Management (TDM) Package(31) consisting :
    - Road Usage Pricing module &
    - .HOV Preferential Treatment module

TABLE 5-2

Urban Transportation - Simplified Criteria for Relative Ranking (Scoring)									
Retained Applications (Application Rejected)	Implemen - tation Costs	Monitory Benefits	Other Benefits	Likelihood of Implementa-tion	National Program Necessity	Compatibility	Availability of Technology	Coverage	Total Score
Traffic Control	4	4	5	4	5	5	5	5	37
Incident Management	4	5	5	5	3	5	5	5	37
Route Guidance	4	4	5	4	3	4	4	3	31
Transportation Demand Management	3	5	5	4	2	5	5	2	31
En-route Driver Information	3	4	4	3	3	4	4	4	29
Traveller Services Information	4	3	3	4	2	4	3	3	26
(Pre-trip Travel Information)	3	3	2	2	3	3	3	3	22
(En-route Transit Information)	4	2	2	3	2	3	3	3	22
(Electronic Payment Services)	2	3	2	3	3	3	3	2	21
(Personalised Public Transit)	3	2	3	2	3	2	3	1	19
(Automated Highway Systems)	1	3	4	1	1	1	1	1	13
(Collision Avoidance)	1	1	3	1	1	3	1	1	12

5.3 Description of Retained Urban ITS Applications

Each of the selected application packages, identified in 5.2, was further refined and detailed including further specification of each function, the extent of implementation throughout the system, the targeted user groups and stakeholders and the supporting technologies. The following pages present each of the application packages and a summary description of the modules. The reader will observe that there appears to be considerable overlap of the information used or provided within the different modules. This arises as a result of the possible packaging of the functions as required by the need to target ITS products to many different market segments. Thus a minor component of route guidance may appear in en-route driver information and visa versa. At this level the functionality is complementary rather than a full stand alone capability.

5.3.1 Traffic Management, Operations And Control (TMOC) Package

5.3.1.1 Incident Management

This module improves the existing capabilities for detecting and responding to incidents. It will help safety officials to quickly and accurately identify incidents and to implement a set of actions to minimize the effects of these incidents on the movement of goods and people. It would be installed along all major roadway links with main emphasis on the freeway network in metropolitan regions and medium/ large urban areas. Incident reporting would be by call in telephone service (cellular phone), police and emergency service patrols and hazardous material incident warning. Incident detection is by road network monitoring (all day), incident prediction, incident verification and queue-end warning.

Incident response involves automatic selection from pre-planned responses including; emergency dispatching, inter-agency coordination (police, emergency services, tow trucks) and, driver advisory (diversionary routes).

The in-vehicle equipment implemented for Incident Management can be used synergistically to provide benefits in other ITS applications in the areas of traffic control, en-route driver information and Route Guidance within the urban/rural transportation sectors. The service provider equipment can be used for urban traffic control.

5.3.1.2 Traffic Control

This module maximizes utilization of available freeway and arterial network capacity through the use of real-time information and coordinated traffic management and control strategies. It would be implemented along all road network links with main emphasis on freeway and arterial networks. It uses a number of advanced technologies and software for the detection and classification of vehicles. The information derived from these sensors is used to optimize traffic flow through a combination of techniques such as demand based adaptive signal control, ramp metering, variable message signs and in vehicle signage. Although usually implemented with a centralized traffic manager, traffic management requires Inter-agency coordination (communication networking).

Where in-vehicle signage equipment is associated with Traffic Control it can also be used synergistically to provide benefits in other ITS applications in the areas of Incident Management, Travel Demand Management, En-Route Driver Information and Route Guidance within the urban/rural transportation sectors. The service provider equipment can be used as a component of urban incident management.

5.3.2 Travel And Traffic Information Services (TTIS) Package

5.3.2.1 En-Route Driver Information

This module provides a broad spectrum of travel related information to drivers after their trips have begun. Unlike traffic control information, which attempts to control traffic through the use of real time commands, en route driver information is of an advisory nature only. It is composed mainly of two sub-systems: Roadside driver advisory that is limited to traffic and roadway conditions and in-vehicle signing. In vehicle signing by means of DSRC communications provides advisory information concerning :

- Environmental conditions
- Vehicle and road conditions (incidents, construction, congestion)
- Alternative routing and suggested diversions (possible shifts to public transportation)
- Commercial traffic delivery/pick-up point information
- Road user pricing information (time, area and facility)
- Parking information (locations, availability and rates)
- Transit system schedule information (and intermodal connections)
- Airport terminal schedule information
- Roadway information (control signs, warning signs, etc.)

The in-vehicle equipment implemented for En-Route Driver Information can be used synergistically to provide benefits in other ITS applications in the areas of incident management, traffic control, travel demand management and Route Guidance within the urban/ rural transportation sectors.

5.3.2.1 Route Guidance

This module provides travelers with step by step instructions/directions on downstream routing to the selected destination based on user selected routing strategies. These strategies can include shortest route, shortest travel time, most scenic route or any of several other strategies. The most effective systems rely on real-time information which is used to derive a suggested route based on current traffic conditions. Lower cost systems usually make use of historic traffic patterns or may be limited to shortest travel distance only. Route guidance can be provided to the driver by means of audible commands and/or displayed on an in-vehicle/personal display device. The route guidance module achieves travel benefits at the individual level by optimizing the individual's use of the transportation system and, by reducing stress levels, it contributes to fewer accidents and hence reduced traffic delays to all users of the transportation system.

5.3.2.2 Traveler Services Information

This module provides traveler with access to transit and other information regarding a variety of travel-related services and facilities. This information will be accessible to the traveler at home, in the office and while en-route either in a vehicle or at public facilities and transit terminals. It provides real time transit information where available but otherwise can use scheduled information.

The module focuses on quick access to travel information, such as:

- transit scheduling
- traffic reports
- weather conditions
- reservations, confirmations, ticket purchase and payment
- emergency services and facilities
- intermodal connections

5.3.3 Transportation Demand Management

The economy's dependence on transportation and the lack of space and funds necessary for significant expansion of the road network has led many governments to consider means by which the demand for surface transportation can be moderated. Although there are many ways in which urban planners could potentially address this requirement these methods often raise land use and policy issues which are outside of the scope of this benefit /cost case study. The ITS application of Transportation Demand Management (TDM) is one, and possibly the most direct, of the tools that can be applied to regulate transportation demand. The major objective of TDM however is to modify transportation demand, to more closely match the existing capacity, rather than moderate or otherwise reduce transportation demand. It should be noted that the modification to the transportation demand by TDM primarily effects the vehicle trips taken and not the person trips taken. However, even in this more limited role TDM is sensitive to public policy issues. This study considers only the performance benefits and the cost attributable to the ITS application of Transportation Demand Management and does not address the more sensitive political and social issues

From an ITS perspective the goals of Transportation Demand Management are:

- temper growth in new traffic in mature metropolitan areas
- reduce energy consumption and emissions
- utilize corridor capacities more fully by taking advantage of any vacant capacity on parallel facilities to smooth out overall peak period traffic flow
- increase vehicle occupancies / load factors throughout the system (particularly for commuting and at special trip generators / events)
- encourage trip chaining to reduce the number of separate unlinked trips emanating from each residence or employment site
- reduce the number of long distance and cross-commuting vehicles by encouraging shift to HOVs / MOVs (from SOVs / LOVs)
- provide preferential and exclusive treatments to high and multiple occupancy vehicles (HOVs & MOVs) over single and low occupancy vehicles (SOVs & LOVs).

In order to assess the Transportation Demand Management (TDM) application package, primary elements of the two modules - *Road User Pricing* and *HOV Preferential Treatments* - are assumed to be implemented in parallel within Toronto metropolitan area with a focus on the commute corridors (e.g.: Queen Elizabeth Way / Gardiner Expressway from Hamilton to Toronto). The two modules may be summarized as follows:

Road User Pricing: Introduces a road user pricing mechanism which, while complementing the current fuel and vehicle taxation and license / permit fees, facilitates additional user charges and price differentials based on time, location and distance of travel and based on vehicle type.

HOV Preferential Treatment: Introduces preferential treatments of High Occupancy Vehicles (HOVs) / Multiple Occupancy Vehicles (MOVs) by offering priority and exclusive access and rates to car / van / bus pools, taxis with passengers, and public transit, , over all Single Occupancy Vehicles (SOVs) / Low Occupancy Vehicles (LOVs) and trucks. The preferential treatment would apply at critical locations within the urban expressway / arterial / street and parking systems.

The two modules are highly complementary as they provide both *incentives* (faster / cheaper / more convenient travel and parking for people in pool vehicles & faster / more reliable transit service) and *disincentives* (additional charge during the most severe congestion periods). The provision of opportunities and encouragement for pool formation and increased transit use provides an important relief valve for those unable to change their travel times (to periods of lesser congestion, therefore lesser price). Additional use, by public agencies and private companies, of innovative working arrangements (e.g.: flextime, compressed workweek, work-at-home) will further complement the transportation / traffic management based TDM measures - providing additional flexibility and choice for the traveling public.

5.4 Benefit/Cost Assessment of Urban ITS Applications

The benefit/cost assessment for the 3 Urban ITS application groups are presented in Appendix C, with a summary of the analysis for each of the groups in Section 5.4.5. Data sources and information utilization are explained in the analysis pages of Appendix C. The following subsections provide a brief overview of the information included in Appendix C.

5.4.1 Input Data

Only existing data/ information was used in the B/C assessment. Most of the data was obtained from published material available from Transport Canada, Ministry of Transportation of Ontario, Transportation Association of Canada, FHWA, and other previous work undertaken by SNC -Lavalin Inc.

The study endeavoured to utilize as much as possible accurate cost estimates, taking into consideration the level of analysis being carried out in the study. The accuracy of the cost estimates is estimated to be in the range of 25% to 50%. It is noted that the cost estimates used assume that each of the ITS application groups (i.e. TMOC, TTIS & TDM) was implemented on a stand alone basis. Overlap within each of the groups was accounted for where warranted.

References used in the B/C assessment are indicated for the values used as RR # (i.e. Reference Report Number) with a complete listing of the references at the end of Appendix C.

5.4.2 Assessment Methodology

5.4.2.1 Methodology Applicable to TMOC

The methodology utilized for the B/C assessment follows the idea documented in the original Terms of Reference for the study. This technique resulted in the identification of order of magnitude benefits and costs for a representative sample corridor with typical congestion and incident levels. The benefits and costs for the sample corridor were then expanded to a national level using approximate multipliers. The validity of this technique is based on the assumption that similar characteristics exist between the sample corridor and across the nation.

The benefits resulting from the implementation of each of the application groups were by the sketch planning technique which identified items such as travel time savings (veh-hrs), fuel savings (litres of fuel), accident reductions, reduction in incident duration, etc. These items were then converted to monetary values.

The monetary values of benefits were scaled up to the national level using a multipliers based on annual total travel volume. Specifically the multiplier is:

$$\frac{\text{annual total travel (veh-km) for freeways and arterials on the national urban network}}{\text{annual total travel for freeways and arterials on the sample corridor.}}$$

All costs were scaled up to the national level using separate multipliers to account for the service provider cost and the vehicular cost. The multipliers used were:

Service provider: $\frac{\text{length of the national urban network}}{\text{length the sample corridor road network}}$

vehicular: $\frac{\text{number of registered vehicles in national urban areas}}{\text{number of registered vehicles in sample corridor}}$

5.4.2.2 Methodology Applicable to TTIS

This followed the same methodology as described in 5.4.2.1

5.4.2.3 Methodology Applicable to TDM

The road user pricing module of the TDM package was assumed to consist of an open toll system which would electronically charge the owners of all motorized vehicles crossing two cordons around Toronto on their in-bound journey (appendix C Para C3.3.5):

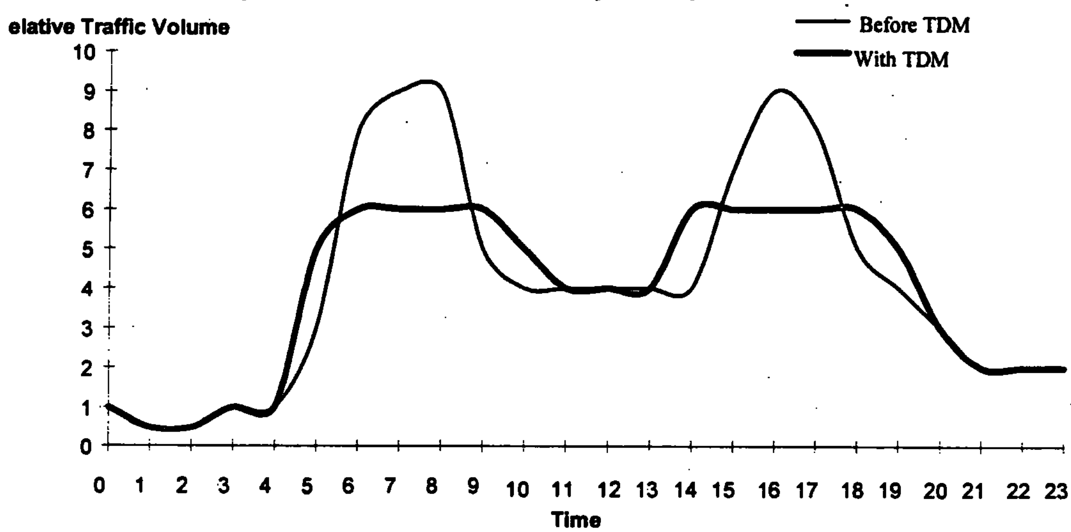
The outer cordon, crossing some 39 facilities, follows Etobicoke Creek, runs just south of Highway #407 easterly to the Metropolitan Toronto / Durham boundary, then south along Rouge Creek to Lake Ontario. (Note: at Highway #401 and

Gardiner Expressway, interrogator units would be installed for both directions at each site)

The inner cordon, crossing some 36 facilities, runs just west of Parkside Drive and Keele Street north to the CP rail-line, then easterly to Balfour Park (Mount Pleasant Rd), and south just west of Don Valley Parkway to Lake Ontario.

It was anticipated that road user pricing would be introduced by initially applying charges, Monday to Friday, during the morning and afternoon peak periods only (6:00-9:00 & 15:30-18:30) - thereby providing for maximum visual verification, i.e. traffic congestion and very low average vehicle occupancies. The charge would apply to each vehicle crossing any cordon within those hours independent of the purpose of the trip, commuting, shopping, etc. The charges would be set to modify the typical demand pattern by lowering and widening the representative traffic peaks as shown in Figure 5.1.

Figure 5-1 Representative Daily Metropolitan Traffic



For sketch planning purposes the charges - in this assessment - are assumed to apply at peak traffic periods during workdays only. Since the demand elasticity in any specific area is an unknown two representative levels are analyzed. For illustration purposes only two rates of the applicable charges are shown in Table 5.3. In the case of inter-regional long distance through traffic, which crosses the outer cordon twice (roughly 44 km along #401), the low rate translates to approximately 7 c / km. The *High* level corresponds to approximately 12 c / km.

TABLE 5.3 - ROAD USER PRICING LEVELS
(SELECTED FOR ILLUSTRATIVE PURPOSES ONLY)

	Representative pricing levels	
	Low	High
	----------	----------
Crossing the outer or inner cordon once *(charged inbound only)*	$ 1.25	$ 2.25
Crossing both cordons *(charged inbound only)*	$ 2.00	$ 3.50
Crossing the outer cordon twice *(charged only once in a 24h period)*	$ 3.00	$ 5.25

The HOV module of the TDM package was assumed to consist of:

- exclusive HOV by-pass lanes, with no metering, at access ramps along all in-coming freeway corridors (e.g.: along QEW within Burlington, Oakville and Mississauga)
- exclusive access to HOV lanes on selected city streets (close to exit ramps from the freeways, e.g.: Gardiner Expressway); additional HOV lanes, including reversible facilities, within the city where appropriate
- exclusive HOV parking facilities with the most convenient access to the highest employment concentrations down-town, mid-town and up-town (a total of 5 parking facilities initially); initially no rate differential compared to SOV parking.

Traffic Models

To help put the benefits analysis into perspective the overall demand for metropolitan-wide travel was first considered. The estimated average number of person-trips per day, based on current 7-day / 24-hour statistics, together with the current modal split percentages, trip lengths and vehicle occupancies were considered to be as shown in Table 5.4

TABLE 5.4 TORONTO METROPOLITAN TRAVEL STATISTICS

Modal Components		Before TDM
Total Person	Trips per Day	**4 000 000**
Auto	Persons	2 640 000
	%	66
	Length (km)	9

	Occupancy	1.4
	# of autos	1 885 714
Transit	Persons	1 040 000
	%	26
	Length (km)	8
Walk&Bike	Persons	320 000
	%	8
	Length (km)	2

The number of vehicles crossing cordons was estimated from the peak hour travel statistics for the major access corridors into the Metropolitan area, see Appendix C3.3.5, as 320,000 vehicle trips.

The impacts of an effective TDM package - installed, at its 'base' level - are speculated to be substantial. Out of a total of 320,000 cordon crossing automobile trips, some 6 to 18% might be ultimately removed from the peak period due to the combined effect of:

- increased modal split for transit and walk & bike
- improved occupancy rates for automobiles (primarily for the work trip purpose)
- chaining / linking and redistribution of non-work trips.

As it is assumed in this simplified model that the auto trip reductions are evenly distributed throughout different trip lengths, the reduction in total vehicle kilometers (veh-km) traveled is also 6 to 18%. This provides for a conservative estimate, as the cordon crossing trips will more generally be due to the medium and long distance commuting trips rather than shorter distance trips.

5.4.3 Summary of B/C Assessments

The overall benefit/cost ratios at the national level for the urban ITS application groups are summarized in Table 5.5

Table 5.5 SUMMARY OF BENEFIT/COST RATIOS

Application Group	**National B/C Ratio**	
	Base Year	Year 10
Traffic Mgmt, Op'ns & Control	5.84	6.46
Travel & Traffic Info Services	1.36	1.51

Transportation Demand Mgmt	1.9	-

In practice implementation decisions by local authorities and individual users will be based upon the benefit/cost ratio applicable to either the local authority or the end user. It is therefore useful to examine the corresponding B/C results that may affect implementation decisions. These are shown in Table 5.6. The table distinguishes ITS service provider costs from ITS in-vehicle costs. Time savings were categorized as traveler benefits.

Table 5.6 National Level Breakdown of Benefit /Cost

	Urban Transportation		
	Traffic Management	Information Services	Demand Management
	Annualized Cost		
Service provider			
Capital	212.2	51.6	38.4
O&M	147.4	58.3	51.3
Sub-total	359.6	109.9	89.7
Vehicle Costs			
Capital		369.6	23.1
O&M			0.0
Sub-total	0.0	369.6	23.1
Total Costs	359.6	479.5	112.8
	Annualized Benefits		
Time Savings	2050	630	39.6
VOC	63	13	13.8
Safety	81	54	14.4
Other	128	27	156
Total Benefits	2322	724	223.8
Benefit-Cost Ratio	6.46	1.51	1.98
Infrast. B/C Ratio	0.75	0.6	0.31
User B/C/ Ratio	N/A	1.78	8.4

5.4.4 Sensitivity Analysis

Since a number of assumptions were made in determining the B/C ratios of the urban ITS application groups, a number of key variables that relied on these assumptions were varied in order to study their effect on the B/C ratios. The percent change for each key variable was introduced based on the level of uncertainty as it relates to the assumption made.

The following summarizes the results of the sensitivity analysis:

	TMOC		TTIS		TDM	
	+10%	-10%	+10%	-10%	low	high
Capital cost	5.91	6.89	1.36	1.62		
Demand change					1.2	1.9
Value of time	6.99			1.4		

5.5 Discussion of results

Three individual urban ITS applications were evaluated: Traffic Management; Information Services; and Transportation Demand Management.

A common cumulative benefit associated with each of these applications is traveler time savings. An important associated benefit of traveler time savings to the transportation infrastructure is reduced congestion in urban areas and hence a potential deferral of additional road building to cope with congestion. The scope of this study prevented a rigorous analysis of savings in future or deferred capacity upgrades made possible by congestion reductions. However the following numbers may serve to illustrate the potential magnitude of these savings.

Assume annual expenditure on building new roads $5 billion

50% spent in urban areas = $25 billion

5% deferred due to ITS = $125 million

This important benefit should not be overlooked when reviewing the benefit-costs ratios.

It is also important to note that there are synergistic advantages to be obtained from implementation of complementary ITS applications. In the applications considered in the urban environment these advantages largely stem from the sharing of information. The added benefits to the end user due to shared information are difficult to measure and are not therefore included in the assessed benefits. A more direct and more easily measured advantage is due to cost savings. A particular example is the use of the incident detection systems, implemented under incident management, and the sharing of the information with the information services.

Finally it should be noted that the savings in travel time used in the study are based on the lower values taken from empirical data obtained from implementations in the U.S. A less conservative assumption in regard to travel time savings could result in the near doubling of the benefits.

5.5.1 Traffic Management

Traffic Management recorded an impressive 6.4:1 benefit-cost ratio, indicating that this application represents the greatest potential for ITS implementation in Canada. The greatest source of benefits is due to time savings achieved by travelers. If time savings were. The remaining benefits from averted collisions, reduced emissions, and reduced fuel consumption result in benefit-cost ratio to service provider of 1:1. This illustrates a common reality in ITS implementation that the beneficiaries may not always shoulder the implementation cost.

Traffic Management also requires a significant service provider investment with a national level annualized costs of $360 million dollars. A large portion of these costs are due to the roadway surveillance system which is necessary to acquire the information used for effective incident and traffic management. This information however is a necessary input to the traveler information systems and in reality a portion of the cost could be recoverable from usage fees associated with route guidance and traveler information systems.

Reduced noxious emissions is a valuable benefit. This annualized benefit of $59 million contributes a benefit value of .164 in the benefit-cost ratio.

Empirical results derived from Traffic Management systems installed in the U.S. {Seattle, Minneapolis} indicate the benefits assessed in this study are conservative. In Seattle traffic management has allowed a 10% growth in traffic while maintaining the same speeds. Accident rates in Minneapolis dropped by 15%-50% while speeds increased by 16-62% and throughput increased by 17%-25%. Noxious emissions were decreased by 5%-13%. In a separate project in Wichita Falls a computer based Traffic Signal System alone was observed to yield.

Travel Time	Decrease of 8%-15%
Travel Speed	Increase 14%-22%
Vehicle Stops	Decrease 0%-35%
Delay	Decrease 17%-37%
Fuel Consumption	Decrease 6%-12%
Emissions	Decrease 4%-13%

The benefits due to Traffic Management in an urban area are significant and would justify investment on a stand alone basis. Also, considering that the real time traffic information derived from the network surveillance capability is of value, and in many cases is a necessary enabling facility for other ITS applications, it is recommended that Transport Canada promote and encourage the implementation of traffic management as an essential component of the national transportation infrastructure.

5.5.2 Information Services

A combined traveler and service provider investment of nearly $500 million for Information Services, commonly known as ATIS, represents the most costly ITS implementation yet yields a positive over-all benefit-cost ratio of **1.5:1**. This modest over-all benefit-cost ratio of 1.5 mirrors the benefit-cost assessment of ATIS applications in urban England. Roughly 80% of the annualized cost of ATIS is for in-vehicle components and the costs are expected to be borne by the individual traveler. When direct benefits and costs were allocated to the user, the benefit-cost ratio falls to **1.1:1.**

However, the anticipated vehicle capital cost of $700 per vehicle for ITS equipment is likely over estimated and, in time, the actual cost will decline in real terms. A 50% reduction in-vehicle costs would increase the benefit-cost ratio to **3:1**. The in-vehicle equipment costs assumed in the analysis were as follows:

In-vehicle receiver units	$100
In-vehicle receiver units/interface	$350
Personal portable CD ROM Device	$250

The VOC annualized benefit of $20 million contributes a benefit value of .042 in the benefit-cost ratio value.

A further advantage that stems from the Route Guidance component of Information Services is that of route Navigation. This capability is mainly applicable non commuter traffic in areas in which the driver is unfamiliar with the roads and is not therefore amenable to the analyses conducted on freeway and arterial corridors. Nevertheless route navigation contributes to lower mileage, less travel time and fewer accidents, since drivers are not searching for street addresses and are less likely to make sudden turns or stops. A rough order of magnitude of the benefits due to route navigation is presented below.

Assume non-commuting travel represents 50% of all travel

Assume 2% of non-commuting trips are in unfamiliar areas

Average distance traveled per year is 18000 km /vehicle

Therefore average distance traveled in which navigation would be useful is 180 km per vehicle

Assume 20% savings in time at an average speed of 60 km/hour, then time savings is 36 minutes per vehicle per year

This results in a national level savings, due to reduced travel time, for 10 million passenger vehicles only, of approximately $66(Commercial) + $24(private) =$90 million. The comparable reduction in fuel cost is $6.93 million.

If only 10% of the accidents occurring in these 180 km of unfamiliar road were eliminated the savings due to accidents would amount to $2.6 million.

The total value of benefits due to route navigation are of the order of $99 million per year.

Since these savings due to route navigation are probably the most visible to the user it is not unreasonable to expect that procurement of route navigation capabilities will be largely driven by the navigational features.

The reasonableness of the assumptions made can be seen from empirical data from Travel Information Services installed in Los Angeles, Rochester-Genesee, New Jersey and Boston which are reported to be yielding the following average benefits:

Travel Time	Decrease of 8%-20% for equipped vehicles
Delay	Decrease 1900 vehicle hours per incident
Fuel Consumption	Decrease 6%-12%
Emissions	Decrease 25% from equipped vehicles

Deployment of travel information services is probably best left to the private sector which is better suited to the promotion and sale of equipment and services to a large number of individual users. Transport Canada should encourage and facilitate private sector involvement by setting standards for interoperability, ensuring that public traffic information can be disseminated to the private sector service providers and creating an appropriate regulatory and business environment.

In reviewing the cumulative benefits due to information services some caution is necessary. The benefits shown in this study have been calculated on a stand alone basis using average values for delays as currently experienced due to accidents and congestion. In the event that incident and traffic management facilities are fully implemented the delays are expected to be reduced by a factor of 20%. This will result in a corresponding reduction in the savings due to traveler information services.

5.5.3 Transportation Demand Management

5.5.3.1 Metropolitan Level Application

The benefits due to changes in travel for vehicles crossing the cordons are

Low Tolls & Medium HOV Package - **$22,936,628** and
High Tolls & Strong HOV Package - **$37,431,396**

Details are presented in Appendix C, C3.3.3 and C3.3.4 for the two different TDM packages.

Fuel and Vehicle Operating Cost - On an annual basis the reduction in fuel consumption costs alone would, based on the assumptions about expected changes, be in the order of **$2 to 7 million** (assuming a $ 0.57 / L fuel price). If an additional distance rate of $ 0.16 / km were applied (which reflects other vehicle operating costs), the vehicle-related savings would be in the order of $8 to $26M per year.

Accidents - The accident reduction is based an accident rate of 3.0 / 1 M veh-km, an average for all facilities in Ontario for several years now. The corresponding benefits related to reduced accidents, that would have resulted in fatalities and property damage, is assumed to be directly related to the reduction in the number of accidents. The estimate of benefits due to injury reduction reflects the higher occupancy rate of vehicles and the benefits are reduced accordingly. There are some indications that the accident rate of HOV vehicles are less than those due to SOV. The results of the analysis, which show a benefit of $805,388 (low) and $2,450,654 (high), are therefore considered to be conservative.

Toll Revenue - "Toll Revenue is not considered a 'benefit' in the sense of benefit-cost analysis. In other words, although taxpayers are made better off by the amount of the highway toll revenues collected, those paying the tolls are made worse off by an equivalent amount- and, therefore, no net gain results for society as a whole"

However, it is useful to speculate on the approximate revenues that might be collected. A simplified peak period model provides an initial estimate for the daily toll revenue as $572 000 (low tolls) and $1 006 000 (high tolls) (Appendix C 3.3.5).

For the purposes of marketing the implementation of the Road User Pricing and HOV modules of the TDM applications package, it will be critical (for the agencies) to fully report on the collected revenues - and to continually demonstrate intelligent, responsible and cost-effective use of those revenues. On this, in large part, will depend the success of the TDM program.

Costs - The equipment, installation and operating costs for the ROAD USER PRICING MODULE and the HOV preferential treatment system are estimated as $7,415,000 and $5,748,000 respectively. Details are presented in appendix C 3.3.1 and 3.3.2. The operating costs have been set at a relatively high level (25 %) to adequately cover expected enforcement needs. (Note: Significant savings were assumed by installing, at most locations, equipment for the in-bound direction only).

The total benefits and costs due to the implementation of TDM applications package in the Metropolitan Toronto setting, consisting of Road User Pricing and HOV modules, are estimated to be as follows (Table 5.6):

TABLE 5.6 - B/C PERFORMANCE OF TDM APPLICATION IN METROPOLITAN TORONTO

Cost Saving Category	**Benefits**	**Benefits**
	(Low Estimates)	(High Estimates)
Vehicle Operating Costs	$8,254,859	$26,068,644
Accidents	$805,388	$2,450,654.00
Emissions	$727,649	$2,303,147
Travel Time	$ 13,148,731	$6,608,952
Total Annual Benefits .	$22,936,627	$37,431,397.00
Operating Cost Components	Costs	Costs
Road User Pricing	$7, 415, 000	$7, 415, 000
HOV	$5,748, 000	$5,743, 000
Total Annualized Costs .	$13 ,163, 000	$13 ,163, 000
B / C Ratio	1.8	2.93

5.5.3.2 National Application

In a national level application of TDM packages, is expected to reflect the characteristics of the metropolitan / urban region in which it is installed. It is estimated that the total annualized implementation costs would roughly increase by a factor of three (i.e. Toronto plus 1.5 applications similar to Toronto, and the equivalent of 0.5 applications within other large and medium size urban areas).

Due to differences in urban development patterns, average trip lengths, amount of cross-commuting, level and duration of commuter congestion, level of transit service, etc., the benefits of such a national TDM program could be expected to increase less - perhaps only by a factor of 1.5 - 2.0. This would result in low and high values for the national level B / C ratios of 1.2 and 1.9 respectively,

5.5.3.3 Sensitivity Analysis

The travel behaviour impacts were estimated for both Low and High Tolls were evaluated in appendix C 3.3.3 & C 3.3.4. Due to significantly higher tolling levels and a more intense HOV program, it is speculated that the high toll rates could result in up to 18% of the automobile trips being removed. This obviously assumes a high degree of success in marketing / implementing / fine-tuning / reconfiguring the various elements of the TDM package, and particularly its HOV program activities. The predicted increase in the average load factor of 1.4 to 1.6 (for all trip purposes) is significant indeed and , requires a substantial behaviour change in commuting habits.

Given that the degree of modification to travel patterns is largely influenced by demand pricing, a variable that can be adjusted seemingly without limit in order to satisfy the objectives for the area, the benefit/cost ratio sensitivity to other parameters is of a secondary order and not significant in the context of this case study.

The travel habits as a result of demand pricing can be modified in several ways. These are:

- Retiming of travel from peak to off-peak periods,
- Shift from single occupancy vehicles to multi occupancy vehicles,
- Shift to public transit,
- Shift to bike or walk, and
- Reduction in of number of trips by chaining together multiple trips

Benefits accruing from the first bullet are due to the reduced travel time resulting from lower levels of congestion. The last bullet only results in a reduction of person trips. However all except the first bullet result in a reduction in the number of vehicle trips..

6.0 Synergistic Benefits

6.1 Potential Synergistic Combinations

Potential synergistic benefits can occur when more than one ITS application is implemented in the same coverage area. Based on the applications analyzed in this cost benefit study the following applications are considered as having potential synergistic benefits primarily due to the use of common equipment in either the infrastructure or in the vehicle. The potential benefits are assessed by examining the benefit cost ratios due to the following combinations of applications:

- Interurban freight Electronic Clearance with Interurban freight Roadside Safety Inspection due to the vehicle use of a common TAG for DSRC.
- Interurban freight Electronic Clearance with Rural Electronic Transactions due to common service provider equipment at border crossings and toll booths.
- Urban TMOC with Urban TTIS and Urban TDM due to the common use of traffic monitoring equipment.
- Rural Electronic Transactions with Rural safety systems due the common use of TAGs for DSRC.

6.2 Analysis Tables

6.2.1 Interurban freight Electronic Clearance with Interurban freight Roadside Safety Inspection

Costs and Benefits	lectronic Clearance	Roadside safety	Summed combination	Synergistic combination
Service provider				
Capital	3.3	$1.58	$4.88	$4.88
O&M	2.04	$1.26	$3.30	$3.30
Sub-total	5.34	$2.84	$8.18	$8.18
Vehicle Costs				
Capital	*4.3*	*$123.9*	$128.20	*$123.9*
O&M		$7.6	$7.60	$7.6
Sub-total	*4.3*	*$131.5*	$135.80	*$131.5*
Total Costs	9.64	$134.9	$144.54	$134.9
Annualized Benefits				
Time Savings	*6.5*+$6.5	*$36.3*	$85.7	$85.7
VOC	0.06	$5.7.3	$11.94	$11.94
Safety	/A	$53	$159.00	$159.00
Other	/A	$7.7	$7.70	$7.70
Total Benefits	13	$103.00	$116.00	$116.00
Benefit-Cost Ratio	**.34**	**0.76**	**0.82**	**0.85**

6.2.2 Interurban freight Electronic Clearance with Rural Electronic Transactions

Costs and Benefits	Interurban freight Electronic Clearance	Rural Electronic Transactions	Summed combination	Synergistic combination
Service provider				
Capital	$3.3	$7.7	$11.00	$7.7
O&M	$2.04	$5.8	$7.84	$5.8
Sub-total	$5.34	$13.5	$18.84	$13.5
Vehicle Costs				
Capital	*$4.3*	*$1.7*	$6.00	$6.00
O&M				
Sub-total	*$4.3*	*$1.7*	$6.00	$6.00
Total Costs	$9.64	$15.2	$24.84	$19.5
Annualized Benefits				
Time Savings	*$6.5*+$6.5	*$3.1*	$3.10	$3.10
VOC	$0.06	$0.6	$0.84	$0.84
Safety	N/A		0	0
Other	N/A	$15.8	$15.80	$15.80
Total Benefits	$13	$19.5	$32.50	$$32.50
Benefit-Cost Ratio	**1.34**	**1.28**	**1.31**	**1.66**

6.2.3 Urban TMOC with Urban TTIS and Urban TDM

Costs and Benefits	Urban TMOC	Urban TTIS	Urban TDM	Summed combination	Synergistic combination
Service provider					
Capital	212.2	51.6	12.8	$284.50	$212.2
O&M	147.4	58.3	17.1	$222.80	$147.4
Sub-total	359.6	109.9	29.9	$507.30	$359.6
Vehicle Costs					
Capital		369.6	7.7	$369.60	*$369.60*
O&M					
Sub-total	0.0	369.6	0.0		*$369.60*
Total Costs	359.6	479.5	37.6	$876.90	$729.2
Annualized Benefits					
Time Savings	2050	630	19.8	$2,233.60	$2,233.60
VOC	63	13	6.9	$85.90	$85.90
Safety	81.	54	7.2	$320.00	$320.00
Other	128	27	78.0	$236.36	$236.36
Total Benefits	2322	724	111.9	3157.9	$3157.9
Benefit-Cost Ratio	6.46	1.51	2.96	3.60	4.03

6.2.4 Rural Electronic Transactions with Rural safety systems

Costs and Benefits	Rural Electronic Transactions	Rural safety systems	Summed combination	Synergistic combination
Service provider				
Capital	$7.7	$45.5	$53.20	$53.20
O&M	$5.8	$10.4	$16.20	$16.20
Sub-total	$13.5	$55.9	$69.40	$69.40
Vehicle Costs				
Capital	*$1.7*	$1.7	$3.40	$1.7
O&M				
Sub-total	*$1.7*	$1.7	$3.40	$1.7
Total Costs	$15.2	$57.6	$72.80	$71.1
Annualized Benefits				
Time Savings	*$3.1*	*$3.8*	$6.90	$6.90
VOC	$0.6	$0.8	$0.40	$0.40
Safety		$58.3	$58.30	$58.30
Other	$15.8	$0.4	$16.20	$16.20
Total Benefits	$19.5	$63.3	$82.80	$82.80
Benefit-Cost Ratio	**1.28**	1.1	**1.13**	**1.16**

APPENDIX A - Inter Urban Freight

A1 - Characterization of Interurban Freight Packages

A2 - Detailed B/C Assessment Calculation

A1 - Characterization of Interurban Freight Packages

	ELECTRONIC CLEARANCE	AUTOMATED ROADSIDE SAFETY INSPECTION
GOALS	• Improve over-all freight logistics within / between NAFTA states • Enhance productivity (reduce travel times and operating costs; extend operating radius within safe working hours) • Improve service level (increase through put capacity of border and other inspection facilities) • Improve service level (increase through put capacity of border and other inspection facilities) • Improve road safety (check driver hours /credentials / weight data to reduce frequency of accidents) • Reduce driver / shipper / receiver stress (improve predictability of Estimated-Time-of-Arrival) • Reduce energy / environmental impact (reduce stop & go and idling)	• Improve road safety for commercial and other vehicles (reduce frequency of accidents) • improve traffic safety law enforcement • simplify complex inspection tasks (inspect more vehicles/drivers & increase detection rates) • provide real-time safety information about carriers, drivers, vehicles, cargo • improve on-board vehicle system monitoring • Reduce energy / environmental impact • reduce energy consumption and harmful emissions per unit (ton-km) of travel • improve pollution source identification and ensure follow-up on remedial measures • reduce number and severity of hazardous materials incidents • Enhance productivity (of carriers in compliance) • reduce travel times and operating costs (quicker inspections) • extend operating radius while maintaining safe driver hours • (inspection by-pass for Premier Carriers)
MODULES	BORDER CROSSINGS & INSPECTIONSTATIONS	FIXED AND MOBILE FACILITIES
DESCRIPTION	Implement/expand clearance mechanisms that will allow enforcement personnel to electronically check safety, driver/passenger/vehicle/cargo credentials, and size and weight data for DSRC-equipped vehicles before they reach an inspection site and then select only illegal or potentially unsafe vehicles for inspection. Legal and safe vehicles will be able to travel at mainline speeds past weigh stations and other inspection sites, and without stopping for compliance checks at ports-of-entry (or be entitled to expedited checks). Random checks are still maintained for enforcement integrity.	Develop, demonstrate and implement automated roadside inspection technologies and approaches, that will allow enforcement personnel to obtain, and act on, real-time safety information about carriers, drivers, vehicles and cargo in an effective manner. These systems will provide for roadside detection of an abnormal safety status indicator in vehicles approaching the inspection station at main line speeds, much faster and more reliable inspections of vehicles called in, and effective follow-up with carriers and drivers on violations identified.
FOCUS	THIS MODULE FOCUSES ON DELAYS AT BORDER CROSSINGS AND OTHER INSPEC-TION STATIONS DUE TO • congested traffic conditions (at inspection facilities and their access systems)	THIS MODULE FOCUSES ON EFFECTIVENESS OF SAFETY INSPECTIONS AT STATIONARY AND MOBILE ROADSIDE STATIONS • with congested (commercial) traffic conditions, ie. where inadequate share of total traffic is being called for standard and random checks with cumbersome, slow and unreliable inspection procedures
	• customs, immigration and other inspection procedures • shipper / consolidator / forwarder / broker/ carrier/receiver procedures	

TARGET	IT IS TARGETED AT ALL TRUCKS, PARTICULARLY THOSE INVOLVED IN • daily repeat crossings (eg. JIT and 'local'plant-to-plant shipments) • long distance shipments (eg. loads suitable for advance clearance via EDI) • with a special road safety-related focus on: • main-line back-up (eg. on freeways/bridges) plus abrupt manoeuvres at entrances and plazas	IT IS TARGETED AT ALL COMMERCIAL VEHICLES, PARTICULARLY THOSE WITH • current appearance of having safety-related problems (to ensure thorough checks on all) active out-of-service rulings and past violations (to catch and monitor poor performers; to ensure that remedial actions are taken) • first-time access to U.S. and Canadian roads from Mexico due to NAFTA (to enforce common safety standards) • established reliability and maintenance quality (to facilitate priority treatment) with an additional road safety-related focus on all vehicle traffic: • main-line back-up on freeways plus abrupt manoeuvres at entrances
SITES	CANADA - U.S. AND U.S. - MEXICO BORDER - CROSSINGS ROAD-SIDE STATIONARY AND MOBILE INSPECTION STATIONS SAMPLE AREA: DETROIT RIVER CROSSINGS BETWEEN ONTARIO AND MICHIGAN • Ambassador Bridge (Windsor-Detroit) • Windsor - Detroit Tunnel • Bluewater Bridge (Sarnia-Port Huron) B/C SITE: Ambassador Bridge	ROADSIDE STATIONARY AND MOBILE INSPECTION STATIONS SAMPLE AREA: ONTARIO FREEWAY NETWORK B / C SITE: Highway #401 between Windsor and London
METHOD	**APPLICATION OF ELECTRONIC CLEARANCE TECHNIQUES, INCLUDING AUTOMATIC CHECK OF (and release from the corresponding stop):** • driver/passenger/vehicle/cargo identity • carrier credentials (annual registration, fuel use tax, operating authority, • insurance, delinquent payment flags) • permits (oversize/overweight) • fitness rating (eg. Premier Carrier), last inspection (time & results), out-of-service-rulings • customs and immigration documents and confirmation of pre-clearance	**APPLICATION OF AUTOMATED INSPECTION TECHNIQUES, INCLUDING AUTOMATIC CHECK OF (and release from the corresponding inspection stop):** • carrier/driver/vehicle/cargo identity (at main-line speeds) • carrier fitness performance: Premier Carrier rating; out-of-service flags and past violations; • last inspection (time & results) [eg: automated brake inspection should cut time by ½-2/3 & make it more accurate] • permits (oversize / overweight)
	COMPLEMENTARY FEATURES (via 2-way DSRC to equipped vehicles only; or via a median-installed cable-antenna to passing vehicles only; or via a standard AM or FM-RDS radio transmissions all vehicles within transmission range) • ATIS (advanced traveller information system) • ATMS (advanced traffic management system) • AFMS (advanced fleet management system) /CVO **COMMERCIAL VEHICLE ELECTRONIC CLEARANCE (EC) FUNCTIONS** • maintenance and integration of databases • 1- and 2-way mobile communications & stationary communications • information retrieval/processing/storage/display • driver/passenger/vehicle/cargo surveillance control & enforcement	**COMPLEMENTARY FEATURES** - see "electronic clearance" application plus • **ON-BOARD SAFETY MONITORING** program which provides warnings/indications en-route based on the non-obtrusive sensing of safety status of driver, vehicle and cargo **COMMERCIAL VEHICLE ARSI FUNCTIONS** • maintenance of databases • 2-way mobile communications & stationary communications • information retrieval/processing/storage/display • carrier/driver/vehicle/cargo monitoring
		• control & enforcement & follow-up

TECHNOLOGIES	**ON-BOARD VEHICLES** • electronic license plate • vehicle-mounted DSRC device • transponder (automatic driver/passenger/ vehicle/cargo identification tag] • on-board computer (OBC) and smart card reader • toll tag (1- or 2-way; for on-board debiting or central charging) • display (eg: indicator light, audio channel, CRT display) **ROAD-SIDE (APPROACHES) AND CUSTOMS PLAZA** • interrogator units facilitating 2-way local RF via DSRC, ie: roadside 'reader' (transmitter/ receiver/processor) & in-pavement, road-side and/or overhead antennas • automatic vehicle classifiers (AVCs) to obtain 'bridge formula' compliance • high-speed weigh-in-motion scales (HSWIM) • computer systems at border crossing plaza, customs brokers, carriers, shippers, receivers • LAN (local area network, to support work stations) • communication links (customs plaza/ inspection site « broker/carrier/shipper/ receiver)	**ON-BOARD VEHICLES** • electronic license plate • vehicle-mounted DSRC device • (tractor & trailer)/cargo identification tag • on-board computer (OBC) and smart card • toll tag (1- or 2-way; for pre-purchased inspection tokens or central charging) • display (eg: indicator light, audio channel, CRT type display) • electronic log book <u>plus</u> sensors, diagnostics devices and other components related to **ON-BOARD SAFETY MONITORING** **ROADSIDE (APPROACHES) AND INSPECTION STATIONS** • interrogator units facilitating 2-way local RF via DSRC, ie: roadside 'reader' (transmitter/receiver/ processor) & in-pavement and/or overhead antennas • brake inspection device (under development), eg: • Vehicle Inspection Trailer (VIT) • portable roller dynamometer • combination flat-plate brake testing and vehicle weighing device an infra-red brake testing device • torque brake testing device • pen-based computers (as a general inspection aid) • communication links (inspection site « carrier/receiver)
	PERIPHERAL EQUIPMENT • conventional signs • changeable message signs • closed-circuit video cameras & VCRs • display terminals (eg. for driver image/ license/signature) • communication link with city traffic control centre	• Computer systems at inspection stations and carriers' fleet management centres • display terminals (eg. for carrier/driver/vehicle/ cargo past and current status) **PERIPHERAL EQUIPMENT** • conventional signs • changeable message signs • closed-circuit video cameras & VCRs • <u>plus</u> system components related to "Electronic Clearance" • communication link with city traffic control centre • automatic vehicle classifiers (AVCs) to obtain bridge formula' compliance • high-speed weigh-in-motion scales (HSWIM) • LAN (local area network, to support work stations)
STAKE-HOLDERS	**ROAD USERS (DIRECT & INDIRECT)** • trucks (operated by for-hire and private carriers) • buses (intercity regular route, charter, school, private) • private vehicular traffic (affected by inspection station activities) • all vehicular traffic accessing complementary services provided	**ROAD USERS (DIRECT & INDIRECT)** • trucks (operated by for-hire and private carriers) • buses (intercity regular route, charter, school, private) • private vehicular traffic (affected by inspection station activities) • all vehicular traffic accessing complementary services provided and

	• shippers & receivers	• shippers & receivers (ie. info on carrier ratings)
	• • freight consolidators/forwarders & agents/brokers • distribution centres, warehouses/terminals, intermodal terminals and yards **OTHERS** • customs • toll authorities • immigration • city traffic managers • provincial/state transport ministries/ departments	• • freight consolidators/forwarders & agents/brokers • distribution centres, warehouses/terminals, intermodal terminals and yards **OTHERS** • provincial/state transport ministries/departments
PRE-REQUISITES	**REGULATIONS AND PROCESSES (CANADA & U.S.)** • regulations to allow electronic logs without manual log back-up • tightening driver log rules enforcement in general	**REGULATIONS AND PROCESSES (MEXICO & CANADA & U.S.)** • reciprocity on safety-related regulations and enforcement intensity and quality
SYNERGIES	**OTHER APPLICATIONS WITHIN FREIGHT TRANSPORTATION (INTERURBAN & URBAN)** • access control at restricted facilities (terminals / yards, urban streets) • ARSI (automated road-side safety inspection) • on-board safety monitoring (of driver/vehicle/cargo condition and performance) • administrative processes (credentials purchase and fuel / km reporting)	**OTHER APPLICATIONS WITHIN FREIGHT TRANSPORTATION (INTERURBAN & URBAN)** • hazardous materials incident response (vehicle itself & other incidents) • access control at restricted facilities (terminals/ yards, urban streets) • administrative processes (credentials purchase and fuel/km reporting) • freight mobility package (real-time vehicle location and traffic information)
	• hazardous materials incident response (vehicle itself & other incidents) • freight mobility package (real-time vehicle location and traffic information) **RURAL APPLICATIONS** • traveller information and assistance (road & weather & tourist & mayday) • electronic transactions (border crossings & toll facilities) • safety (at grade crossings & construction zones) **URBAN APPLICATIONS** • travel/traffic information services package • traffic management operations and control package • transportation demand management package: road user pricing module **OTHER ITS APPLICATIONS (SEE 'COMPLEMENTARY FEATURES')** • fleet management/dispatch/rerouting systems • incident response systems (traffic mgt and hazardous product teams)	 **RURAL APPLICATIONS** • traveller information and assistance (road & weather & tourist & mayday) • electronic transactions (border crossings & toll facilities) • safety (at grade crossings & construction zones) **URBAN APPLICATIONS** • travel/traffic information services package • traffic management operations and control package • transportation demand management package: road user pricing module **OTHER ITS APPLICATIONS** • incident response systems (traffic mgt and hazardous product teams)
ASSUMP-TIONS	**ASSUMPTIONS MADE ON SKETCH PLANNING TECHNIQUES AND B / C ASSESSMENT** • number of installations (electronic clearance lanes, etc) in a typical border implementation • road user charge differentials (electronic vs. conventional clearance) • base volumes and any changes in trip making (once EC in effect) • multiplier to obtain an illustrative total for Canada-US border (based on sample site).	**ASSUMPTIONS MADE ON SKETCH PLANNING TECHNIQUES AND B / C ASSESSMENT** • number of installations in a typical implementation • road user charge differentials (automated vs. conventional inspection) • multiplier to obtain an illustrative total for an automated Canadian inspection system.

A2 - Detailed B/C Assessment Analysis

A2.1 Electronic Clearance

A2.1.1 Toll Operations and C&I

(a) *Impact of Truck Volumes and EC Penetration*

In this analysis the total volume of two-way truck trips at a crossing is allocated, in the absence of data, based on a judgement call to three eight hour periods in the day to reflect peak volumes of traffic (60%), medium volumes of traffic (30%) and low volumes of traffic (10%). It is further assumed that the majority of truck crossings occur during weekdays and that, as a result of the low volume of trucks, there would be no savings during weekends. To provide a common baseline for the traffic load on toll lanes with and without electronic tolling, the number of lanes required to maintain an even flow of trucks in each period is calculated on the basis of the traffic volume for both the toll operation and the C&I operation separately. This is based on the current manual operation and the average time required to process a truck at each booth.

A similar computation is then made assuming that all except two lanes are transferred to Electronic Clearance[1]. The difference in the number of lanes required reflects the manpower savings. The daily manpower savings are calculated by summing the savings in each period.

The analysis supports the assumption that there are insignificant savings during periods of low volume such as would occur at night and during weekends. The annual savings are therefore based on savings during weekday operation only. They assume annual salary for toll booth operators of $35 000 and for C&I inspectors $65 000; which, when multiplied with 1.2 to reflect direct employee benefits, result in $42 000 and $78 000. To further illustrate the true potential savings - considering that organizations, seeking productivity gains throughout their operations, should be fully credited with reductions in overhead as well - a sensitivity analysis is performed using a multiplier of 2.25 (ie. with $78 750 and $ 146 250).

(b) *Implementation Cost*

The implementation cost of a 4-lane, one-way system is provided in Reference 1 (p.8-7: 'per site' = $277 150 + $797 500). Scaling the variable elements of these costs to sites (ie. one direction of a crossing) with 2 ,4 and 6 electronic lanes gives the following implementation costs: $848 030, $1 074 650 and $1 292 274 respectively.

1 Manual lanes, or at least the equivalent manual processing on some automated lanes, will be required for the foreseeable future (not all vehicles will be equipped, neither trucks nor automobiles).

Additional, non-recurring costs (not included here) for design and engineering, implementation management, marketing and public information program, project evaluation plan - in the order of $ 1 450 000 (Ref 1: p.8-8) - would apply to the first system, declining substantially thereafter. To illustrate this cost, the 2-, 4- and 6-lane systems have been assigned with $ 250 000, $ 350 000 and $ 450 000 respectively (for totals, see Table A2-1).

The annualized cost was calculated assuming an annual maintenance cost of 10 %, a discount rate of 10% and an economic life of 10 years as follows (using the 4-lane site as an example):

Annualized cost: $ 231 855 + ($ 1 424 650 * 10%) = $ 374 320.
PV O&M

TABLE A2-1 ELECTRONIC CLEARANCE IMPLEMENTATION COSTS AND 'AGENCY' B / C RATIOS

# of One-way Electronic Lanes per Site	Implementation Cost	Annualized Cost	'Agency' B / C Ratio
2 Lane Site	$ 1 098 030	$ 288 502	0.56 : 1
4 Lane Site	$ 1 424 650	$ 374 320	1.22 : 1
6 Lane Site	$ 1 742 274	$ 457 774	1.21 : 1

B / C ratios for the toll agency as derived from the annual manpower savings (approx. $134 000 x 1.2 / $ 380 000 x 1.2 / $ 460 000 x 1.2) are shown in column 4 of Table A2-1. Although these ratios (0.56:1 1.22:1 1.21:1) for 2- 4- and 6-lane systems do not yet incorporate in-vehicle equipment costs (nor corresponding trucker benefits), they are useful in presenting a possible agency perspective for transparent border installations.

(c) Expansion to National Level

There are 13 interstate level crossings along the border between Canada and the U.S. Of these, it is assumed, 6 crossings handle one-way truck volumes in excess of 900 000 annually and require (6+2)-lane operation and 7 handle truck volumes of 500 000 to 900 000 and require (4+2)-lane operation. Nine crossings are associated with bridges or tunnels for which toll collection will be appropriate.

There are 21 crossings on principle highways that could handle truck volumes of 200000 to 500000 and require (2+2)-lane operation in peak hours. However, since these are shown to have a B/C ratio of less than 1, they are unlikely to be implemented and are not included in the analysis. Further, since it is unlikely that completely unmanned operation will be allowed, it is considered that the 59 rural crossings will be too small to justify the implementation of Electronic Clearance for trucking operations only. However when the aditional load due to other rural traffic is added they may become cost effective.

The total cost of implementation of Electronic Clearance, Toll plus C&I on the 13 primary crossings is $(6x1,742,274 + 7x1,424,650) = $20,426,194. The total annualized cost, including 10% of total installation cost for annual maintenance, becomes $3324269 + ($20426194 * 10%) = $5,66,888].

The total annual manpower savings becomes $ 6 504 000 (based on Figure 3.4 in main body of report, a roughly = 6 x 460 000 x 1.2 + 7 x 380 000 x 1.2) - resulting in a national level 'agency' B / C ratio of 1.21 : 1.

A2.1.2Truck Operator Cost

(a) Time Savings per Truck

The St. Clair and Detroit River crossings together handle nearly 25% of all the cross border truck traffic between the U.S. and Canada Based on the frequency of crossings (Ref 1: p.8-4/Section 8.1.2), 7,590 or 50% out of a total of 15, 150 trucks regularly using these crossings might be expected to use Electronic Clearance (Ref 1: Section 8.1.2/p.8-4). Although this is lower than the value of 90% given by the table of assumptions, see section 2 of the main body of the report, a more conservative figure is used to reflect the lower cost benefit ratio applicable to trucks making infrequent crossings. The average saving in processing time was estimated at 90 seconds per crossing for trucks using EC (Ref 1: Exh 8.7 p.8-20).

A further saving in time stems from the reduction in queuing delays. Current queue delays were calculated based on the traffic volume at the bridge crossings and totaled 45000 to 64000 vehicle hours per year (Ref 1: p.8-22). The two bridges together handle 90% of the crossings so that the average queuing delay per crossing is 1.12 minutes. Assuming that queuing delays would be reduced by 25% to 50%. The overall savings in time is therefore on average 106 to 123 seconds per vehicle per one-way crossing.

It should be noted that the average savings in time are used only for computational purposes as the real benefits of a savings of typically two minutes per one-way trip are probably not significant. What is significant is the savings that occur due to reduction in the frequency of long delays. A study of the distribution of delay and its impact on cost of trucking operations is outside the scope of this study.

(b) Cost Savings

Truck Operations

The cost of truck operations - ie. the time related to the driver, the company operations, and the truck itself[2] - is $38.00 Canadian per hour (Ref 1: p.8-20). Factoring up of the annual savings in the study area is based on 2750167 crossings per year (Ref 1: S2.4) of which some 50% are assumed to benefit from Electronic Clearance. This gives a total annual saving of $1.5M-1.8M

[i.e 0.5 x 2750167 x 38$/h x (106-123)s/3600s/h = $1538566 to $1785317].

Assuming 50 % of trucks making daily crossings, 35 % of trucks making weekly crossings and 15 % of trucks making monthly crossings the average savings per truck per crossing becomes $1.54 to $1.80.

The annual EC-related savings per truck are;

$(346-401) per year per truck making daily crossings,

$(77-89) per year per truck making weekly crossings and

$(18.50-21.50) per year per truck making monthly crossings.

For the purposes of this analysis, an equipment capital plus installation cost of $ 150.00 has been assumed to give a total of $1138500 for 7590 trucks.

Truck Fuel & Emissions

The equivalent monetary value of the reduction in total annual truck fuel consumption is already incorporated through the $38/h time rate of the driver/ carrier/truck. However, the actual litres (of fuel) are required to arrive at corresponding (CO+NOx+VOC) emissions reduction. The fuel consumption reduction, due to reduced idling and stop-and-go cycles (2 x 300.5 x 2750167cr /a x [(123s/cr/ 3600s/h) x 2.5L/h (idling) + 6 x (2cycles/cr x 20.4L/1000 cycles) (stop-and-go)] = 454075 L/a.

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2 The determination of the time value for cargo is considered to be outside the scope of this sketch-planning based assessment. (Note: except for some JIT shipments, it would be small in relation to other time elements in any case).

The rates of emissions (g/km/vehicle) and the associated societal cost of emissions in $/tonne are shown in table A2-2 below.

Table A2-2 Vehicle Emissions in g/km

Vehicle Type	CO	NO_X	VOC
Light Truck (1,470,404)	16.33	1.31	1.55
Heavy Truck(196,993)	23.15	11.85	2.57
Average all trucks	17.13	2.54	1.67
Societal cost per tonne	$1,000	$5,000	$5,000

Source: Transportation System Division of Environment Canada, Ontario 1995. Diesel and Gas data combined using number of registered vehicles

Assuming a consumption rate of 30l/100km and the above values for levels and cost of emissions, given in g/veh-km and $s /tonne the overall cost of emissions are used to calculate emissions:

The amount of emissions are: 454075*100/30 km x (17.13 + 2.54 + 1.67)g/km = 32.28 tonne which, when converted to equivalent monetary units, corresponds to $ **57,779** savings per year at the site.

Accidents

Because of the enhanced ability to check driver hours and credentials, and truck weight data, and the reduction in driver stress (more predictable ETA), there will be a reduction in accidents involving trucks (and other vehicles). However, for the purposes of this B/C assessment (on a sketch planning platform) no estimate is prepared, nor benefits included.

Road Maintenance and Rehabilitation

Because of the enhanced ability to check truck weight data and to track carrier compliance information in general, there will be a reduction in the damage done to roads by over-weight trucks. However, for the purposes of this B/C assessment no estimate is prepared, nor benefits included.

(c) *Expansion to National Level*

Since the study site carries approximately 25% of all border crossing truck traffic, the national savings are calculated by the use of a simple multiplier (3.8 = 4 x 0.95) - which, for illustrative purposes, assumes 5% of the total traffic will occur at crossings not equipped with EC . The national savings over all one-way truck crossings are therefore between $6.0M and $7.0M (average $6.5M).

[ie. 3.8 x $(1538566 + 57,779) = $6,066,111
(Truck operations + emissions)

& 3.8 x $(1785317 + 57,779) = $7,003,764].

Using the multiplier of 3.8, the cost of national level truck implementation = $4,326,000

A2.1.3 B/C Performance of EC

The overall costs and benefits that accrue at the national level due to the implementation of Electronic Clearance for agency and truck operations are, together with corresponding B/C ratios, presented in Table A-2-3:

TABLE A1-3 B / C PERFORMANCE OF ELECTRONIC CLEARANCE

	ANNUALIZED COST ($)	*ANNUAL SAVINGS ($)*	*B / C RATIO*
Agency	5,367,000	6,504,000	1.2
Truck Operations	4,326,000	6,500,000	1.5
Total	9,693,000	13,004,000	1.34

A2.2 Benefit / Cost Assessment of Automated Roadside Safety Inspection

A2.2.1 Introduction

This B/C assessment considers the implementation of *Automated Roadside Safety Inspection* capabilities in Canada and is presented by four sections as follows:

- Costs
- Benefits
- B/C Performance
- Sensitivity Analysis

Since this case study considers economic benefits to Canada, it is based on cost savings accruing to the operators of Canadian ARSI sites and to the Canadian carriers only. The U.S. is in the process of evaluating and implementing similar sites along major freeway corridors - which, in due course, will benefit Canadian carriers operating long distance trucking routes and having the required on-board equipment. These cost-savings are not included in this assessment.

Among the stated goals this assessment will address the expected impacts either directly or indirectly - within the limits of the selected sketch planning techniques - as follows:

Enhance productivity *(of carriers in compliance)*

- reduce travel times and operating costs *(quicker inspections)*
- extend operating radius while maintaining safe driver hours *(inspection by-pass for Premier Carriers)*
- improve road safety for commercial and other vehicles *(reduce frequency of accidents)*
- improve traffic safety law enforcement
- simplify complex inspection tasks *(inspect more vehicles/drivers & increase detection rates)*
- provide real-time safety information about carriers, drivers, vehicles, cargo
- improve on-board vehicle system monitoring
- reduce energy/environmental impact
- reduce energy consumption and harmful emissions per unit (ton-km) of travel
- improve pollution source identification and ensure follow-up on remedial measures
- reduce number and severity of hazardous materials incidents

A2.2.2 Infrastructure Costs

(a) Unit cost of roadside installations

Automated Roadside Safety Inspection is made up of many components. A representative list, presented in Table A2-4, is based on the components associated with roadside safety inspection in the U.S. National Architecture Study (Cost Analysis/Projections, Apr 96). Software and integration costs ($252 000) would apply to the first system only, dropping substantially thereafter; to illustrate this, $70 000 per system has been assumed. These components are likely to vary from site to site so as to reflect specific safety concerns applicable to the region. To reflect the lesser number of installations anticipated for Canada a conservative value based on the upper bound of U.S. cost estimates has been used and converted at US$1.0 = C$1.4.

TABLE A2.4 - ARSI COST ELEMENTS

Roadside Sub-System	Capital Cost ($)	Operating Cost ($)
ELECTRONIC SCREENING		
• CVO Detection System	70 000	
• Communication to Detection system	700	
• Wireless communication to vehicle	200	
• Signal Indicator System	14 000	
• Software & Integration ($301·000 / 252 000)	70 000	
Total	**$ 154 900**	**$ 12 880**
WEIGH-IN-MOTION		
• WIM Load Cell	14 000	
• Interface	5 600	
• Wireline Communication	1 400	
Total	**$ 21 000**	**$ 1 680**
SAFETY INSPECTION		
• Handheld Safety Devices	4 200	
• Safety Database Vehicle I/F	700	
• Wireless Communication Device	700	
Total	**$ 5 600**	**$ 3 220**
ES + WIM + SAFETY INSP	$ 181 500	$ 17 780

(b) Expansion to National Level

For the purposes of assessing the national level cost it is assumed that installations will be made at an equivalent number of sites as are currently used for permanent weigh stations. The number of weigh stations installed in each province is presented in Table A2-5. (Source: Telephone survey, 15.2.96)

The cost of installation and operation will vary based on the complexity of each system. For purposes of this benefit-cost analysis a mix of system installations - allowing one quarter of each type (25% of 184 = 46) - is assumed, resulting in installation (I) and *operating (O)* costs as presented in Table A2-6.

The over all capital cost of roadside systems across Canada is therefore $10,,200. The replacement life varies between 10 and 20 years. Assuming an average of 12 years under Canadian conditions, the annualized cost (using a 10% discount rate) is $ 1,584,486 per year are the total cost, including 10% O&M, are $ 2,853,166.

TABLE A2.5 - WEIGH STATIONS BY PROVINCE

Province	Weigh Stations
Nova Scotia	5
New Brunswick	7 + 13 portable
Newfoundland	7
Ontario	40
P E I	4
Quebec	33 + ? portable
Manitoba	10
Saskatchewan	18
Alberta	20
B C	36
Yukon	2?
N W T	2
Total	**184 + 13 portable**

A2.2.3Vehicular Cost

(a) Unit costs

Vehicle equipment required for operation compatible with roadside safety inspection includes on-board trip and cargo monitoring modules. Estimates for installed costs are based on the U.S. Architecture Study cost analysis (April 1996),

Table A2-6 On-Board Trip Monitoring Equipment(per vehicle)

Onboard cargo monitoring	$1,200
Mileage and Fuel Reporting Sensors	$350
Trip computer	$140
Total	**$1,690**

Although the life cycle of the on-board equipment - which for the most part should be transferable to a new vehicle - is expected to be some 10-15 years, new systems during this early development phase may make these devices redundant within 5-7 years.

(b) Expansion to National Level

The application of greatest concern is heavy trucks of which there are estimated to be 500 000 operating in Canada (Royal Commission on National Passenger Transportation 1992). Assuming that 90 % of all heavy trucks are fitted with trip and cargo monitoring in order to meet safety requirements, see assumed penetrations Section 2 of the main body, the total capital cost is: 0.9 x 500 000 x $1,690= $ 760,500,000. Based on a 10-year replacement life, the annualized cost are calculated as $123,901,670. Annual operating costs for this equipment, expected to be low, are estimated at $7,605,000, or 1% of capital. The overall annualized implementation costs therefore are: $131,506,000.

TABLE A2-7 - ARSI - NATIONAL COSTS

DESCRIPTION	**Installation** *Operation*	**Electronic** *Screening*	**Weigh-in** *-Motion*	**Safety** *Inspection*	**A R S I** *Totals*
Full, including CVO Detection	I = 46 x $ (	154900	+21000	+5600)	= **8349000**
	(O = 46 x $	*12880*	*+1680*	*+3220)*	*= 817880*
General with WIM & Safety Insp.	I = 46 x $ (		21000	+5600)	= **1223600**
	O = 46 x $ (		*1680*	*+3220)*	*= 225400*
Specialized for WIM only	I = 46 x $ (		21000	)	= **966000**
	O = 46 x $ (		*1680*	*)*	*= 77280*
Specialized for Safety Inspection	I = 46 x $ (			5600)	= **257600**
	O = 46 x $ (			*3220)*	*= 148120*
Total Installation Costs					**10796200**
Total Operation cost					***1268680***

A2.2.4 Benefits

Benefits from the use of Automated Roadside Safety Inspection are expected to arise from:

- reduced delays for trucks
- reduced fuel consumption and (CO+NOx+VOC) emissions for trucks
- reduced costs for road maintenance and rehabilitation
- lower accident rates due to more effective inspections and the parallel safety/ compliance campaign
- lower staffing cost for roadside inspection stations.

(a) Reduced Truck Delays

Reduced truck delays would accrue due to the greater efficiency of electronic inspection. No definitive figures are available for truck delays at inspection / weigh stations; therefore the following numbers, although considered reasonable, are provided more as an illustration of what may be possible:

- assume average truck delay reduced, conservatively, by 3 minutes per inspection (note: during congested periods, complete by-pass by premier carriers would save significantly more)
- total length of freeways and selected highways 24 000 km, therefore assuming 50% of inspection stations are located on these freeways and major highways, the average separation of inspection/weigh stations (24 000/50%*184) = 260 km
- annual average distance traveled by trucks = 44 448 km (Ref: Royal Commission Report, Vol 4 / Table 4.1)
- assume 75 % of travel on freeways/highways, the chance of a station being open <u>and</u> truck being stopped as 1/2, and of those stops two thirds being avoidable due to EC, then average (avoidable) weigh station stops per year = (0.75 x 44448 km / 260 km) x 1/2 x 2/3 = 42.5
- annual delays are then 42.5 x 3 min per truck, = 125.5 min
- at a cost of $ 38/h the total annual cost per truck = $ 80.75
- The total annual saving to all trucks is then (450 000 x $ 80.75) = $36,337,500.

(b) *Truck Fuel & Emissions*

The equivalent monetary value of the reduction in total annual truck fuel consumption is already incorporated through the above $38 / h time rate of the driver / carrier / truck. However, the actual litres (of fuel) consummed are required to arrive at corresponding emissions reduction. The annual fuel consumption reduction by Canadian (equipped) trucks, due to reduced idling (2.5 L / h) and stop-and-go / speed-change cycles (trucks = 6 x autos, during 1996) is 0.9 x 500 000 x [(125.5 min / a — 60 min / h) x 2.5 L / h (idling) + 42 stops / a x (1 cycle / stop x 6x79 L / 1000 cycles + 2 cycles / stop x 6x13.8 L /1000 cycles) (stop-and-go)] =14,600,000L / a

Assuming 30 L / 100 km truck fuel consumption , the mass of the high (environmental) cost emissions(CO/NOx / VOC) is calculated as:14,600,000L*.33km/l) x (14.38+7.36+1.59 g/km) = 11,367 tonnes/year

When converted to equivalent monetary units this corresponds to an annual national level savings of: $5,683,500 per year

(c) *Accidents*

Heavy trucks are estimated to be involved in 30 000 accidents including 3 % of serious accidents which cause 9 % of fatalities, for an average 500 fatalities and 9 500 injuries per year (Royal Commission on National Passenger Transportation 1992: Table 8(2)-15). Assuming that 10% of these accidents are due to safety infractions of which 50% could be avoided by automated safety inspections and that double the average injury charge (of $ 11 000) is applied due to a 2:1 ratio of serious vs. minor injuries when trucks are involved, the total annual value of injuries and fatalities in road accidents would be reduced by:

0.05 x (500 x $ 1 500 000 + 9 500 x $ 22 000 + 30 000 x $ 3 500) = $53, 000, 000.

(d) *Other Cost Savings*

Inspection Costs

For the purposes of this assessment, it is assumed that Automated Roadside Safety Inspection would result in a saving of one person year per station. The annual savings, using the 1.2 multiplier for salary+benefits would then be (184 x $ 35 000 x 1.2) = $ 7,728,000

Road Maintenance and Rehabilitation

Because of the enhanced ability to check truck weight and condition data, and track carrier compliance information in general, there will be a reduction in the damage done to roads by trucks with excess weight and worn-out/broken suspensions. However, for the purposes of this B/C assessment no estimate is prepared, nor benefits included.

(e) *Total Benefits*

A summary of the annual benefits due to the implementation of ARSI is then as follows:

• reduced truck delays (incl. reduced truck fuel)	$36,337,500.
• reduced truck emissions	$5,683,500
• reduced accidents	$53,000,000
• lower staff cost for inspection stations	$7,728,000
T o t a l (salary + benefits)	***$102,700,000***

A2.2.4 Benefit Cost Ratio

The benefit /cost ratios for automated roadside safety inspection applicable to the inspection authorities, society and the truck operators are :

	Benefits ($Ms)	**Costs ($Ms)**	**B/C**
Inspection authority + society	$66.3	$2.8	23:1
Truckers	$36.3	$131.5	0.27:1
Total	$102.7	$134.3	0.76:1

Ref: Study of Institutional Impacts of New Technology Applications: St. Clair & Detroit Rivers Highway Border Crossings (MMM et al; Fnl Report, May 1994)

1) Number of trips per year per customer (230/50/12/1) specified in Exhibit 8.2; multiply by 2 to obtain number of crossings.
2) Potential AVI enrollment, specified as (80/60/25/0) in Section 8.1.2, is modified to 80/60/30/10.
3) Total trucks based on: (30 V 460 + 40 V 100 + 25 V 24 + 5 V 2) - 100 = 2700000; V = 14666.
4) Total 1992 2-way truck crossings (Amb Br + D-W Tunnel + BW Br) given in Section 2.4 as: 1625000 + 299872 + 825295 = 2750167 ~ 2.7M
5) For medium traffic conditions the time savings per equipped (Y) truck estimated as: 30s (traffic) + 90s (C&I) = 120s = 0.03333h;

For 25% of the total 3520 trucks, making a total of 404800 crossings during medium traffic conditions, the total time savings is = 404800 x 0.03333h = 13493h.

APPENDIX B -Rural ITS Applications

B1 - Outline of Rural ITS Applications

B2 - Characterization of Retained Rural Applications

B3 - Benefit/Cost Assessment of Rural ITS in Canada - Input Data

B1 - Outline of Rural ITS Applications

	Application Description	Primary/Secondary User Services (Ref. Appendix B)	Targeted Users	Objectives (Ref. Appendix E)	Key ITS Functions/Technology	Potential Applications	Existing Similar Initiatives
1.	Hazardous Road Condition Warnings	(I) 1.1 (II) 1.4, 1.5, 2.2	All Intercity Travellers	1.1, 1.2, 2.2, 4.2, 5.1, 5.2, 5.3	Roadway Condition Sensors, Communications	Ont. Hwy 400, TCH Sections (variations Pre-Trip/In-Vehicle)	• BC Avalanche Warning System • TRAVEL-AID, Washington State
2.	Intermodal Traveller Information Systems	(I) 1.2 (II) 1.1, 1.3, 2.1, 2.2	Multi-Modal Travellers	2.1, 2.3, 3.1, 4.1, 5.2, 5.3	Kiosks, Agency Interfaces, Data Fusion, Communications	Rail, Air, Marine Terminals e.g. Victoria Ferry (variations Pre-Trip/In-Vehicle)	• PROMISE, Europe
3.	Road Availability/Accessibility in Arctic	(I) 1.2 (II) 1.1, 1.4, 2.1, 2.2	Remote Region Travellers	1.1, 1.3, 2.1, 4.2, 5.1, 5.2	Satellite, Road Sensors, Communications	Seasonal Roads in North	
4.*	Tourist Information Kiosks	(I) 1.3 (II) 1.1, 1.2, 1.5, 2.2	Tourist Travellers	2.3, 4.2, 5.2, 5.3	Electronic Data Transfer, Communications	Gas Stations, Rest Areas, Community Centres on TCH (variations Pre-Trip/In-Vehicle)	
5.	Park Traveller Information Systems	(I) 1.3 (II) 1.1, 2.2	Tourist/Park Travellers	2.1, 2.3, 4.2, 5.2, 5.3	Traffic Sensors, Video, EDT, Communications, CMS, HAR, Kiosks	Visitor Guide, Traffic Advisory, Reservation System for Banff	• Yosemite, California
6.	Collision Avoidance @ Intersections/Railway Crossings	(I) 1.4 (II) 1.1, 1.5	All Rural Travellers	1.1, 1.2, 1.3, 2.2	Traffic Detectors, Smart Controllers, Safety Barriers	At-Grade Crossings on TCH, Remote Intersections	• Smart Signal System, NJ
7.	Animal Crossing Warning System	(I) 1.4 (II) 1.1, 1.5	All Intercity Travellers	1.1, 1.2, 1.3, 2.2	Motion Detectors, CMS, Video, Communications	Along TCH sections prone to migratory patterns of large animals	
8.	Remote Incident Detection	(I) 1.5 (II) 1.1, 1.2, 6.1	All Intercity Travellers	1.1, 1.3, 2.1, 2.2, 3.1, 3.2, 4.2, 5.2	Cell Phone/Traffic Sensors, Smart Controllers, CMS, HAR, Communications	Located on known, accident prone sections of heavily travelled rural roads e.g. Highway 400.	• TRANSMIT, Washington, D.C. • Reach-75
9.	Portable Construction Zone Traffic Management System	(I) 1.5 (II) 1.1, 1.2, 2.2	All Intercity Travellers	1.1, 1.2, 1.3, 2.1, 2.2, 3.1, 3.2, 4.2, 5.2	Portable Traffic Sensors, Portable Video, Portable CMS, Portable HAR, OTA Communications	Bridge reconstruction/rehabilitation on TCH	• Intelligent Work Zone TMS, Minn.

	Application Description	Primary/Secondary User Services (Ref. Appendix B)	Targeted Users	Objectives (Ref. Appendix E)	Key ITS Functions/Technology	Potential Applications	Existing Similar Initiatives
10.	Border Crossing Pre-Clearance System	(I) 2.1 (II) 1.2, 1.4	International Travellers	2.1, 2.3, 3.1, 3.2, 4.2, 4.3, 5.1, 5.2, 5.3	AVI, EDT, Video, CMS, Sensors, Communications	Key U.S./Can. border crossing points e.g. Peace Bridge	• 2 operational tests on U.S./Mexico Boarder • NITEC
11.*	Road Weather Information System	(I) 2.2 (II) 1.1, 1.2, 1.5, 2.1	All Intercity Travellers	1.1, 1.2, 1.3, 2.1, 2.2, 5.2	Weather Sensors, Interfaces, Kiosks, Cable TV, Computers	Sections of TCH prone to adverse weather	• Arizona, Wyoming, Idaho, I-75 Fog Warning, RWIS, Minn.
12.	Ridesharing/Ride Matching Program	(I) 2.3 (II)	Rural Commuters	2.1, 3.1, 3.2, 4.1	Computer/Cable TV, software, Communications, Kiosks, Employer	Large rural employers	
13.	Ferry Electronic Payment and Reservation System	(I) 2.3 (II) 4.1	Ferry Users	2.1, 2.3, 3.1, 3.2, 3.3, 4.1, 4.2, 5.2, 5.3	AVI, Kiosks, Computer System	Manitoulin Island Ferry	
14.	Transit/Emergency/Maintenance Vehicle Monitoring/Scheduling	(I) 3.1, 6.2 (II)	Agency Operations	1.2, 2.3, 4.1, 5.1, 5.2	GPS/AVL Systems, Communications, Central Systems	Emergency/Maintenance Vehicle Monitoring on TCH Sections	• ARTIC, Minn. • Smart Bus
15.*	Rural Taxi Monitoring and Control System	(I) 3.3 (II)	Rural Taxi Users	2.3, 4.1, 4.2, 5.2	AVI, Driver ID, Communications	Air/Rail Terminal Access	• Pearson • Winnipeg
16.*	Electronic Toll and Traffic Management	(I) 4.1 (II) 1.1, 1.5	Toll Users	1.1, 2.1, 2.2, 2.3, 3.1, 3.2, 4.1, 4.2, 4.3, 5.2, 5.3	AVI, Video, Communications, CMS, HAR	Highway 407, PEI Fixed Link	
17.	SmartCard Tech. for Rural Transit	(I) 4.1 (II) 3.1	Transit Users	2.3, 4.1, 4.3, 5.2	Smartcard Technology	Rural transit operators	• Ajax • Mississauga
18.*	May Day/Emergency Request System	(I) 6.1 (II) 1.5	Travellers with Equipped Vehicles	1.1, 1.3, 2.3, 5.1, 5.2, 5.3	Cell Phone, Radio, Satellite Systems	Value added components/3rd party service	• PUSHME, Washington State • I-95 Corridor
19.	Call Box Systems	(I) 6.1 (II) 1.5	All Rural Travellers	1.1, 1.3, 2.3, 5.1, 5.2, 5.3	Call Box Systems	Heavily Travelled TCH Sections	• Many Interstate Sections
20.	Intercity Bus with On-Board Safety/Advisory Systems	(I) 7.5 (II) 7.1	Travellers with Equipped Vehicles	1.1, 1.2, 1.3, 2.1, 2.2, 2.3, 3.1, 3.2, 4.2, 5.2	Vehicle/Driver Sensors	New vehicle components	• VORAD, Voyageur • IVSAWS

B2 - Characterization of Rural ITS Applications

	RURAL TRAVELLER INFORMATION SYSTEMS	RURAL VEHICLE ELECTRONIC TRANSACTION SYSTEMS	RURAL SAFETY SYSTEMS
GOALS	Reduce the number and severity of accidents and other incidents; Reduce congestion due to incidents; Reduce traveller stress and uncertainty; Reduce road and intermodal travel times; Improve intermodal transportation utilization; Reduce travel costs incurred by fleet operators, operating agencies and individuals.	Increase capacity at toll plazas and border crossings; Improve convenience of toll payment; Reduce fuel consumption and harmful emissions; Reduce travel time; Reduce costs incurred by fleet operators, toll agencies, customs agencies and individuals; Reduce traveller stress.	Reduce the frequency and severity of accidents and other incidents; Reduce congestion due to incidents; Enhance traveller security/reduce stress; Reduce travel times; Reduce fuel consumption and harmful emissions.
DESCRIPTION	Rural Traveller Information Systems include: Hazardous Road Condition Warnings - inform motorists of adverse travel conditions (e.g. weather, construction, incidents, rock slides etc.) before they are encountered; Intermodal Traveller Information - provide travellers with real-time schedule/operations information for rail, air, marine and bus services;	Electronic Toll Collection - The toll levy is transacted electronically (e.g. using Automatic Vehicle Identification / Vehicle-Roadside Communications Technology) which permits time savings for highway users and reduces the toll collection cost for the operating agency. Border Crossing Clearance Systems - Travellers and goods may make their declarations prior to reaching the border and pass them electronically to border inspectors. The electronic transfer of information may use technologies such as automatic vehicle identification and thereby permit travellers to reduce time and stoppages currently typical at border crossings and allow federal governments to minimize the cost and maximize the efficiency of border clearance systems.	Rural Safety Systems include: Portable Construction Zone Traffic Management System (TMS) - monitors construction zone conditions and informs motorists of lane restrictions, delays, queue locations, etc. before they are encountered; Intersection/Railway Crossing Collision Avoidance - provides motorists with consistent advance warning of conflicting traffic at roadway intersections and railway grade crossings.

	Tourist Information Kiosks - provide guidance to and information/schedules for local tourist attractions; Road Weather Information Systems - collect information on weather conditions and distribute to motorists, maintenance crews, emergency response personnel, etc. In all cases, information can be provided pre-trip or in-vehicle. The intent is to allow travellers to: avoid hazardous situations or be prepared to encounter them; plan trips to avoid delays and minimize overall travel time.		
TARGET	All Rural Traveller Information Systems target all intercity/rural travellers. Particular target groups are: Multi-modal travellers for Intermodal Traveller Information Systems; Tourist travellers for Tourist Information Kiosks	Toll users; International travellers.	All intercity/rural travellers for the Portable Construction Zone TMS; All travellers with equipped vehicles for Collision Avoidance at Intersections/Railway Crossings.
SITES	Hazardous Road Condition Warnings and Road Weather Information System - isolated roadway segments with moderate to heavy traffic and a history of problematic weather/road conditions; Intermodal Traveller Information Systems - intermodal exchange points, i.e. rail, air, marine and bus terminals; Tourist Information Kiosks - gas stations, rest areas, community centres, parks, etc. at or near tourist attractions.	Electronic Toll Collection - Toll facilities in rural settings throughout Canada, including the Northumberland Strait Bridge, Highway 407 in Ontario, bridges and tunnels connecting the United States and Canada, various other major bridges and tunnels as well as ferries. Border Crossing Clearance Systems - more than 20 major border crossing sites between Canada and the United States. B/C assessment was carried using the Peace Bridge toll and border crossing operation connecting Fort Erie, ON with Buffalo, NY.	Portable Construction Zone TMS - major construction zones on rural roadway sections with moderate to heavy traffic, particularly in locations with restricted cross section/geometry and/or sight distances. Intersection/Railway Crossing Collision Avoidance - rural highway sections with a history of intersection and/or grade crossing collisions. The section of the Trans Canada Highway (Hwy. 1/97) through the Rockies between Revelstoke and Kamloops in British Columbia was used for the B/C assessment. This section includes 7 major intersections, but no railway grade crossings.

	The B/C assessment was carried out on the section of the Trans-Canada Highway (Hwy. 17) between Sudbury and Sault Ste. Marie in northern Ontario. This isolated section of highway includes several towns and villages providing traveller/tourist services and has intermodal transfer points for bus, rail, air and marine (ferry) modesy		All B/C calculations for the railway grade crossing collision avoidance application were done at the national level
METHOD	Data would be collected from: • road surface condition sensors; • weather condition sensors • road users (by cellular phone, CB radio, etc.);; road maintenance and police patrols • closed circuit television or special sensors (e.g. avalanche/rock slide detectors) for critical areas; • transportation system and tourist attraction operators. Data form these sources would be processed into reports for dissemination, either locally or at a central facility.	Both modules involve the application of Vehicle to Roadside Communications (DSRC) to exchange information between the vehicle and roadside equipment. For electronic toll collection: Highway operators fund the implementation of roadside equipment (e.g. AVI card readers) communications systems and a central system (hardware and software) to facilitate electronic funds transfer; May also require the involvement of the financial community to act as credit providers and fund holders, integrated with the various other financial instruments and accounts that most travellers would have access to.	Portable Construction Zone TMS - Construction contractor or highway agency deploys CCTV cameras, portable CMS as well as, possibly, temporary vehicle detectors, HAR and DSRC in the construction zone in addition to the regular traffic control devices and radio communications system. Field equipment is connected to a computer in an on-site "control centre" where conditions are monitored and appropriate response messages generated. Intersection/Railway Crossing Collision Avoidance - Detectors placed on the intersecting facility detect the speed and direction of approaching vehicles or trains.
	Information would be distributed through some or all of the following channels: • commercial television or radio (pre-trip) highway advisory radio (HAR) or commercial radio (in-vehicle); • in-vehicle display devices (not included for B/C assessment); • road-side computerized information kiosks • ; ··changeable message signs at entrances to monitored roadway segments (road and weather condition advisories only).	In the case of the border crossing systems: federal departments (occasionally coupled with bridge/tunnel commissions) would be responsible for the implementation of highway/roadside infrastructure, communications and central systems; Central system requires interface with both customs and immigration systems; require interfaces with other federally supported systems such as truck safety, commercial vehicle registration, etc.	As a DSRC-equipped vehicle approaches the intersection / crossing, its speed is measured and a local processor calculates whether a collision is possible. The driver of the DSRC-equipped vehicle is given an audible/visual warning, as a supplement to existing traffic control devices, if a collision could occur.
TECHNOLOGIES	On-Board Vehicles:	On-Board Vehicles - Automatic Vehicle Identification / Vehicle-Roadside Communications transponder tags, Type II+ (read-write capability with three-colour LED display) would be required to support these modules.	On-Board Vehicles:

	·AM/FM radio for receiving HAR and commercial broadcasts;	Other on-board equipment could include smartcard readers for tracking revenue (for toll collection) or personal identification (for border crossing). The simple display of the Type II+ transponder or audio capabilities may be used in the vehicle to advise motorists of transaction difficulties in the event of toll collection or authorize clearance in the border crossing application.	·Construction Zone TMS: AM/FM radio for receiving HAR broadcasts;
	Enhanced display device with vehicle to roadside communications (DSRC) link.	Roadside - License plate reader systems are typically required for both modules. Communications systems are required to communicate both video and data from field equipment to a central location.	Construction Zone TMS and Collision Avoidance: simple display device with DSRC link;
	Road-Side:	Peripheral Equipment - At the control centre both hardware and customized software are required for the application. Monitors, communication switching equipment and communications equipment for links with external information sources would also be required.	Road-Side:
	HAR and DSRC transmitters;		Construction Zone TMS and Collision Avoidance: DSRC readers;
	Road/weather condition sensors;		Construction Zone TMS: temporary CCTV cameras, vehicle detectors, HAR transmitter, portable CMS and field equipment communications;
	Data acquisition/controller units with communications links and/or local processing hardware/software as required;		Collision Avoidance: vehicle/train presence and speed detectors, control/processing units and field equipment communications.
	Changeable message signs (CMS);		Peripheral Equipment:
	Information display kiosks/terminals (at gas stations, rest areas, intermodal terminals, tourist attractions, etc.).		Construction Zone TMS: on-site control centre with central computer, video and communications equipment;
	Peripheral Equipment:		
	Central data fusion/ communications/control centre;		
	Autofax for automatic dissemination of information to media and response personnel;		

	Wireless communications with remote devices; Power supply for remote devices.		
STAKE-HOLDERS	Road Users: all intercity travellers (includes tourists and truckers); road maintenance and emergency response agencies; commercial vehicle operations companies. Others: rail, air, marine and bus system operators; local area business/tourist attraction operators; local area broadcasters, TV and radio; federal, provincial and municipal governments (transportation and tourism agencies).	Toll users; international travellers; international cargo shipments by truck; toll agencies and private highway operators; Canadian customs and immigration; automobile manufacturers and equipment suppliers; departments responsible for vehicle registration, vehicle safety, customs and immigration information, security; financial community.	Road Users: all intercity travellers; road maintenance and construction crews/contractors. Others: rail system operators; vehicle manufacturers and equipment suppliers; federal, provincial and municipal governments (transportation agencies).
PRE-REQUISITES	New/modified regulations may be required to govern collection/distribution of tourist information; Agreements with broadcasters required for dissemination of information;	Application of full automated toll road systems is currently being demonstrated at a few sites in North America. An application of the border crossing systems and second generation electronic toll systems is planned for demonstration over the next 12 to 18 months. Technology advances are required for inter-operability of AVI/DSRC equipment and standards must emerge to ensure multiple applications are secure and easily accessible using DSRC technology	Sufficient base of equipped vehicles and intersections/crossings required for implementation of Collision Avoidance Systems; Regulatory approval required for Construction Zone HAR transmitters;

	Regulatory approval required for HAR transmitters.		Regulatory approval may be required for modifications to railway signalling systems.
SYNERGIES	DSRC infrastructure and in-vehicle display useful for other applications within Rural Transportation as well as a variety of Interurban Freight, Urban and Other ITS applications; Communications system could be used for Rural Safety Systems, Interurban Freight and Other ITS applications;	This group of applications could provide the in-vehicle equipment necessary to provide traveller information to the drivers. Border crossing handling of commercial vehicle shipments may overlap in terms of information exchange and on-board technology with inter-urban freight applications.	DSRC infrastructure and in-vehicle display useful for other applications within Rural Transportation as well as a variety of Interurban Freight, Urban and Other ITS applications; Data from Construction Zone TMS can be used in Hazardous Road Condition Warnings;
	Changeable message signs, HAR and kiosks can be used by Rural Safety Systems; Information from Urban Traveller Information Systems can be provided to rural travellers destined for urban areas, and information from Rural Traveller Information Systems can be provided to urban travellers destined for rural areas; Data collected for Rural Safety Systems can be used for Hazardous Road Conditions Warnings; Rural Traveller Information Systems improve conditions for efficient interurban freight transportation.	Vehicles equipped with DSRC equipment could be used as probes for traffic management applications in both urban and rural settings. The presence of AVI equipment on-board vehicles could permit synergistic efforts with private sector for such initiatives as: Non-stop access to parking structures; - provision of private sector information such as advertising en-route; - traveller and vehicle identification for security access for large employers.	Rural Safety Systems improve conditions for safe and efficient interurban freight transportation. Key general assumptions used in the B/C assessment include:
ASSUMPTIONS	Key general assumptions used in the B/C assessment include: All vehicles are equipped with an AM/FM radio which can receive HAR broadcasts;	Key general assumptions used in the B/C assessment include: 60% of commercial vehicles and 33% of private vehicles using an equipped toll or border crossing facility will be equipped with Type II+ DSRC transponder tag;	• 45% of commercial vehicles and 25% of private vehicles will be equipped with DSRC and a simple display device; • The in-vehicle equipment required is pre-existing, installed for other ITS applications (e.g. electronic toll collection or border crossing clearance systems);

	Benefits include reduced accidents, travel time, fuel consumption and emissions;	Expected benefits include reduced time, fuel consumption and emissions for vehicles using the facility, reduced operating costs for toll and border crossing operations;	• All vehicles are equipped with an AM/FM radio which can receive HAR broadcasts;
	Construction can be used to represent other, more difficult to quantify, hazardous road conditions;	Existing Canada Customs staff will be used to operate the border crossing pre-clearance system, so there is no staff cost increase from implementation of this application;	Benefits include reduced accidents, travel time, fuel consumption and emissions.
	Intercity AADT and total travel (veh-km) data provided by Transport Canada include only vehicles travelling end to end over a roadway segment; effects of local traffic are represented by a 50% increase applied to the base numbers.	Costs and benefits for the border crossing system will be shared between US and Canada Customs, but only those relevant to Canada Customs will be considered in the analysis.	Other assumptions are detailed in the B/C assessment input data included in Appendix 2.
	Other assumptions (e.g. percentage of travellers using a service) are detailed in the B/C assessment input data included in Appendix 2.	Other assumptions are detailed in the B/C assessment input data included in Appendix 2.	

B3 Benefit/Cost Assessment of Rural ITS in Canada -

B3.1 RURAL TRAVELLER INFORMATION SYSTEMS

B3.1.1 Input Data

(a) Services

A. Hazardous Road Condition Warnings
B. Intermodal Traveller Information
C. Tourist Information Kiosks
D. Road Weather Information Systems

(b) Study Corridor Description

Location:	Hwy. 17,	Sudbury - Sault Ste. Marie
Length:	302km	
Intercity AADT:	3,800	
Total Travel:	434	million vehicle-km
Commercial Travel:	60	million vehicle-km
Passenger Travel:	374	million vehicle-km

(c) Related Corridor Information

A.	Avg. Annual # of Lane-Blocking Events in Hazardous Conditions	16
B.	# of Terminals	
	Ferry	1
	Rail	3
	Air	4
	Bus	10
C.	Tourist Attractions/Services	10 towns/villages
D.	# of Annual Weather-Related Traffic Events	2,521
	# of Annual Weather-Related Road Closures	2

(d) Related general information

A. Uses construction as a stand-in for all "hazardous road conditions", since other conditions are difficult to quantify

% roads resurfaced per year = 7% Ontario Design Method

% roads reconstructed per year = 3% Ontario Design Method

related incidents = 10% increase during construction

B. # terminals:

Ferry = 1
Ferry Service per Day = 5 months a year, 4 times daily ≈ 2 per day
Rail = 2 stations + 1 transfer point
Airports = 4 total (2 major, 1 secondary, 1 local)
Bus Service per Day (at 10 stations):

Sault St. Marie to Sudbury 4 times per day (7 days)
Sudbury to Sault St. Marie 4 times per day (7 days)
Little Current to Espanola 4 times per day each way (5.5 days per wk)
Serpent River to Elliot Lake 4 times per day each way

C. Tourist Attractions

4 provincial parks
4 picnic parks
10 towns/villages

D. AR (1992) = 0.8 (averaged MTO Traffic Volumes 1992 Report)

accidents = .8 × (434 million veh-km though traffic + 217 million veh-km local traffic)

= 521 accidents per year

- # incidents = 10 × # accidents (Highway 417 CCTV Study - MTO)
- therefore 5731 events (incidents + accidents) annually

% accidents by road conditions (based on Ottawa Highway 17 WB 1988):
Clear = 71/126 = 56%
Wet = 16 = 13%
Light Snow = 8 = 6%
Slush = 8 = 6%
Packed Snow = 1 = 1%
Ice = 20 = 16%
Gravel = 2 = 2%

- 44% of accidents when roads not clear = 229 accidents

average # of road closures per year due to weather = 2 (local resident estimate)
average cost of accident (Transport Canada):
Property Damage = $3,454
Personal Injury = $29,606 Serious injury in rural areas)
Fatal = $1,569,912

B3.1.2 Estimation of Benefits

A. ***% of Vehicles reached = 80% (a.m. radio)***
11.4% incident reduction for equipped vehicles (Transport Canada recommendation)

- assume incident blocks road completely (during construction) for one hour and that incidents on shoulder do not affect traffic (low volume)
- assume that 80% of traffic volume occurs during 12 hour period
- assume that 80% of traffic events occur during same 12 hour period
- if average arrival rate of vehicles is assumed over a one hour period (duration of incident) then the average time a vehicle is delayed is 30 minutes (see attached document, "ESTIMATION OF DELAY DUE TO TRAFFIC EVENTS" for details)
- average number of vehicles delayed = 253 vph (AADT × 80%/12) through traffic + 127 vph (50%) local traffic = 380 vph
- 380 vph × 30 min = 11,400 veh-min = 190 veh-hr per event

Total distance in corridor = 302 km

- % study area resurfaced annually = 7% (Ontario Pavement Design Method) = 21 km
- % study area reconstructed annually = 3% (Ontario Pavement Design Method) = 9 km
- assume resurfacing at rate of 1 km per day (IBI)
- assume reconstruction in minimum 7 km segments at one per season (4.5 months)
- assume annual construction is equivalent to 3.5 km for entire year
- assume accident rate constant over the year
- overall accident rate = 0.8
- non-construction area rate = 0.799
- construction area rate = 0.879
- difference = .0799 = .08 (10%)
- travel in construction = 7.28 million veh-km (including local traffic)
- average annual # of accidents in construction zones = .879 × 7.28 = 6.4

% of property damage accidents = 80% (IBI) = 360
% of personal injury accidents = 20% (IBI) = 88
% of fatal accidents = 1.3% of personal injury accidents (ITE - Traffic Engineering Handbook) = 0.26%

Average cost = 3,454×.8 + 29,606×.1974 + 1,569,912×.0026 = $12,689

- system benefits apply to all equipped vehicles travelling through construction (hazard) zones, so accident reduction = 6.4 × 80% × 11.4% = 0.584

  cost of accidents = 12,689 × 0.584

= $7410

- # incidents = 10 × # accidents (Highway 417 CCTV Study - MTO)
- therefore 70 events (incidents + accidents) in construction zones
- % incidents on shoulder = 84% (IBI 1985 Ottawa Queensway Report)
- % accidents on Shoulder = 7.2%
- % events on Shoulder = 77%
- reduction in delay only applies to events on the roadway = 23%
- events on roadway = 16 events/year
- average reduction in events on roadway during peak 12 hours of the day = 16 × 80% of motorists reached × 80% of events × 11.4% event reduction = 1.17 events/year

Cost of Time = 1.17 × 190 veh-hr/event × 9.10 $/hr (Transport Canada B/C Book)

= $2023

Fuel Savings = 1.17 × 190 veh-hr/event × 2.1 L/hr (MTO)× $.55/L

= $257

Emissions Savings annually (MTO):

Hydrocarbons (63.9 g/veh-hr) = 14 kg
Carbon Monoxide (604.8 g/veh-hr) = 134 kg
Nitrogen Oxide (118.1 g/veh-hr) = 26 kg
Carbon Dioxide (15,240 g/veh-hr) = 3388 kg

Economic cost of emissions **=$449**

Total = <u>$10,139</u>

B. Saved Time at Connection

- assume 50% of people making connection use the service
- assume save 5 minutes on average
- assume 100 people per ferry (capacity 140 vehicles w/ 70% utilization rate)
- assume buses half full (20 passengers, average)
- assume 150 people per day take the train
- assume 20 flights daily with average of 50 passengers

Ferry = 4 sailings × 100 passengers × 50% × 5/60 hr × 153 days = 2,550 person-hrs/yr

Rail = 150 passengers × 50% × 5/60 hr × 365 days = 2,281 person-hrs/yr

Airport = 20 flights × 50 passengers × 50% × 5/60 hr × 365 days = 15,208 person-hrs/y

Buses = 22.3 buses/day (average) × 20 passengers × 50% × 5/60 hr × 365 days = 6,783 person-hrs/yr

Total Time Savings = 26,822 person-hours per year

Cost of Time = 26,822 person-hr × 9.10 $/hr (TransCan B/C Book)

Total = $244,080

C. ***Assume 10% of travellers use the information service.***

Assume travellers who use the service spend an average of $1 per car more in the local area.

Circuitous travel saved

- IBI estimate: circuitous travel = 7% of km of travel

= 10% × 7% × 3800 (intercity AADT, not local traffic) × 50 km/50 km/hr
= 26.6 veh-hr daily = 9,709 veh-hr annually

Cost of Time = 9709 veh-hr × 9.10 $/hr (TransCan B/C Book)

= $88,352

Fuel Savings = 9709 veh-hr × 12 L/100 km × 50 km/hr × $.55/

= $32,040

Emissions Savings annually (MTO):

Hydrocarbons (63.9 g/veh-hr) = 620 kg
Carbon Monoxide (604.8 g/veh-hr) = 5,872 kg
Nitrogen Oxide (118.1 g/veh-hr) = 1,147 kg
Carbon Dioxide (15,240 g/veh-hr) = 147,965 kg

=$19,705

Economic Benefits = $1/car × 380 = $380/day

= $138,700

Total = $ 278,797

D. *Event Delay Savings*

- assume 80% of motorists are reached by the system (am radio)
- assume 11.4% incident reduction (Transport Canada recommendation)
- 229 accidents annually during poor weather
- # incidents = 10 × # accidents (Highway 417 CCTV Study - MTO)
- therefore 2519 events annually
- reduction of 2519 × 80% × 11.4% = 230 events
- average event duration = 1 hour
- average traffic volume = 240 vph (including local traffic)
- average delay = 30 minutes
- % incidents on shoulder = 84% (IBI 1985 Ottawa Queensway Report)
- % accidents on shoulder = 7.2%
- % events on shoulder = 77%
- reduction in delay only applies to events on the roadway = 23%
- annual delay = .5 hr × 240 vph × 230 events × .23 = 6,348 veh-hr annually

Fuel Savings = 6,348 veh-hr × 2.1 L/veh-hr × $.55/L

= $7,332

Closure Delay Savings

closures per year due to weather = 2 (local resident estimate)

Average duration of closure info benefit (over existing condition) = 3 hours ≡ 720 veh

- assume 25 % divert to alt route which takes same time
- save average of 300 km (end to halfway point and back) = 6 hours

annual delay = 2 closures × 6.0 hours delay × 25% × 720 = 2160 veh-hours annually

- 75% return to last town
- save 33.5 km (average distance between towns) ≡ 40 minutes (at 50 km/h)
- assume average closure covers half of total distance or 4.5 lengths between towns
  annual delay = 2 × 40 min × 75% × 720 × 4.5 = 3240 veh-hours annually

Total time saving = 11,748 veh-hours annually

Cost of Time = 11,748 veh-hr × 9.10 $/hr (TransCan B/C Book)

= $106,907

Fuel Savings = 5400 veh-hr × 6 L/veh-hr(50 km/hr) × $.55/L

= $17,820

Emissions Savings annually (MTO):

Hydrocarbons (63.9 g/veh-hr) = 751 kg
Carbon Monoxide (604.8 g/veh-hr) = 7,105 kg
Nitrogen Oxide (118.1 g/veh-hr) = 1,387 kg
Carbon Dioxide (15,240 g/veh-hr) = 179,040 kg

=$23,882

Total Benefit = $156,341

TOTAL BENEFIT ON STUDY CORRIDOR = $689,357 ANNUALLY

B3.1.3Scale-up of Benefits to National Intercity Highway Network

Study Corridor Total Travel (million vehicle-km)	434	
National Intercity Highway Network Total Travel (million vehicle-km)	53,579	
Multiplier (National Network/Study Corridor)	120	
Estimated Annual Benefits on National Intercity Highway Network, Base Year		**$82,722,840**
Traffic Growth Rate (per year)	1%	
Estimated Annual Benefits on National Intercity Highway Network, Year 10		**$90,995,124**

B3.1.4Calculation of Costs

(a) Capital Costs Summary

Central control facilities (in existing building) = $50,000

HAR transmitters (not including towers) = 6 @ $15,000 = $ 90,000

Road/Weather Condition Sensors= 9 @ 50,000 = $ 450,000 + $50,000 central processor

processing hardware/software= $50,000 (including autofax)

CMS= 2 @ 75,000 = $150,000

kiosks= 10 @ 10,000 = $100,000

power supply for remote devices= 27 @ 1,500 = $40,500

Total = $980,500

(b) ***Operating Costs***

assume 10% capital cost, including communications

= $98,050

CALCULATION OF COSTS

Capital Cost	**Qty.**	**$/Unit**	**Total**
HAR Transmitters	6	$15,000	$90,000
Road/Weather Sensors	9	$50,000	$450,000
Processing Hardware/Software	2	$50,000	$100,000
CMS	2	$75,000	$150,000
Kiosks	10	$10,000	$100,000
Central Control Facility	1	$50,000	$50,000
Power Supply	27	$1,500	$40,500
Total Estimated Capital Cost on Study Corridor			**$980,500**
Annual Value of Total Estimated Capital Costs on Study Corridor (10%, 10 yr.)			**$159,570**
Operating Costs			
Maintenance & Operations @ 10% of Capital Cost/Year			**$98,050**
Total Estimated Annual Value of Costs on Study Corridor			**$257,620**

B3.1.5 Scale-Up of Costs to National Intercity Highway Network

Study Corridor km	302
National Intercity Highway Network km	43 398
Multiplier (National Network/Study Corridor)	140
Estimated Annual Value of Costs on National Intercity Highway Network	**$36,066,800**

B3.1.6BENEFIT/COST SUMMARY

	Base Year	**Year 10**
Estimated Annual Value of Benefits	$82,722,840	$90,995,124
Estimated Annual Value of Total Costs	$36,066,800	$36,066,800
Benefit/Cost Ratio	2.29	2.53

B3.2 - VEHICLE ELECTRONIC TRANSACTION SYSTEMS

B3 2.1Related information

A.

 # Annual Toll Transactions at Peace Bridge going into Canada = 4.05 million (Richard Zavergiu report - page 2, assuming 50/50 directional split)

Average Toll Transaction Time = 20 second (Peace Bridge administration estimate)

Annual Transactions at all Canadian Toll Facilities = 10 million

B. # Vehicles passing through Canadian Customs = 4.05 million (RZ Report)

Average Customs Transaction Time, passenger = 20 s (Canada Customs)
Average Customs Transaction Time, commercial = 1 min (Canada Customs)

Annual # of Canada Customs Vehicle Transactions (Statistics Canada, International Travel, Internal Files, January 1996):

- Total number of cars (based on 1994, most recent complete year of data) = 24,400,000
- % Trucks = 12% (Census Canada for Ontario), so total number of trucks = 3,327,000
- total number of vehicles = cars + trucks = 27,727,000

B3.2.2Estimation of Benefits

A. Transaction Time = 20 seconds
Queued Time = 20 seconds

Max Time Saving = 40 sec/veh

% Trucks = 12% (Census Canada for Ontario)

Number of commercial vehicle trips with auto-toll device = 60% = 4.05×12%×60%= 291,60

Number of passenger vehicle trips with auto-toll device = 33% = 4.05×88%×33%=1,176,12

Total number of vehicle trips with auto-toll device = 1,467,720

Transaction Time Saving = 40 s × 1,467,720 = 16,308 veh-hr annually

Cost of time for trucks = $18/veh-hr (J. Parviainen)

Cost of Time = 291,600 veh × 40/3600 hr × \$18/veh-hr + 1,176,120 veh × 40/3600 hr × \$9.10/veh-hr(TransCan B/C Book)

= \$177,239

Fuel Savings = 16,308 veh-hr × 2.1 L/veh-hr (MTO) × \$.55/L

= \$18,835

Emissions Savings annually (MTO):

Hydro Carbons (63.9 g/veh-hr) = 1,042 kg
Carbon Monoxide (604.8 g/veh-hr) = 9,863 kg
Nitrogen Oxide (118.1 g/veh-hr) = 1,926 kg
Carbon Dioxide (15,240 g/veh-hr) = 248,534 kg

=\$33,153

Toll Operating Cost = 5 staff @ \$40,000/year/booth

= \$200,000

Total = \$429,227

B. Average Time Queued = greater than 1 minute, 40 seconds

Transaction Time Saving = 2 minutes per vehicle (Richard Z report)

% Trucks = 12% (Census Canada for Ontario)

Number of commercial vehicle trips with DSRC module = 60% = 4.05×12%×60%= 291,600
Number of passenger vehicle trips with DSRC module = 33% = 4.05×88%×33%=1,176,120
Total number of vehicle trips with DSRC module = 1,467,720

Transaction Time Saving = 2 min × 1,467,720 = 48,924 veh-hr annually

Cost of Time = 291,600 veh × 2/60 hr × \$18/veh-hr + 1,176,120 × 2/60 hr × \$9.10/veh-hr

= \$531,716

Fuel Savings = 48,924 veh-hr × 2.1 L/veh-hr (MTO) × \$.55/

= \$56,507

Emissions Savings annually (MTO):

HydroCarbons (63.9 g/veh-hr) = 3,126 kg
Carbon Monoxide (604.8 g/veh-hr) = 29,589 kg
Nitrogen Oxide (118.1 g/veh-hr) = 5,778 kg
Carbon Dioxide (15,240 g/veh-hr) = 745,601 kg

=\$99,439

Toll Operating Cost = 5 staff @ 40,000/year/booth

= $200,000

Total = $887,662

Total Estimated Benefits at study site = $1,316,889

B3.2.3Scale-up of Benefits to National Intercity Highway Network

Study Site Transactions (Toll & Customs)	8,100,000	
National Intercity Highway Network Total Transactions	32,181,600	
Time/Fuel Savings Multiplier (National Network/Study Site)	3.97	
Number of Equipped Facilities (Operating Cost Savings Multiplier)	35	
Estimated Annual benefits on National Intercity Highway Network, Base Year		**$17,727,000**
Traffic Growth Rate (per year)	1%	
Estimated Annual Benefits on National Intercity Highway Network, Year 10		**$19,500,000**

B3.2.4Calculation of Costs

Capital Cost

- synergies of equipment and technology for two applications
- based on RZ report for 4 applications
- Cost of toll and customs facilities = 2/3 × $2.63 Million (RZ Report) = 1.75 Million
- Cost of Customs or Toll facilities only = 1.25 million
- Cost of DSRC modules = $50 per unit (IBI estimate)
  assume 1,467,720 trips by vehicles with DSRC module = 5870 vehicles making an average of 1 trip per day for 250 days per year.
- total cost for DSRC modules = 5870 × $50

TOTAL $293,500

Operating Costs

Maintenance = 10% of capital cost per year (RZ Report)

- include capital cost for transponders in calculation to represent annual registration fee
  $204,350 per year (toll and customs)
  $154,350 per year (toll or customs only)

B3.2.5Scale-up of Costs to National Intercity Highway Network

Number of Rural Toll Facilities = 4 (IBI)

Number of Border Crossing Toll and Customs Facilities = 8 (map count)

Number of Border Crossings with custom facilities only = 54 (map count)

Assume 80% of traffic crosses at 50% of border crossings (including the 8 toll/customs facilities) for scaling of costs and benefits

Estimated Annual Value of Total Costs on National Intercity Highway Network

TOTAL $15,245,210

B3.2.6 BENEFIT/COST SUMMARY

	Base Year	Year 10
Estimated Annual Value of Benefits	$17,727,000	$19,500,000
Estimated Annual Value of Total Costs	$15,245,210	$15,245,210
Benefit/Cost Ratio	1.16	1.27

B3.3 - RURAL SAFETY SYSTEMS

B3.3.1 Related information

A. ***% roads resurfaced per year = 7% (Transport Canada)***
% roads reconstructed per year = 3% (Transport Canada)

\# related incidents = 10% increase during construction

B. ***AR = 0.7 (MOTH average for two lane rural Highways with AADT 5,000-10,000 in B.C.) = 2***
% of property damage accidents = 80% (IBI) = 205
% of personal injury accidents = 20% (IBI) = 51
% of fatal accidents = 1.3% of personal injury accidents (ITE - Traffic Engineering Handbook) = 0.26% = 1 accident
% of rural accidents occurring at intersections = 19.4% (ITE - Traffic Engineering Handbook)
\# of intersection collisions = 257 × 19.4% = 50

C. ***# of railway grade crossings = 23,225 (Transport Canada)***
Busiest 5% of railway grade crossings = 1158 (Transport Canada)
Annual accidents at busiest 5% of railway grade crossings = 1092 (Transport Canada)
Average AADT at busiest 5% of railway grade crossings = 12,338 (Transport Canada)

B3.3.2Estimation of Benefits

A. Technology reaches 100% of motorists
Incident Reduction = 11.4% (Transport Canada recommendation)

- assume incident blocks one direction of travel on the road completely (during construction) for one hour and that incidents on shoulder do not affect traffic (low volume)
- assume that 80% of traffic volume occurs during 12 hour period
- assume that 80% of accidents occur during same 12 hour period
- average number of through vehicles delayed = 163 through traffic (AADT×80%/12/2) + 82 for local traffic (50%) = 245 vph
- average delay = 30 minutes
- total delay = 7350 veh-min = 122.5 veh-hr per event

Total distance = 205 km

- % study area resurfaced annually = 7% = 14 km
- % study are reconstructed annually = 3% = 6 km
- assume resurfacing at rate of 1 km per day (IBI)
- assume reconstruction in minimum 7 km segments at one per season (4.5 months), so 12 km reconstructed over 4.5 months every second year
- assume annual construction is equivalent to 2.3 km for entire year
- assume accident rate constant over year
- overall accident rate = 0.7
- non-construction area rate = 0.699
- construction area rate = 0.769
- difference = 0.07
- travel in construction = 6.17 million veh-km (including local traffic)
- average annual # of accidents in construction zones = 0.769 × 6.17 = 4.7

- average cost of accident (Transport Canada):

Property Damage = $3,454
Personal Injury = $29,606
Fatality = $1,569,912
Average = 3,454×.8 + 29,606×.1974 + 1569912×.0026 = $12,689

- system benefits apply to all vehicles travelling through construction, so
  accident reduction = 4.7 × 11.4% = .54
  cost of accidents = 12,689 × .54

= $6,852

- # incidents = 10 × # accidents (Highway 417 CCTV Study - MTO)
- therefore annual average of 52 events in construction zones
- % incidents on shoulder = 84% (IBI 1985 Ottawa Queensway Report)
- % accidents on shoulder = 7.2%
- % events on shoulder = 77%

- reduction in delay only applies to events on the roadway = 23%
- events on roadway = 12 events/year
- reduction in events on roadway during peak 12 hours of the day = 12 × 11.4% × 80%

  = 1.09 events/year

Cost of Time = 1.09 × 122.5 veh-hr/event × 9.10 $/hr (TransCan B/C Book)

= $1,215

Fuel Savings = 1.09 × 122.5 veh-hr/event × 2.1 L/hr (MTO)× $.55/L

= $154

Emissions Savings annually (MTO):

HydroCarbons (63.9 g/veh-hr) = 8.5 kg
Carbon Monoxide (604.8 g/veh-hr) = 81 kg
Nitrogen Oxide (118.1 g/veh-hr) = 16 kg
Carbon Dioxide (15,240 g/veh-hr) = 2035 kg

=$272

Total = <u>$8,493</u>

B. equipped vehicles = 45% commercial and 25% private

% total vehicles equipped = .45×.0736 + .25×.9264 = 26.5%

\# of preventable intersection collisions = 50 × 26.5% × 1.5 (including 50% local traffic)

= 20 accidents

average cost of accident (Transport Canada):

Property Damage = $3454
Personal Injury = $29,606 (Serious injury rural accidents)
Fatality = $1,569,912
Average = 3454×.8 + 29,606×.1974 + 1,569,912×.0026 = $12,689

cost of preventable accidents = 12,689 × 20

= $253,780

Cost of Time = 20 × 122.5 veh-hr/event × 9.10 $/hr (TransCan B/C Book)

= $22,295

Fuel Savings = 20 × 122.5 veh-hr/event × 2.1 L/hr (MTO)× $.55/L

= $2,830

Emissions Savings annually (MTO):

HydroCarbons (63.9 g/veh-hr) = 157 kg
Carbon Monoxide (604.8 g/veh-hr) = 1482 kg
Nitrogen Oxide (118.1 g/veh-hr) = 289 kg
Carbon Dioxide (15,240 g/veh-hr) = 37,338 kg

=$5,024

Total = $283,929

TOTAL (FOR SCALE UP) = $292,422

C. ***NOTE; All calculations performed at national scale, for busiest 5% of railway grade crossings***

- # of railway grade crossing collisions = 1092
- assume equipped road vehicles = 26.5% (same passenger/commercial split as for study site)
- assume 100% of trains equipped because system using existing railroad signalling equipment
- assume cost of property damage accidents is double normal
- assume injuries are generally serious
- assume injury and fatality rates are double normal

average cost of accident (Transport Canada):

Property Damage = $6908
Personal Injury = $77,852
Fatality = $1,569,912
Average = 6908×.6 + 77,852×.3896 + 1,569,912×.0104 = $50,803

cost of preventable accidents = 50,803 × 1092 × 26.5%

= $14,701,372

- average number of through vehicles delayed = 514 (AADT/24)
- assume average delay = 1 hour (grade crossing collision more severe than general roadway event, so longer road closure)
- 514 veh-hr per event

Cost of Time = 1092 × 26.5% × 514 veh-hr/event × 9.10 $/hr (TransCan B/C Book)

= $1,353,546

Fuel Savings = 1092 × 26.5% × 514 veh-hr/event × 2.1 L/hr (MTO) × $.55/L

= $171,796

Emissions Savings annually (MTO):

HydroCarbons (63.9 g/veh-hr) = 950 kg
Carbon Monoxide (604.8 g/veh-hr) = 89,959 kg
Nitrogen Oxide (118.1 g/veh-hr) = 17,566 kg
Carbon Dioxide (15,240 g/veh-hr) = 2,266,817 kg

=$30,400

Total National Rail Crossing Benefits = $16,257,114

B3.3.3Scale-up of Benefits to National Intercity Highway Network

Study Corridor Total Travel (million vehicle-km)	367	
National Intercity Highway Network Total Travel (million vehicle-km)	53,579	
Multiplier (National Network/Study Corridor)	146	
Total Estimated Annual benefits on National Intercity Highway Network, Base Year		**$57,457,406**
Traffic Growth Rate (per year)	1%	
Estimated Annual Benefits on National Intercity Highway Network, Year 10		**$63,203,146**

B3.3.4Calculation of Costs

A. Construction Zone TMS Capital Costs

DSRC readers = 2 @ 12,000 = 24,000
temporary CCTV = 2 @ 12,000 = 24,000
temporary vehicle detectors = 4 @ 5000 = 20,000
HAR transmitters = 1 @ 15,000 = 15,000
portable CMS = 2 @ 75,000 = 150,000
control centre = 1 @ 50,000 = 50,000

Total (per site) = $283,000

B. Intersection Collision Avoidance Capital Costs

DSRC readers = 4 @ 12,000 = $48,000
Vehicle detectors = 8 @ 5,000 = $40,000
Controller = 1 @ 10,000 = $10,000

Total (per site) = $98,000

C. Rail Crossing Collision Avoidance Capital Costs

1158 sites equipped as follows:

vehicle detectors = 4 @ 5000 = $20,000
DSRC readers = 2 @ 12,000 = $24,000
rail detectors = 2 @ 5000 = $10,000
controller = 1 @ 10,000 = $10,000

Total per site = $64,000

Rail System National Total **= $74,112,000**

Operating Costs

A. - assume 10% of capital = $28,300 annually per site for construction zone TMS, includes communications

B. - assume 2% of capital (MTO FTMS maintenance standards) = $1,960 annually per site

C. - assume 2% of capital = $1,482,240 annually, nation-wide

B3.3.5Scale-Up of Costs to National Intercity Highway Network

Study corridor km	205
National Intercity Highway Network km	43,398
Multiplier (National Network/Study Corridor)	212
Equipped Railway Grade Crossings (5% of public crossings in Canada)	1,158
Multiplier for Railway Grade Crossings	1,158
Estimated Annual Value of Total Costs on National Intercity Highway Network	

TOTAL NATIONAL COSTS $55,823,680

B3.3.6 BENEFIT/COST SUMMARY

	Base Year	*Year 10*
Estimated Annual Value of Benefits	$57,457,406	$63,203,146
Estimated Annual Value of Total Costs	$55,823,680	$55,823,680
Benefit/Cost Ratio	1.01	1.12

APPENDIX C Urban ITS Applications

C1 - Outline of Urban ITS Applications

C2 - Characterization of Retained Urban ITS Applications

C3 - Benefit/Cost Assessment of Urban ITS in Canada

C-1 Outline of Urban ITS Applications

ITS APPLICATION CATEGORY	MAIN OBJECTIVES	APPLICABLE CONDITIONS	PRIMARY USERS	FUNCTIONS	POTENTIAL ITS FEATURES	AREAS OF APPLICABILITY
1. Traffic Management and Control	Maximize use of available transportation system capacity Reduce congestion Reduce frequency of accidents Reduce travel time Reduce travel stress Reduce transportation costs Reduce air pollution.	Traffic congestion - Freeways - Urban streets Road closures Weather conditions	Private vehicular traffic Transit system users Commercial vehicles Transportation and traffic agencies Parking and toll authorities	Monitoring Detection Verification Response Information processing Communications	ATMS (CCTV, VMS, Communications, Aerial Surveillance etc.) Ramp metering/closure Highway advisory radio Diversion (vehicle, emergency) HAZMAT warning Signal priority Traffic probing Weather reports Incident reports	Metropolitan regions Urban areas (large, medium & small)
2. Route Guidance	Maximize use of transportation system Reduce congestion Reduce travel time Reduce travel stress Reduce transportation costs Reduce air pollution	Traffic congestion Road closures Weather conditions Transit schedules	Private vehicular traffic Transit system users Pedestrians Bicyclists Emergency vehicles Commercial vehicles	Monitoring Detection Verification Information processing Communications	Diversion (vehicle, emergency) In-vehicle signing Incident reporting (cellular phone) Parking information Transit schedules HAZMAT warning AVI AVL Fee collection/access control.	Metropolitan regions Urban areas (large, medium & small)
3. Incident Management	Reduce congestion due to incidents Reduce secondary accidents Reduce travel time Reduce travel stress Reduce energy consumption.	Traffic congestion Road closures Weather conditions Transit schedule Intermodal connections	Private vehicular traffic Transit vehicle operators Commercial vehicles Transportation and traffic agencies	Monitoring Information processing Communications	CCTV Aerial surveillance Roving vehicles Emergency response/dispatching HAZMAT warning Diversion (vehicle, emergency) Incident reporting	Metropolitan regions Urban areas (large, medium & small)

4. En-route Driver Information	Improve safety Reduce congestion Reduce travel time Reduce travel stress Reduce energy consumption	Traffic congestion Road closures Weather conditions Transit schedules Intermodal connections	Private vehicular traffic Transit vehicle operators Commercial vehicles Parking and toll authorities	Monitoring Information processing Communications	In-vehicle signing RDS Weather/hazard warnings Diversion (vehicle) Highway advisory radio HAZMAT warning In road and road side detection Parking information Road pricing	Metropolitan regions Urban areas (large, medium & small)
5. Automated Highway Systems	Reduce number and severity of accidents Reduce congestion Reduce vehicle emissions Reduce fuel consumption Enhance high occupancy vehicle operation	Traffic congestion	Private vehicular traffic Transit system operators Commercial vehicles	Monitoring Information processing Detection Communications	AVI AVL Automated collision avoidance CMS Driver/vehicle station reporting In-road & road side detection	Metropolitan regions Urban areas (large & medium)
6. Pre-trip Travel Information	Reduce congestion Increase mobility Reduce travel time Reduce transportation costs Reduce travel stress	Transit information Traffic congestion Intermodal connections Weather conditions	Private vehicular traffic Commercial vehicles Transit system operators Bicyclists.	Monitoring Information processing Communications	Driver/vehicle station reporting Parking information Transit schedule reports	Metropolitan regions Urban areas (large, medium & small)
7. En-route Transit Information	Reduce energy consumption Improve accessibility to transportation Reduce travel stress Reduce transportation costs Improve transportation customer service (reduce wait time)	Traffic congestion Intermodal connections Transit scheduling Road closures	Transit system users	Communications Information processing Intermodal coordination	VMS HOV lane use Diversion (transit route)	Metropolitan regions Urban areas (large, medium & small)

8. Personalized Public Transit	Improve transportation customer service Reduce energy consumption Reduce transportation costs Improve accessibility to transportation Increase average vehicle occupancy.	Transit scheduling Intermodal connections traffic congestion	Transit dependents Transit operators	Monitoring Information processing Communications Response	Dispatching (transit) Diversion (transit) Driver/vehicle station reporting Electronic transit payment Fee collection/access control In-vehicle signing Incident reporting Weather/road report	Metropolitan regions Urban areas (large, medium & small)
9. Collision Avoidance	Enhance traveller security Reduce frequency of accidents Reduce severity of accidents Reduce transportation costs Improve travel time.	Traffic congestion Weather conditions Highways and roads Intersections	Private vehicular traffic Commercial vehicles Transit (bus) vehicles	Monitoring (sensors) Information processing Driver/vehicle interface	Automated collision avoidance AVI AVL In-road and road side detection In vehicle signing Hazard warnings	Metropolitan regions Urban areas (large, medium & small)
10. Transportation Demand Management	Support sustainable development (increased self-containment of communities) Reduce energy consumption and emissions Increase transportation productivity Reduce vehicle distance travelled Temper growth in new traffic Utilize corridor capacities more fully (person-throughput) Increase fairness and equity (HOVs over SOVs).	Traffic congestion - commute corridors - urban street network - special trip generators All vehicle traffic - cross-commuting - unlinked trips	Private vehicular traffic Taxis and jitneys Transit buses & streetcars Trucks (for-hire & private carriers) Transportation, traffic and land-use agencies Parking and toll authorities Employers.	Monitoring Information processing Communications Control & enforcement Intermodal coordination	Home/office display of traffic conditions and modal options Changeable message signs In-vehicle signing Automatic vehicle I.D.: access control & enforcement (HOV ramps/lanes/parking & ARZ in city core) Automatic debiting (ETC): road user & peak charges Modal interchange optimization: operations and user information Special alerts: incidents/weather conditions/ sports events etc.	Metropolitan regions Urban areas (large & medium)

11. Traveller Services Information	Reduce transportation cost Improve travel time Reduce travel stress Improve transportation customer service	Transit scheduling Intermodal connections	Private vehicular traffic Transit vehicles Transit operators Parking authorities	Information processing Communications	In vehicle signing AVI AVL Fee collection and access control Non emergency assistance Parking information Transit schedule and station reporting	Metropolitan regions Urban areas (large, medium & small)
12. Electronic Payment Services	Increase capacity of transportation system Improve transportation customer service Reduce travel time	Transportation services Parking Commute corridors (tolls) Transit services Intermodal connections	Private vehicular traffic Transit system users Commercial vehicles Parking and toll authorities Transit system operators	Monitoring Information Processing Communications	AVI AVL Road pricing Parking information Electronic toll collection Electronic transit payment	Metropolitan regions Urban areas (large, medium & small)

C2 - Characterization of Retained Urban ITS Applications

	TMOC PACKAGE	TMOC PACKAGE	TTIS PACKAGE	TTIS PACKAGE	TTIS PACKAGE
MODULE	**INCIDENT MANAGEMENT**	**TRAFFIC CONTROL**	**TRAVELLER SERVICES INFORMATION**	**ROUTE GUIDANCE**	**EN-ROUTE DRIVER INFORMATION**
GOALS	Reduce severity of accidents, including fatalities, injuries, etc.	Maximize the movement of people and goods	Improve personal mobility	Improve personal mobility	Improve personal mobility
	Reduce non recurring congestion due to incidents	Reduce travel time	Enhance traveller security	Reduce overall travel time	Reduce overall travel time
	Reduce frequency of accidents	Reduce recurring congestion	Maximize utilization of capacity of the transportation system	Reduce congestion	Improve safety of the travelling public
	Reduce travel time	Improve transportation system and planning	Reduce energy consumption and harmful emissions	Improve safety of the travelling public	Reduce driver's stress and frustration
	Maximize utilization of capacity for the transportation system	Reduce driver's stress and frustration	Increase use of transit system	Reduce driver's stress and frustration	Reduce energy consumption and emissions
	Reduce driver's stress and frustration	Reduce energy consumption and emissions	Improve marketing and service exposure	Reduce energy consumption and harmful emissions	Increase use of transit system
	Reduce energy consumption and harmful emissions	Reduce frequency of accidents		Increase use of transit system	
DESCRIP-ION	This module improves the existing capabilities for detecting incidents. It will also help safety officials to quickly and accurately identify incidents and to implement a set of actions to minimize the effects of these incidents on the movement of goods and people.	This module maximizes utilization of available freeway and arterial network capacity through the use of real-time information and coordinated traffic management and control strategies and equipment.	This module provides traveller with access to information regarding a variety of travel-related services and facilities. This information will be accessible to the traveller at home, in the office and while en-route either in a vehicle or at public facilities and transit terminals.	This module provides travellers with instructions/directions on downstream traffic/transit manoeuvres and how to best reach their destinations. It relies on real-time information which is used to derive a suggested route that is displayed on an in-vehicle/personal display device.	This module provides travel related information to drivers after their trips have begun. It is composed mainly of two sub-services: Driver advisory (traffic, transit and roadway conditions) and In-vehicle signing (roadway signing, road warning, hazards, traffic control, etc.).

TARGET	TRAFFIC CONDITIONS DUE TO: non-recurring congestion	MANAGING AND CONTROLLING TRAFFIC ALONG: region/city-wide traffic corridors	QUICK ACCESS TO TRAVEL INFORMATION, SUCH AS: transit scheduling	MAXIMIZING THE USE OF THE TRANSPORTATION SYSTEM CAPACITY AND IMPROVING TRAVEL CONDITIONS: recurring congestion	TRAFFIC CONDITIONS DUE TO: recurring and non-recurring congestion
	weather conditions	freeway networks	traffic reports	road closures/construction	road closures and construction
	road closures	major arterial networks	weather conditions	weather conditions	weather conditions
	others	ramps and HOV facilities	reservations, confirmations, ticket purchase and payment	airport and transit operations	airport and transit schedules
		IT IS TARGETED AT ALL TRAFFIC INCLUDING:	emergency services and facilities	IT IS TARGETED AT ALL DRIVERS/ USERS INCLUDING:	IT IS TARGETED AT ALL TRAFFIC INCLUDING:
	IT IS TARGETED AT ALL TRAFFIC INCLUDING:	private vehicular traffic	intermodal connections	private vehicular traffic	private vehicular traffic
	private vehicular traffic	corridor and transit vehicle operations	IT IS TARGETED AT ALL VEHICLE OPERATORS AND TRAVELLERS INCLUDING:	transit vehicle operation	transit vehicle operation
	transit vehicle operation	commercial vehicle operations	private vehicular traffic	commercial vehicles	commercial vehicles
	commercial vehicle operation	emergency vehicle operations	transit users	transit users	intermodal connections
	emergency vehicle operation	other non-vehicle travellers (bicyclists/pedestrians)	transit vehicle operators	car pooling / ride matching	parking and toll authorities
			commercial vehicle operators parking and toll authorities	pedestrians/bicyclists	
SITES	METROPOLITAN REGIONS AND MEDIUM/ LARGE URBAN AREAS All major roadway links with main emphasis on the freeway network	METROPOLITAN REGIONS AND MEDIUM/ LARGE URBAN AREAS all road network links with main emphasis on freeway and arterial networks SAMPLE AREA - Greater Toronto Area (Milton to Oshawa)	METROPOLITAN REGIONS AND SMALL/ MEDIUM/ LARGE URBAN AREAS SAMPLE AREA - Greater Toronto Area (Milton to Oshawa)	METROPOLITAN REGIONS AND MEDIUM/ LARGE URBAN AREAS All road network links SAMPLE AREA - Greater Toronto Area (Milton to Oshawa)	METROPOLITAN REGIONS AND MEDIUM/ LARGE URBAN AREAS All road network links SAMPLE AREA - Greater Toronto Area (Milton to Oshawa)
	SAMPLE AREA - Greater	B/C CORRIDOR - Hwy 403/	B/C CORRIDOR - Hwy 403/ QEW		B/C CORRIDOR - Hwy 403/

	Toronto Area (Milton to Oshawa) B/C CORRIDOR - Hwy 403/ QEW corridor in Mississauga	QEW corridor in Mississauga	corridor in Mississauga		QEW corridor in Mississauga
METHOD	INCIDENT REPORTING Call in telephone service (cellular phone) Police and emergency service patrols Hazardous material incident warning	ARTERIAL/FREEWAY NETWORK INTEGRATION Real-time monitoring and detection along freeway and major arterial networks Real-time data collection and processing Real-time adaptive response plans and algorithms Vehicle/Pedestrian detection and signalization along arterial network	AVAILABLE SERVICE FEATURES Emergency service directory and facility locations Dial-up reservations, confirmations and ticket purchasing services Road user pricing / toll collection Parking information (locations, availability and rates)	B/C CORRIDOR - Hwy 403/QEW corridor in Mississauga DRIVER/USER ADVISORY Environmental conditions Road conditions (incidents, construction, congestion, signing information, hazardous areas) Alternative routing and suggested diversions (possible shifts to public transportation)	DRIVER ADVISORY Environmental conditions Vehicle and road conditions (incidents, construction, congestion) Alternative routing and suggested diversions (possible shifts to public transportation) Commercial traffic delivery/pick-up point information
	INCIDENT DETECTION Road network monitoring (all day) Incident prediction Incident verification Queue end warning	Area-wide coordination (freeway-arterial traffic control equipment) Centralized traffic management and control centre Inter-agency coordination (communication networking) ROUTE GUIDANCE Automatic Vehicle Identification (AVI) Automatic Vehicle Location (AVL)	Transit system schedule information	IN-VEHICLE/PERSONAL SIGNING DEVICE Parking/Ticketing information Transit/Airport terminal schedule information Commercial traffic deliveries/ pick-up points information AUTOMATIC VEHICLE/PERSON IDENTIFICATION & LOCATION	IN-VEHICLE SIGNING Road user pricing (time, area and facility) Parking information (locations, availability and rates) Transit system schedule information (and intermodal connections) Airport terminal schedule information Roadway information (control signs, warning signs, etc.)

	INCIDENT RESPONSE Response plans (automated selection) Emergency dispatch Inter-agency coordination (police, emergency services, tow trucks) Driver advisory (diversionary routes) Accident investigation sites Clearance requirements (time, type of tow trucks)	Real-time optimization of possible routes and travel times Real-time motorist/traveller information displays		Real-time information input to central database Continuous real-time user identification information Continuous indexing of relevant database information	
TECHNOLOGIES	**ON-BOARD VEHICLES** Vehicle probes Hazardous material warning devices n-vehicle signing displays Digital Mapping ROAD-SIDE Communication subsystem (fibre optic lines)	**ON-BOARD VEHICLES** AVI and AVL transponders In-vehicle signing displays Digital Mapping Highway Advisory Radio Vehicle probes (cellular phones, GPS based route guidance) ROAD-SIDE Communication subsystem (fibre optic lines, microwave, etc.)	**ON-BOARD VEHICLES** 2-way transponder (DSRC) In-vehicle displays Voice recognition Digital mapping CD-ROM directory databases PERSONAL PORTABLE COMMUNICATIONS DEVICE CRT information display	ON-BOARD VEHICLES 2-way transponder (DSRC) In vehicle displays Voice recognition Digital Mapping ROAD SIDE Communication subsystem	**ON-BOARD VEHICLES** 2-way transponder (DSRC) In vehicle displays Voice recognition Digital Mapping ROAD-SIDE Communication subsystem (fibre optics, microwave, infrared, etc.) Variable message signs

	Variable message signs (driver advisory)	Variable message signs	Interactive video/audio display	Variable message signs	Computer systems
	CCTV cameras (monitoring, verification)	Vehicle detection systems (inductive loops, microwave/ infrared sensors and video imaging)	Digital mapping	Computer systems	OTHERS
	Road sensors (inductive loops, microwave, infrared, etc.)	Signalized intersections (vehicle/pedestrian detectors)	CD-ROM directory database	Sign posts transmitters	2-way mobile communications (cellular, 2-way radio, etc.)
	TRAFFIC CONTROL CENTRE	Ramp metering	ROAD-SIDE	PERSONAL PORTABLE COMMUNICATIONS DEVICE	1-way mobile communications (highway advisory radio, beacons, FM subcarrier)
	Traffic surveillance (aerial reporting)	CCTV cameras (video image processing)	Communication subsystem	2-way transponder (DSRC)	Real-time global positioning/location system (GPS)
	Real-time information database	AVI and AVL readers (part of toll collection system)	Computer systems	CRT information display	
	Database processing (computer systems equipment)	TRAFFIC CONTROL CENTRE	Interrogation units	Interactive video/audio display	
	Computer algorithms for automatic incident detection	Traffic surveillance (aerial monitoring)	INTERACTIVE KIOSK LOCATIONS	CD-ROM database	
	Traffic prediction data processing (signal timing adjustments)	Real-time information database processing	Located in transportation terminal, facilities and centres	OTHERS	
	Computerized traffic signal control	Dynamic traffic prediction data processing	Interactive audio/video displays	2-way mobile communications (cellular, 2-way radio)	
	Monitoring and video recording equipment	Computer algorithms for optimization of traffic movement	CD-ROM database		
	Inter-agency coordination (communication networking)	Real-time adaptive traffic coordination algorithms			
		Traffic control data processing			
		Computerized traffic signal control			

		Inter-agency coordination (communication links)			
PRE-REQUISITES	Governmental support is required in the development of this module especially in the roles of research and development, operational tests, deployment and institutional/ legal areas.	Governmental support is required in the development of this module especially in the roles of research and development, operational tests, deployment and institutional/ legal areas.	This module will in all likelihood follow other modules and services such as En-route Driver Information and Route Guidance. Governmental support could be required in the deployment of this service as it relates to safety issues.	Real-time global positioning/location system (GPS) This service will rely heavily on real time information provided by other services including Traffic Control, Incident Management, Travel Demand Management and others.	. This module is very much dependent on the implementation of other services, including traffic control and incident management, in order to provide the real-time information to the driver.
STAKE-HOLDERS	ROAD USERS Private automobile drivers Commercial traffic operators Transit vehicle operators OTHERS	ROAD USERS Private vehicle drivers Commercial vehicle operators ransit vehicle operators OTHERS Transportation authorities	ROAD USERS Private vehicular traffic Commercial traffic operators Emergency vehicles Transit vehicle drivers OTHERS	ROAD USERS Private vehicular traffic Commercial traffic operators Emergency vehicles Transit vehicle drivers/passengers OTHERS	ROAD USERS Private vehicular traffic Commercial traffic Emergency vehicles Transit vehicle drivers OTHERS
	Transportation authorities Transit operators Emergency service agencies Traffic managers (private/public) Public safety officials Media (cable television, radio)	Transit operators Emergency service agencies Traffic managers (private/public) Media (cable television, radio)	Automobile manufacturers Communications companies Toll authorities Parking operators Transit/Airport operators Car rental agencies	Automobile manufacturers Communications companies Toll authorities Parking operators Traffic managers Transportation authorities	Automobile manufactures Communications companies Toll authorities Parking operators Traffic managers Car rental agencies
SYNERGIES	**OTHER MODULES WITHIN THE TRAFFIC MANAGEMENT, OPERATIONS AND CONTROL PACKAGE** Traffic control	**OTHER MODULES WITHIN THE TRAFFIC MANAGEMENT, OPERATIONS AND CONTROL PACKAGE** Incident management	**OTHER MODULES WITHIN THE TRAVEL AND TRAFFIC INFORMATION SERVICES PACKAGE** Route guidance	**OTHER MODULES WITHIN THE TRAVEL AND TRAFFIC INFORMATION SERVICES PACKAGE** En-route driver information	**OTHER MODULES WITHIN THE TRAVEL AND TRAFFIC INFORMATION SERVICES PACKAGE** Route guidance

	OTHER ITS APPLICATIONS WITHIN THE URBAN/ RURAL TRANSPORTATION SECTORS En-route driver information Route Guidance	OTHER ITS APPLICATIONS WITHIN THE URBAN/ RURAL TRANSPORTATION SECTORS En-route driver information Route guidance Travel demand management	En-route driver information OTHER ITS APPLICATIONS WITHIN THE URBAN/ RURAL SECTORS Traffic control Travel demand management	Traveller services information OTHER ITS APPLICATIONS WITHIN THE URBAN/ RURAL SECTORS Traffic control Incident management Travel demand management	Traveller services information OTHER ITS APPLICATIONS WITHIN THE URBAN/ RURAL SECTORS Traffic control Incident management
ASSUMP-TIONS	**ASSUMPTIONS MADE ON SKETCH PLANNING TECHNIQUES AND B/C ASSESSMENT:**	**ASSUMPTIONS MADE ON SKETCH PLANNING TECHNIQUES AND B/C ASSESSMENT:**	**ASSUMPTIONS MADE ON SKETCH PLANNING TECHNIQUES AND B/C ASSESSMENT:**	**ASSUMPTIONS MADE ON SKETCH PLANNING TECHNIQUES AND B/C ASSESSMENT:**	**ASSUMPTIONS MADE ON SKETCH PLANNING TECHNIQUES AND B/C ASSESSMENT:**
	Base case traffic volumes / accident rates Traffic diversions and potential routes Cost of fatalities, injuries and property damage accidents Energy consumption / emissions Multiplier to obtain total for Canada (based on sample corridor)	Base case traffic volumes / accident rates Energy consumption / emissions Multiplier to obtain total for Canada (based on sample corridor)	Availability of transit services Multiplier to obtain illustrative total for Canada (based on sample corridor) • • •	Traffic volume information for current years Service available to all users when deployed Multiplier to be developed to expand to all of Canada (based on sample corridor)	Base case traffic volumes Current transit operations Multiplier to obtain total for Canada (based on sample corridor)

C3 - Benefit/Cost Assessment of Urban ITS in Canada

C3.1 TRAFFIC MANAGEMENT, OPERATIONS & CONTROL PACKAGE

A. Incident Management
B. Traffic Control

C3.1.1Background Data/ Assumptions

Avg. Trip Length (Fwy Corridor):	17.4 km
Avg. Trip Length (Art Corridor):	9.2 km
Avg. Trip Time along Fwys:	13.1 min (Avg. Speed= 80km/h)
Avg. Trip Time along Artls:	13.8 min (Avg. Speed= 40 km/h)
Avg. Fwy Corridor AADT:	96,800 vpd
Avg. Major Arterials AADT:	20,000 vpd
Commercial Traffic on Fwys:	15% of AADT
Commercial Traffic on Artls:	6 % of AADT
# of Annual Accidents in Fwy Corridor	946 accidents (RR # 5)
Avg. Fwy Incident Duration (Occ. to Clear.)	86 min(RR # 1)
Fuel Consumption	2.1 Litre/veh-hr (RR # 1)

C3.3.2CALCULATION OF ESTIMATED BENEFITS

A. Savings due to provision of Incident Management along freeways

1- Reduction in secondary accidents= 11.6% (RR # 1)

(0.116 x 946 acc.) = 110 accidents (1% fatal, 35% injury, 64% PDO)
Distribution of accident severity based on (RR # 2).

1.1 fatal accidents x $ 1.5 Million (RR #13)=	$ 1,650,000
38.5 injury accidents x $ 1 1,000 x 1.447 (RR #13) =	$ 612,804
70.4 PDO accidents x $ 3,500 (RR #13) =	$ 246,400

Cost of accidents = $ 2,509,204

2- ***Travel time saved (due to less incidents)***

Total # of annual accidents before system implementation 946 (RR # 2)
incidents = 2.2 x (# accidents) - (RR # 1)
Total annual incidents before system implementation = 2100

- 5.4 % reduction (RR # 1)= 113 incidents
- Avg. incident duration, from occurrence to clearing of traffic = 86 min. s (RR # 1)

Each incident involves an average of 43 minutes per vehicle for 50 % of traffic delayed in one direction (i.e. Avg. number of vehicles delayed during incident = 96,800/24 x1.43 x ½ x 50% = 1441 vehicles)

Delay per incident = 1441 x 43min = 61,920 veh-min
Total delay = 61,920/60 x 113 = 116,616 veh-hrs (Comm. - 17,492 veh-hrs / Pass - 99,123 veh-hrs)

Cost of time (Comm.) =17492 x $ 38.00 = $ 664,696
Passenger travel is divided into work related (46 %) and non work related (54%) - (RR #2)

Cost of time (Pass) = (0.46 x 99,123 x $24.00)+(0.54 x 99,123 x $7.45) = $1,493,089
Total Cost of time (less incidents)

=$ 2,157,785

3- ***Travel time saved (due to reduction in incident duration)***

- 65% reduction in incident duration (RR # 1)
- 43 x 1441 vehicle -min. before system implementation
- 15 x 501 vehicle- min. after system implementation
- 54,448 vehicle - min. saved per incident

Total time saved = 54,448 min./60 x (2100 - 113) incidents = 1,803,136 veh-hrs
Cost of time (Comm.) = 270470 veh hrs x $ 38.00 = $ 10,277,876
Cost of time (Pass) = (0.46 x 1,532,665 x $24.00)+(0.54 x 1,532,665 x $ 7.45)

= $ 23,082,532

Total cost of time (reduction in incident duration)

=$ 33,364,408

4- ***Fuel Consumption = 2.1 litres/ veh-hr***

Fuel cost per litre = $ 0.55
Total veh-hrs saved = 116,616 + 1,803,136 = 1,919,752 veh-hrs
Fuel savings = 1,919,752 veh-hrs x 2.1 lit/veh-hr = 4,031,479 litres

Total cost of fuel = 4,031,479 x $ 0.55/ litre

= $ 2,217,313

B. Savings due to improved traffic flow along freeways and arterials

1- ***Freeways- 20 % reduction in avg. trip time (RR # 3)***

Avg. trip time in Fwy corridor = 13.1 min.
Trip time during peak hours = 13.1 x 1.5 = 19.6 min.(20% reduction= 3.93min)
Reduction in travel time along the freeway network is assumed to happen during the morning and afternoon peak periods which represents 33 % of AADT (250 days per yr.)
Total AADT in Freeway corridor = 196,000
Peak period traffic on fwys = 33 % of AADT= 64,680
Travel time saved = 64,680 x 3.93 x 250 = 1,051,050 veh-hrs
Cost of time (Comm.) = 157,657 x $ 38.00 = $ 5,990,985
Passenger travel is divided into work related (46 %) and non work related (54%) - (RR #2)
Cost of time (Pass) = (0.46 x 893,392 x $24.00)+(0.54 x 893,392 x $7.45) = $13,457,175
Total cost of time (Fwys)

= $ 19,448,160

2- ***Arterials- 8 % reduction in avg. trip time (RR # 3)***

Avg. trip time in Artl corridor = 13.8 min.
Trip time during peak hours = 13.8 x 1.5 = 20.7 min.(8 % reduction = 1.65in)
Reduction in travel time along the arterial network is also assumed to happen during the morning and afternoon peak periods which represents 33 % of AADT (250 days per yr)
Total AADT on Arterial corridor = 240,000
Peak period traffic on artls= 33% of AADT = 79,200
Travel time saved = 79,200 x 1.65x 250 = 544,500 veh-hrs
Cost of time (Comm.) = 32,670 x $ 38.00 = $ 1,241,460
Passenger travel is divided into work related (46 %) and non work related (54%) - (RR #2)
Cost of time (Pass) = (0.46 x 511,830 x $24.00)+(0.54 x 511,830 x $7.45) = $7,709700

Total cost of time (Arterials)

=$ 8,951,160

3- ***Fuel Consumption = 2.1 litres/ veh-hr***

Fuel cost per litre = $ 0.55
Total veh-hrs saved = 1,051,050 +544,500 = 1,595,550 veh-hrs
Fuel savings = 1,595,550 veh-hrs x 2.1 lit/veh-hr = 3,350,655 litres

Total cost of fuel (fwys) = 1,051,050 x 2.1 x $ 0.55/ litre

= $ 1,213,962

Total cost of fuel (artls)= 544,500 x 2.1 x $ 0.55/ litre

=$ 628,950

Total Estimated Annual Benefits on Study Corridor (Fwys)

=$ 60,910,832

Total Estimated Annual Benefits on Study Corridor (Artls)

= $9,580,110

C3.1.3Scale-up of Benefits to National System

Fwy Study Corridor Annual Total Travel	**1230 million veh-km**
Artl Study Corridor Annual Total Travel	**803 million veh-km**
Nat'l Urban Fwy Network Annual Total Travel veh-km	**36534 million**
Nat'l Urban Artl Network Annual total Travel veh-km	**24747 million**
Fwy Multiplier (Nat'l Network/Study Corridor)	**29.7**
Artl Multiplier (Nat'l Network/Study Corridor	**30.8**
Total Estimated Annual Benefits Nat'l Fwy Network	**$1,809,051,700**
Total Estimated Annual Benefits Nat'l Artl Network	**$295,067,380**
Total Estimated Annual Benefits Nat'l Urban Network (base year)	**$2,104,119,080**
Growth assumed at 1% Total Estimated Annual Benefits Nat'l Urban Network (year 10)	**$2,324,255,900**

C3.1.4 CALCULATION OF ESTIMATED COSTS

Capital Costs

- Infrastructure costs for freeways include provisions for the following subsystems:
- Vehicle detection subsystem
- Changeable message sign subsystem
- Closed circuit television subsystem
- Ramp metering subsystem
- Communication subsystem
- Interface with incident management and information dissemination agencies
- Operations center (cost for this item has been prorated at 25% of the cost of a complete operation center, since one center is assumed to serve a whole metropolitan area).

These subsystems are assumed to be installed in such a way as to optimize installation and operation and minimize expenditures (light infrastructure distribution of field equipment-RR # 8)

Cost for all subsystems = $ 22,620,000 ($ 650,000 per km)

Cost for operation center @ 25% = $ 2,000,000

Cost for system engineering @ 10%= 2,462,000

Capital cost for freeways

=$ 27,082,000

Infrastructure costs for arterials include provisions for :

Computerized traffic control system including an operation center

Field equipment upgrading (controllers, detectors, communications, installation contract, CICU devices, etc., assuming 2 signals per 1.5 km = 150 signals)

Cost for system engineering = $ 500,000

Cost for operation center upgrading (assume existing bldg.)= $ 500,000

Cost for field equipment = $ 1,500,000 (10,000 per signal location)

Capital cost for Arterials

= $ 2,500,000

Annual Operating Cost

Annual operating cost (fwys) = $88,500 /km /year (total of 35 km)(RR # 1)= **$3,100,000**

Annual operating cost (artls) - Assume 10 % of capital cost = **$ 250,000**

C3.1.5Scale-Up of Costs to National Urban Road Network

Length of Fwy Study Corridor	**34.8 km**
Length of Artl Study Corridor	**110 km**
Length of Nat'l Urban Fwy Network	**1512 km**
Length of Nat'l Urban Artl Network	**5650 km**
Fwy Multiplier (Nat'l Network/Study Corridor)	**43.4**
Artl Multiplier (Nat'l Network/Study Corridor	**51.4**
Total Estimated Annualized Costs on Nat'l Fwy Network	**$325,843,000**
Total Estimated Annualized Costs on Nat'l Artl Network	**$33,764,700**
Total Estimated Annualized Costs on Nat'l Urban Network	**$359,607,700**

C3.1.6BENEFIT/ COST SUMMARY

Total Estimated Annual Benefits	**$ 2,324,255,900**
Total Estimated Annualized Costs	**$ 359,607,700**
Benefit / Cost Ratio	**6.46**

C3.2 TRAVEL & TRAFFIC INFORMATION SERVICES PACKAGE

A. En-Route Driver Information
B. Route Guidance
C. Traveler Services Information

C3.2.1Background Data/ Assumptions

Length of Total Road Network	**144.8 km**
Avg. Trip Length in Corridor	**16.0 km**
Avg. Trip Travel Time in Corridor:	**13.2 min**
Peak Period Traffic (AM & PM)	**33% of AADT**
Total Corridor AADT	**436,000 vpd**
Avg. Corridor AADT:	**33,700 vpd**
Commercial Traffic in Corridor:	**11.2% of AADT**
# of Annual Accidents in Corridor	**946(fwys) + 2400(artls) (RR #5) = 3355**
Avg. Incident Duration in Corridor	**$359,607,700**

In estimating the penetration rate for each of the modules in urban areas, it was assumed that the total penetration rate for En-Route Driver Information and Route Guidance is 70% for commercial vehicles and 55% for automobiles. The penetration rates for each of the modules are:

- For En-Route Driver Information module (45% comm. / 20% autos) - 23 % combined
- For Route Guidance module (25% comm. / 25 % autos) - 25 % combined
- For Traveler Services Information module (25% comm. / 25% autos) - 25% combined

C.3.2.2 CALCULATION OF ESTIMATED BENEFITS

A. Savings due to availability of En-Route Driver Information

1- Travel time savings due to advance knowledge of incidents

Avg. incident duration (from occurrence to clearance) of 86 minutes along the road network (averaged for both fwys & artls) and the average delay per vehicle = 43min
Avg. additional travel due to detouring = 23 min. (assumed)
Therefore net avg. travel time saved = 20 min.
Incidents on fwys = 2.2 x # accidents (RR # 1) / incidents on artls= 4.2 x # accidents (RR # 11)
Number of annual incidents in corridor = 12,200
Assume 30% of traffic delayed during incident= 33700/24 x 50%(1 direction) x 30% = 210 veh
Traffic receiving information based on penetration rate = 45%commercial and 20% passenger
Delay savings(Commercial vehicles) = (45%) x 0.11 x 210 x 12,200 x 20 min. = 42,273 veh-hrs
Delay savings(Passenger vehicles) = (20%) x 0.89 x 210 x 12,200 x 20 min. = 152,012 veh-hrs
Cost of time (comm.) = 42,273 x $38.00 = $ 1,606,374
Cost of time (pass) = (152,012 x 0.46 x $24.00) + (152,012 x 0.54 x$7.45)= $ 2,289,756

Total Cost of Time **= $ 3,896,130**

2- Travel time savings due to advance knowledge of congestion areas (assume 10%)

Congestion savings would happen during peak periods only (i.e. 33% of the time)
Assume 40% of traffic in sample corridor experiences congestion during peak periods (174,400)

Trip time during peak hours = 13.2 x 1.5 = 19.8 min.
Net avg. travel time saved per trip during peak period (13.2 x 10%) = 1.98 min.
Delay savings(Comm. vehicles) = (45%) x .11 x 174,400 x 33% x 1.98min x 250 = 23,502 veh-hrs
Delay savings(Passenger vehicles) = (20%) x 0.89 x 174,400 x 33% x 1.98 min. x 250 = 84,515 veh-hrs
Cost of time (comma) = 23,502 x $38.00 = $ 893,076
Cost of time (pass) = (84,515 x 0.46 x $24.00) + (84,515 x 0.54 x$7.45)= $ 1,273,049

Total Cost of Time **= $2 ,166,125**

3- **Fuel consumption = 2.1 litres/veh-hr**

Fuel cost per litre = $ 0.55
Fuel savings = (42,273 +152,012 +23,502 + 84,515) x 2.1 = 634,342 litres

Cost of fuel = 634,342 x $ 0.55 **= $ 349,158**

B. Savings due to availability of Route Guidance

1- **Travel time savings due to advance knowledge of incidents**

Avg. incident duration of 86 minutes along the road network (combined for both fwys & artls)
Average delay per vehicle = 43min
Avg. additional travel due to detouring = 13 min. (assumed)
Therefore net avg. travel time saved = 30 min. per trip
Number of annual incidents in corridor = 12,200
Assume 30 % of traffic delayed due to incident = 33,700/24 x 50%(1 dir) x 30% = 210 veh
Delay savings = (25 %)210 x 12,200 x 30 = 320,250 veh-hrs (comm.- 35,227 / pass- 285,022)
Cost of time (comm.) = 35,227 x $38.00 = $ 1,338,626
Cost of time (pass) = (285,022 x 0.46 x $24.00) + (285,022 x 0.54 x$7.45)= $ 4,283,625

Total Cost of Time **= $ 5,622,251**

2- **Travel time savings due to advance knowledge of congestion areas (assume 20 %)**

Congestion savings would happen during peak periods only (i.e. 33% of the time)
Assume 40% of traffic in sample corridor experiences congestion during peak periods (174,400)
Avg. travel time per trip = 13.2 min.
Trip time during peak hours = 13.2 x 1.5 = 19.8 min.
Net avg. travel time saved per trip during peak period (13.2 x 20%) = 3.96 min.

Traffic receiving information based on penetration rate = 25%
Delay savings = (25%) 174,400 x 33% x 3.96min x 250 = 237,402 veh-hrs (comm.-26,114/pass-211,287)
Cost of time (comm.) = 26,114 x$ 38.00 = $ 992,332
Cost of time (pass) = (211,287 x 0.46 x $24.00) + (211,287 x 0.54 x$7.45)= $ 3,182,624

Total Cost of Time **= $4,174,956**

3- **Fuel consumption = 2.1 litres/veh-hr**

Fuel cost per litre = $ 0.55
Fuel savings = (237,402 +320,250) x 2.1 = 1,171,062 l itres

Cost of fuel = 1 ,171,062 x $ 0.55 **= $ 644,088**

C. ***Savings due to provision of traveler services information***

1- **Travel time savings due to availability of device**

Reduction in the amount of wasted travel is about 8 % of total trip time (RR # 3)
Assume 25% of device owners use it on a daily basis resulting in less extra trips, not getting lost, advance parking information , etc.
436,000 x 25% x 25% x 1.06 min. x 365 = 175,700 veh hrs (comm.- 19,680/ pass- 156,020)
Cost of time (comm.) = 19,680 x$ 38.00 = $ 747,840
Cost of time (pass) = (156,020 x 0.46 x $24.00) + (156,020 x 0.54 x$7.45)= $ 2,350,100

Total Cost of Time **= $ 3,097,940**

2- Reduction in the # of accidents (2 %) = 2% (3355) = $1,005,000
67 accidents reduced
(0.67 fatal acc. 24 injury acc & 43 PDO acc)
0.67 fatal accidents x $1.5 Million (RR #13) =
23.0 injury accidents x $11,000 x 1.447 (RR #13) = $366,091
43 PDO accidents x $ 6,000 (RR #13) = $258,000

Cost of Accidents **= $ 1,629,091**

3- **Fuel consumption = 2.1 litres/veh-hr**

Fuel cost per litre = $0.55
Fuel savings = 175,700 x 2.1 = 368,970 litres
Cost of fuel = 368,970 x $0.55 = $ 202,900

Total Estimated Annual Benefits on Study Corridor **= $21,782,639**

C3.2.3Scale-up of Benefits to National Level

Study Corridor Total Travel	2033 million veh-km
Nat'l Urban Network Total Travel	61281 million veh-km
Multiplier (Nat'l Network/Study Corridor)	30.1
Estimated Annual Benefits on Nat'l Urban Network (base year)	$ 655,657,430
Growth per year assumed at 1 %	
Total Annual Benefits on Nat'l Urban Network (year 10)	**$ 724,173,630**

C3.2.4CALCULATION OF ESTIMATED COSTS

Capital Costs

A. The main components for a Radio Data System (RDS)-Traffic Message Channel (TMC) included in the capital and installation costs are in-vehicle receivers, encoders, central computers and control center.

In-vehicle receiver units (Qty= 55,000, cost/unit=$ 100)	$ 5,500,000
Encoders (Qty=5, cost/unit=$ 30,000)	$ 150,000
Central computer (Qty= 1)	$ 50,000
Control center (assume existing building)	$ 100,000
Capital cost =	**$ 5,800,000**

B. The main components for a Route Guidance System included in the capital and installation costs are in-vehicle display units / interfaces and infrastructure (roadside beacons, central computer equipment, software development, development of road network information and provision for a control center facility).

In-vehicle receiver units/interface (Qty= 60,000, cost/unit=$ 350)	$ 21,000,000
Infrastructure cost	$ 5,000,000
Capital cost =	**$ 26,000,000**

C. The main components for a Traveller Services Information included in the capital and installation costs are personal portable device, CD-ROM Directory database and information kiosks.

Personal portable device (Qty= 60,000, cost/unit=$ 250)	$ 15,000,000
Information kiosks (Qty=10, cost/unit=$ 10,000)	$ 100,000
Directory database development(software & hardware)	$ 1,000,000
Capital cost =	**$ 16,100,000**
Total Capital cost (Equipment)=	**$ 41,500,000**
Total capital cost (Others) =	**$ 6,400,000**

Annual Operating Cost

A.	Operating cost (2 staff @ $40,000 ea/yr & $ 20,000 communications)	$ 100,000
	Maintenance cost (encoders and Central computer @ 10%)	$ 18,000
B.	Operating cost(5 staff @ $40,000 ea/yr & $ 100,000 communications)	$300,000
	Maintenance cost (@ 10%)	$ 500,000
C.	Operating cost(3 staff @ $40,000 ea/yr & $30,000 communications)	$ 150,000
	Maintenance cost (@ 10%)	$ 110,000

Total annual operating & maintenance cost on study corridor **$ 1,178,000**

C.3.2.5 Scale-Up of Costs to National Urban Road Network

# of Registered Vehicles in Study Corridor	240,000
# of Registered Vehicles Nat'l Urban Areas	13,125,000
Length of Study Corridor	144.8 km
Length of Nat'l Urban Network	7162 km
Multiplier (Nat'l Network/Study Corridor) Equipment	54.68
Multiplier (Nat'l Network/Study Corridor) Other costs	49.46
Total Annualized Cost on Nat'l Urban Network (Equipment)	$ 369,338800
Total Annualized Cost on Nat'l Urban Network (Others)	$ 109,784,700
Total Annualized Cost on Nat'l Urban Network	**$ 479,123,500**

C.3.2.6 BENEFIT/ COST SUMMARY

Total Estimated Benefits (year 10)	**$ 724,173,630**
Total Estimated Costs	$ 479,123,500
Benefit/ Cost Ratio	1.51

C3.3 - TRANSPORTATION DEMAND MANAGEMENT

C3.3.1COST OF ROAD USER PRICING MODULE

APPROXIMATE EQUIPMENT/INSTALLATION/OPERATING COSTS

• AVI Equipment + Installation	
• freeways = 58 lanes x $ 100 000 / lane =	$5 800 000
• highways and arterials = 126 lanes x $ 30 000 / lane =	$3 780 000
• other roads and streets = 46 lanes x $ 20 000 / lane =	$920 000
• in-vehicle Type II+ tags = 1.2 M vehicles x $ 30 x 55% =	$20 000 000
Sub-Total	**$30, 500,000**

• Communications + Computers + Software	$4 500 000
• System Integration	$2 000 000
Total E&I .	**$37,000,000**

EQUIPMENT + INSTALLATION (annualized for 15-year life-cycle @ 10 %)	$4 865 000
ANNUAL OPERATING COST (at 15 % of total E&I, not including tags)	$2 550 000
Road User Pricing Module: Total Annualized Cost	**$7 415 000**

1 $ 30 price inferred from MTA Bridges & Tunnels tag deposit (= $ 23 US).
2 55% average penetration without enforcement

C3.3.2 COST OF HOV MODULE

APPROXIMATE EQUIPMENT/INSTALLATION/OPERATING COSTS

• HOV By-Pass Lanes (18 on-ramps, on widened shoulders; 2 off-ramps)	$8,000,000
• Equipment + Installation (eg: conventional and changeable message signs, ITS beacons: parking availability, interrogator units)	$4,000,000
• TDM Marketing- road user pricing & HOV systems program (rationale, etc) -	$1,000,000
free electronic plate for first 200 000 vehicles @ 30 ea	$6,000,000
Total E&I .	**$19,000,000**

EQUIPMENT + INSTALLATION (annualized for 15-year life-cycle @ 10 %)	$2 498500
ANNUAL O &M COST (at 25 % of E&I, not including free plates)	$3 250 000
HOV Module: Total Annualized Costs	**$5,748,500**

C3.3.3BENEFITS ANALYSIS -low tolls & medium hov package

Item	Para-meter	Parameter units	Data	Summations
Autos crossing cordon peak hours			320,000	
Persons crossing cordon	1.4	persons/ vehicle	448,000	
Persons transferring to transit	1.50	%	6,720	
Persons transferring to bike	0.23	%	1,008	
Persons not travelling	0.53	%	2,352	
Remaining person trips by auto			437,920	
Remaining auto trips @ higher occupancy rate	1.45	persons/ vehicle	302,014	
rush hour vehicle trips saved			17,986	6%
distance saved(km)	9	km	161,876	
Annual distance saved	235	work days/ year	38,040,828	
fuel saved	0.1	litres/km	3,804,083	
fuel cost saved	0.57	$/litre		$2,168,327
Other vehicle O&M cost	$0.16	$/km		$6,086,532
Total vehicle Operating Cost				$8,254,859
VOC saved @ $5000/t	2.19	g/mile	$258,873	
NOx@ $5000/t	1.79	g/mile	$201,058	
CO @ $1000/t	22.65	g/mile	$35,260	
CO2 @ $33/t	298	g/mile	$232,459	
Emission cost				$727,649
accidents saved			114	
fatal accidents			0	$318,367

Injury accidents(based on revised occupancy rate)			29	$188,768
Property accidents			85	$298,253
Total Accident reduction				$805,388
Time value due to reduced congestion	1.5	minutes/trip	$15,543,851	
Value of lost time of persons switching due multimodal travel	10	minutes/trip	$2,395,200	
Net savings				$13,148,731
Total Benefits				$22,936,628
B/C ratio				1.74

Note: Changes to welfare cost due to increased levels of traffic in off peak periods and higher usage of transit are not included in the above assessments. In practice it is expected that the higher levels of traffic in offpeak hours will be well below the maximum roadway capacity and will not therefore create additional delays. Similarly the increased ridership on public transit of less than 0.5% .The associated small increase in transfer payments will have neglible effect on the benefit/ cost ratios.

C.3.3.4 BENEFITS ANALYSIS - high tolls & strong hov package

Item	Para-meter	Parameter units	Data	Summations
Autos crossing cordon peak hours			320,000	
Persons crossing cordon	1.4	persons /vehicle	448,000	
Persons transferring to transit	4.00	%	17,920	
Persons transferring to bike	0.60	%	2,688	
Persons not travelling	1.40	%	6,272	
Remaining person trips by auto			421,120	

Remaining auto trips @ higher occupancy rate	1.6	persons/ vehicle	263,200	
rush hour trips saved			56,800	18%
distance saved(km)	9	km	511,200	
Annual distance saved	235	work days /year	120,132,000	
fuel saved	0.1	litres/km	12,013,200	
fuel cost saved	0.57	$/litre		$6,847,524
Other vehicle O&M cost	$ 0.16	$/km		$19,221,120
Total Operating Cost				$26,068,644
VOC saved @ $5000/t	2.19	g/mile	$817,520	
NOx@ $5000/t	1.79	g/mile	$640,116	
CO @ $1000/t	22.65	g/mile	$111,390	
CO2 @ $33/t	298	g/mile	$734,120	
Emission cost				$2,303,147
accidents saved			360	
fatal accidents			1	$1,005,397
Injury accidents(based on revised occupancy rate)			91	$503,380
Property accidents			269	$941,877
Total Accident savings				$2,450,654.00
Time value due to reduced congestion	1.8	minutes/trip	$12,995,939	
Time value due multimodal	10	minutes/trip	$6,386,987	
Net savings				$6,608,952
Total Benefits				$37,431,396
B/c ratio				2.84

C3.3.5 ANTICIPATED REVENUE - PEAK PERIOD ROAD USER PRICING MODULE OF THE TDM PACKAGE

Low and (high) rates for crossing one, two or three cordons are set at $0.00 ($0.00), $1.25 ($2.25) &$2.00($3.50) respectively

		TRIPS (1	CORDONS CROSSED (2			TOLL REVENUE (3	
			None	One	Two	Low	High
Ham-W⇒Metro	M	2 734	-	15% 410	85% 2 324	5 161	9 057
	A	1 988	-	15% 298	85% 1 690	3 753	6 586
Halton⇒Metro	M	11 727	-	20% 2 345	80% 9 382	21 695	38 113
	A	3 746	-	20% 749	80% 2 997	6 930	12 175
Peel⇒Metro	M	66 507	-	25% 16 627	75% 49 880	120 544	211 991
	A	50 853	-	25% 12 713	75% 38 140	92 171	162 094
York⇒Metro	M	68 854	5% 3 442	20% 13 771	75% 51 641	120 496	211 728
	A	57 244	5% 2 862	20% 11 449	75% 42 933	100 177	176 026
Durham⇒Metro	M	29 541	-	30% 8 862	70% 20 679	52 436	92 316
	A	13 007	-	3 902	9 105		
Fringe⇒Metro & Ext	M	5 206	-	25% 1 302	75% 3904	9 436	16 594
	A	5 317	-	25% 1 329	75% 3 988	9 637	16 948
West⇒East	M	1 186	- -		100% 1 186	2 372	4 151
	A	2 029	- -		100% 2 029	4 058	7 102
Total Daily Revenue						**$571, 954**	**$1, 005, 528**
annual revenue						$148,460,000	$261,300,000

1) 1991 TTS Auto Driver Trips / Peak Periods (Morning = 6:00-8:59 Afternoon = 15:30-18:29)
Source: Metropolitan Toronto Planning Department (Apr 1996)
2) Approximate percentages assumed to illustrate methodology.
3) Initial (implied) revenue - before travel behaviour changes

C.3.3.6 BENEFIT/ COST SUMMARY (Toronto)

	Low Impact	High Impact
Estimated Benefits (year 10)	$22,936,628	$37,431,396
Total Estimated Costs	$13,163,500	$13,163,500
Benefit/ Cost Ratio	1.74	2.84

REFERENCES

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RR# 2: Highway User Cost Tables, June 1993, Transportation Association of Canada.

RR# 3: Intelligent Transportation Infrastructure Benefits : Expected and Experienced - Operation Time Saver, January 1996, USDOT, FHWA.

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RR# 5: Provincial Highways, Traffic Volumes , 1992 Report, Ministry of Transportation of Ontario.

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RR# 8: Freeway Traffic Management Systems- District 6 Strategic Planning Study, Final Report, January 1994, Ministry of Transportation of Ontario.

RR# 9: The Transportation Tomorrow Survey- 1991 Travel Survey Summaries for the GTA, June 1994, University of Toronto, Data Management Group.

RR# 10: Transportation in Canada: A Statistical Overview, 1995, Transportation Association of Canada

RR# 11 User Benefits from an arterial Incident Detection & Response System, 1994 ITE Compendium of Technical Papers

RR# 12 City of Guelph, Feasibility Study- Computerized Traffic Signal Control System, Benefit Cost Analysis, 1987.

APPENDIX D

List of General Information Sources

INFORMATION SOURCES

1. 1993 Road Motor Vehicles Registration, Statistics Canada.
2. 1989 Cordon Count Summary for Metropolitan Toronto Screen Lines.
3. 1991 Travel Survey Summaries for the Greater Toronto Area.
4. Transportation in Canada: A Statistical Overview, TAC.
5. US National Architecture Report, April 1996