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Intelligent Transportation Systems – An Approach to Benefit-Cost Studies

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INTELLIGENT TRANSPORTATION SYSTEMS – AN APPROACH TO BENEFIT-COST STUDIES

by
Richard Zavergiu

for
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16. Abstract

The identification, measurement, and allocation of benefits and costs for Intelligent Transportation Systems (ITS) are critical areas of investigation that influence the decision making related to ITS implementation. Traditional methods have concentrated on safety improvements and congestion relief where time savings and reduction of incidents have generated the bulk of ITS benefits for transportation users. This approach limits the scope of a benefit-cost analysis. It fails to link mobility enhancements to improved economic performance and it neglects to tally benefits for beneficiaries other than travellers. Combined, these factors have led to an underestimation of ITS benefits.

In this report, an alternative is developed that identifies four separate beneficiaries. A hierarchy of benefits and costs identifying and classifying benefits in relation to relevant costs is proposed. This framework will allow policy makers to understand how the financing of ITS deployment could be structured by identifying who should pay for various ITS components, calculating capital and operating costs, locating the revenue streams available, and finally determining whether there is a case for financial assistance from the public sector.

To demonstrate how such a framework would work in a real-world ITS application, two case studies are included: one on border crossing and the other on congestion charging.

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16. Résumé

L'identification, la mesure et la distribution des retombées et des coûts liés aux systèmes intelligents de transport (SIT) sont autant de champs d'étude qui influenceront la décision d'implanter ou non ces systèmes. Les méthodes classiques d'analyse des avantages-coûts des SIT ont, jusqu'ici, été centrées sur les gains de sécurité et la fluidification de la circulation qui ont produit la plupart des retombées profitant aux usagers. Or, cette méthodologie est forcément limitée dans sa portée étant donné qu'elle ne tient compte ni des retombées économiques découlant des gains de mobilité, ni des retombées profitant à des bénéficiaires autres que les usagers. Leur prise en compte a mené à sous-estimer les impacts bénéfiques des SIT.

Le présent rapport propose une méthode différente qui recense quatre groupes de bénéficiaires. Elle suggère un cadre analytique qui permet de recenser les retombées et les coûts et de les hiérarchiser. Ce cadre montre aux décideurs comment maîtriser le processus de financement des SIT, c'est-à-dire identifier les payeurs selon le système envisagé, calculer les dépenses en investissements et en exploitation, déterminer où aller chercher les recettes et, enfin, déterminer si l'engagement de fonds publics est nécessaire ou non.

Afin de montrer l'utilité de ce cadre analytique dans un contexte concret, deux études de cas ont été menées, l'une sur l'automatisation des formalités dans les postes-frontières, l'autre sur la tarification de la congestion routière.

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EXECUTIVE SUMMARY

Intelligent Transportation Systems (ITS) is the term used to describe a variety of technological advances that are revolutionizing the interfaces between driver, vehicle, and roadway. These systems are based on electronic technologies, telecommunication, information processing and control, and navigation technologies. ITS makes it feasible to provide a whole range of road transportation services that were previously not technically or economically possible: road pricing, regulatory compliance, broadcasting safety bulletins, on-board navigation systems, traffic flow monitoring, and environmental impact monitoring. Supplementing these services, ITS also gives the public sector the opportunity to withdraw from the customary role of transportation infrastructure investor and manager in favour of private sector participation.

Government policy and associated directives on ITS are guided by benefit-cost studies that profile the transportation changes generated by ITS and determine whether the desired incremental changes offset the capital and operating costs of ITS deployment. As a result, the identification, measurement, and allocation of costs and benefits for ITS are critical in the decision-making related to the system's implementation and development.

The comprehensive review of existing benefit-cost analyses undertaken for this study indicated that traditional methods have concentrated on safety improvements and congestion relief where time savings and incident reductions have generated the bulk of ITS benefits for transportation users. The scope of this approach is very limited in that it fails to link mobility enhancements to improved economic performance and neglects to tally benefits for groups other than travellers.

The alternative benefit-cost framework developed here identifies four separate beneficiaries: individual transportation users, transportation infrastructure providers and managers, the community, and potential private investors and ITS technology suppliers.

A hierarchy of benefits and costs is also presented. Benefits of the first order are generally targeted to individual transportation users, while second order benefits apply to transportation infrastructure providers and managers. In both instances, conventional metrics such as vehicle miles travelled, commuting duration, mode of choice, reduced emissions, and passengers transported are comprehensive units to measure. The value of incremental improvements differs substantially according to the beneficiary. For example, while time savings achieved from traffic demand management may be marginal for the individual traveller, the benefits of effected increases in throughput for the transportation infrastructure could be considerable. At the highest level of the hierarchy, the macro economic stage, the benefits of ITS deployment are measured in terms of economics and social equity. Improvements in the transportation network are directly related to an area's economic performance, be it at a metropolitan, regional, provincial, or national level. As a result, the ability to link transportation innovations to economic performance becomes as important as demonstrating that transportation advancements are technically feasible and effective in changing travel behaviour.

Quantifying the net impact of transportation improvements on the economy is difficult because the linkage between mobility and economic development, while well accepted, is not well understood. Mobility implies accessibility for individuals and businesses to employment, housing, labour, and markets. The economic value of the increased accessibility provided by improved transportation systems must be assessed in order to evaluate the relative benefits and costs of ITS deployment.

The proposed framework will allow policy makers to understand how the financing of ITS deployment could be structured by identifying who should pay for various ITS elements, calculating capital and operating costs, locating available revenue streams, and finally, determining whether there is a case for financial assistance from the public sector.

To demonstrate how a framework would work in a real-world ITS application, a case study on the Ontario-Michigan border crossings (focussing on the Windsor-Detroit Tunnel) is included in the report. Under current non-ITS operations, toll collections and Customs and Immigration primary processing reduce the operational capacity of the tunnel to approximately 900 vehicles per hour from the 1 300 vehicle capacity it is physically designed to accommodate. ITS-equipped border crossings would increase the operational capacity to 1 300 vehicles per hour. The cost of an Automatic Vehicle Identification (AVI) installation is estimated to be $Cdn 2.63 million. This case study measures two types of second order benefits for the tunnel operators: deferred capital investment to twin the tunnel; and recovered revenues from vehicles presently diverted to other crossings. Costs include capital and operating costs. Earlier studies allocated the capital cost of AVI border processing to Customs and Immigration. However, the findings of this case study indicate that a significant portion of the capital and operating costs for AVI installation could be allocated to the tunnel operators.

The report concludes with a case study on congestion charging that explores the advantages and disadvantages of introducing variable road pricing to effect travel behaviour changes in urban settings. Twenty years ago, when the oil crisis hit North America, conventional wisdom held that rising fuel prices would encourage future generations of motorists to ration their automobile use to reduce fuel consumption. This has not occurred. In the 18 years following 1975, the cost of owning and operating an automobile in Canada increased marginally by 1.7 cents to 33.09 cents a kilometre in constant 1990$. Variable costs declined from 11.12 to 7.71 cents. Fixed costs or ownership costs increased from 20.26 to 25.38 cents. Thus, the incentive for motorists to use alternative transportation modes declined substantially. Technically it is now possible to use ITS to correct this trend, by incorporating the social costs of automobile transport into the private costs. Whether it is desirable from a public policy standpoint is still under debate.

SOMMAIRE

Systèmes intelligents de transport (SIT), tel est le terme qui regroupe l'ensemble des moyens technologiques intéressant les interfaces conducteur-véhicule-route et qui sont en train de les bouleverser. Au débouché de plusieurs technologies : électronique, télématique, informatique et navigation, ces systèmes visent à rendre possible une foule de services de transport routier qui, jusqu'ici, se trouvaient en dehors de nos possibilités économiques ou techniques, qu'il s'agisse de péage, contrôles routiers, messageries radiodiffusées, navigation routière, gestion du trafic et contrôle environnemental. En outre, ces systèmes permettront au secteur public de se retirer du domaine du financement et de la gestion d'infrastructures routières qui était traditionnellement le sien pour le laisser au secteur privé.

Dans la formulation de politiques et de directives concernant les SIT, le gouvernement se guide sur des études avantages-coûts qui font des projections sur l'impact des SIT sur le secteur des transports, pour ensuite établir si les mutations qui se produisent compenseront les dépenses à consentir, en investissement et en exploitation. Il s'ensuit que la méthodologie par laquelle les chercheurs identifient, mesurent et calculent les retombées et les coûts associés aux SIT risque d'avoir une influence décisive sur toute décision se rapportant à la mise en oeuvre et au développement futur de ces systèmes.

Une étude exhaustive des méthodes d'analyse des avantages-coûts a montré que, jusqu'ici, elles ont été centrées sur les gains de sécurité et la fluidification de la circulation (décongestionnement des artères), et que la majorité des retombées profitant aux usagers provient surtout des économies de temps que les SIT leur permettent de réaliser et de la diminution des incidents qu'ils rendent possible. Or, cette méthodologie est forcément limitée dans sa portée étant donné qu'elle ne tient compte ni des retombées économiques découlant des gains de mobilité, ni des retombées profitant à des bénéficiaires autres que les usagers.

Le cadre d'analyse proposé dans le rapport est novateur dans ce sens qu'il permet de recenser l'ensemble des bénéficiaires qu'il subdivise en quatre groupes distincts : usagers; fournisseurs et gestionnaires d'infrastructures routières; grand public; groupes privés d'investissement et fournisseurs intéressés par les SIT.

Une méthode de hiérarchisation des retombées et des coûts est proposée. Les retombées du premier niveau sont généralement attribuées aux usagers, alors que celles du deuxième niveau vont aux fournisseurs et aux gestionnaires d'infrastructures routières. Dans ces deux cas, les paramètres mesurables pris en compte sont les distances parcourues, les temps de déplacement, la répartition modale, les réductions dans les quantités de matières polluantes produites et le nombre de personnes transportées. Les gains acquis ont une valeur qui varie selon le bénéficiaire. Par exemple, le gain de temps obtenu grâce à une meilleure gestion du trafic d'une route donnée peut être considéré comme négligeable au niveau de la personne,

mais ce gain peut devenir très intéressant si cette gestion améliorée se traduisait par une augmentation du débit écoulé par cette même route. Au sommet de cette hiérarchie, soit le niveau macro-économique, les retombées des SIT se mesurent en gains économiques et en justice sociale. On sait que l'impact bénéfique d'un réseau de transport amélioré est directement lié aux progrès économiques de la collectivité qu'il dessert, qu'il s'agisse d'une agglomération urbaine, d'une région, d'une province ou d'un pays. Il s'ensuit que l'aptitude à établir un lien entre innovations dans les transports et progrès économiques constitue un facteur aussi important que de faire la démonstration de l'intérêt technique des SIT ou de leur aptitude à influencer les habitudes de déplacement.

Il est difficile de chiffrer les effets économiques nets d'un réseau de transport amélioré en raison du fait que si la notion de lien entre gain de mobilité et développement économique est admise, elle reste par contre mal définie. La mobilité se définit comme la possibilité qu'ont les individus et les entreprises d'avoir accès aux emplois, aux logements, à la main-d'oeuvre, à des marchés. Afin de pouvoir évaluer correctement les retombées et les coûts des SIT, il faut donc être en mesure de chiffrer les effets économiques des gains de mobilité obtenus grâce à un réseau de transport amélioré.

Le cadre analytique proposé montre aux décideurs comment maîtriser le processus de financement des SIT, c'est-à-dire identifier les payeurs selon le système envisagé, calculer les coûts d'investissement et d'exploitation, déterminer où aller chercher les recettes et, enfin, déterminer si l'engagement de fonds publics est nécessaire ou non.

Afin de montrer le fonctionnement de ce cadre analytique dans un contexte concret, une étude de cas a été menée, dont les résultats figurent dans le présent rapport. Elle a porté sur le projet d'automatisation des contrôles aux postes-frontières entre l'Ontario et l'État du Michigan (projet de tunnel Windsor-Detroit). Les contrôles primaires douaniers et d'immigration ainsi que le péage, comme ils se font aujourd'hui sans le bénéfice des SIT, ne permettent de traiter que 900 véhicules par jour, au lieu des 1 300 prévus au départ. Ce dernier chiffre pourra être atteint une fois le projet d'automatisation réalisé. Installer un système d'identification automatique de véhicules (AVI) coûtera autour de 2 630 000 dollars canadiens. Cette étude a approfondi deux cas de retombées de deuxième niveau profitant aux exploitants du tunnel : remise à plus tard des immobilisations nécessaires à la construction d'un second tunnel et récupération de la clientèle actuellement détournée vers d'autres postes-frontières. Les coûts pris en compte sont les dépenses d'investissements et coûts d'exploitation. Les études antérieures avaient imputé aux autorités douanières et d'immigration les investissements nécessaires à la mise en oeuvre du projet d'automatisation. Le cas d'espèce a montré, cependant, qu'une partie importante de l'enveloppe des investissements et de l'exploitation rattachée à ce projet pourrait être imputée aux exploitants du tunnel.

Le rapport se termine par une étude de cas sur les retombées et les inconvénients de la tarification de la congestion routière, principe selon lequel on varie le prix d'utilisation des voiries urbaines afin d'influencer les habitudes de déplacement des automobilistes. Lorsque, il y a une vingtaine d'années, l'Amérique du Nord connut la crise pétrolière, les esprits sages disaient que cette crise finira par faire comprendre aux automobilistes qu'ils devront se servir de moins en moins de leur véhicule pour économiser l'essence et ainsi en réduire la consommation. Or, rien de tout ceci n'est arrivé. Au cours des 18 années depuis 1975, le coût de possession et d'exploitation d'une voiture au Canada n'a augmenté que de 1,7 cent le km, pour atteindre 33,09 cents en dollars constants de 1990. Les coûts variables ont chuté de 11,12 cents le km à 7,71 cents et les coûts fixes ou coûts d'acquisition ont passé de 20,26 à 25,38 cents le km, donnant un coup de hache aux mesures incitatives visant à favoriser un autre mode de transport. Sur le plan purement technique, les systèmes intelligents de transport permettent désormais d'imputer à l'utilisation de l'automobile un coût social, qui pourra s'ajouter au coût purement financier. C'est là le fond d'un débat qu'il faudra engager un jour.

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1. INTRODUCTION

Intelligent Transportation Systems (ITS) is the term used to describe a variety of technological advances that are revolutionizing the interfaces between driver, vehicle, and roadway. These systems are based on electronic technologies, telecommunication, information processing and control, and navigation technologies.

Implementation of ITS not only can relieve traffic congestion and reduce travel time for goods and passenger movement, it also allows government to effect transportation policies that previously were difficult to achieve. Many European nations, including Great Britain, have come to recognize that the greatest value of ITS is as a means to achieve policy objectives. The greater the reach of the transportation policy in bringing about change or improving productivity, the greater the benefits generated by ITS.

The identification, measurement, and allocation of benefits are critical areas of investigation that will influence the decision making process for ITS implementation. A comprehensive benefit-cost analysis allows policy makers to determine whether an ITS implementation is warranted and how the infrastructure can be financed, by identifying who should pay for various ITS components, calculating capital and operating costs, locating available revenue streams, and finally determining whether there is a case for financial assistance from the public sector.

To simplify such analyses, ITS has been divided into 29 applications, organized into eight complementary bundles:

- Travel and Transportation Management
- Travel Demand Management
- Public Transportation Operations
- Electronic Payment
- Commercial Vehicle Operations
- Emergency Management
- Advanced Vehicle Control and Safety Systems
- Border Crossing Control

As visiting researcher with Transport Canada's Transportation Development Centre (TDC), the author's task was to review current ITS benefit-cost studies and to develop a Canadian framework for such studies. The resulting framework is presented in this report. It incorporates some of the elements of a study done for ITS America by MITRE, a U.S., not-for-profit, government-sponsored organization. The Canadian framework's major distinction from earlier work is the recommendation that analysts group benefits and costs under the following beneficiaries:

- Individual transportation users
- Transportation infrastructure providers and managers
- The community
- Potential private investors/ITS technology suppliers

This classification system will help transportation authorities to trace the causes and effects of ITS-generated changes in the transportation network and to identify which beneficiaries should bear the cost of introducing the various ITS infrastructure components.

1.1 Project Mandate

The research objective set out in August 1994 was "to develop a framework for assessing the benefits and costs of Intelligent Transportation Systems (ITS)"[1]. The scope of the research was broadly defined as follows:

- All application classifications set out in *A Strategic Plan for the Development of IVHS (ITS) in Canada*
- Freight and passenger (public and private) transportation
- Short-term, long-term, direct, and indirect effects of ITS
- Interactions with policy, economic, and technological changes

1.2 Deliverables

The commitment was to follow the work plan outlined below, without ignoring other promising avenues of research. Rather than merely duplicating ITS America's efforts to develop a benefit-cost framework and methodology, this exercise was designed to provide value-added input to the ITS benefit-cost debate.

---

1 Until recently ITS was known as IVHS - intelligent vehicle-highway systems.

The investigation was obliged to meet the following conditions:

- review current and proposed North American ITS programs, as well as available literature on evaluations of ITS projects and on relevant methodologies for assessing the broad impacts of technological change;
- prepare a detailed work statement for the balance of the research to be undertaken, in consultation with TDC staff;
- present interim results at the IVHS Roundtable meeting in Toronto, 25 October 1994;
- based on feedback from the IVHS Roundtable and consultation with TDC staff, refine the work statement and select specific areas for detailed investigation;
- develop case studies of key ongoing and proposed Canadian projects and programs, with emphasis on analyses that will assist Transport Canada in decision-making on projects related to the national highway system;
- prepare a report for publication by TDC on the complete research program and the results obtained.

2. DEFINING INTELLIGENT TRANSPORTATION SYSTEMS

Introduced in the United States in 1991, the Intermodal Surface Transportation Efficiency Act (ISTEA) established the principles for leadership in intelligent vehicle-highway systems (IVHS) research and development, defined goals for a national IVHS program, and laid out key milestones for its achievement. It described a long-range program for using modern communications, information processing, control, and electronics technologies to improve the operation of surface transportation systems across the nation (1).

The impetus for the ISTEA came in the 1980s, when numerous state and local transport authorities acknowledged that the old way of simply laying down concrete for new highways was no longer effective and that alternative methods for preserving and improving mobility were needed. This realization was based on growing funding and highway rights-of-way shortages and a heightened awareness of the damage that existing transportation systems impose on the environment. The desire to maintain and improve mobility in an economically and environmentally sustainable manner gave birth not only to the ISTEA, but also to IVHS, now ITS.

Although many individual ITS technologies predate ISTEA, the North American ITS movement gained its initial momentum from this legislation. The scope of the implementation of ITS is quite extensive and can be paralleled to the creation of the interstate highway that began in the 1950s.

> *We envision, during the next 20 years, the implementation of a national IVHS program, comparable in scope to the Interstate Highway System, with major participation by the private and public sectors. The primary focus of such a program is the creation of a truly balanced transportation system that includes the following:*
>
> - *a national system of travel-support technology, smoothly coordinated among modes and jurisdictions to promote safe, expeditious, and economical movement of goods and people;*
> - *a system that encompasses mobility and accessibility for urban, suburban, and rural transportation users;*
> - *a new level of cooperation and commitment between the public and private sectors to deliver the systems and create the infrastructure that will implement a mobility revolution;*
> - *a vigorous U.S. IVHS industry supplying both domestic and international needs;*

- *a safe, efficient surface transportation system that complements and interacts smoothly among air, transit, rail, maritime, and highway operations (2).*

2.1 Goals, Objectives, and Strategies of ITS

The underlying assumption of ITS is that travellers, be they individuals or freight operators, make rational decisions about their travel behaviour in response to the information available to them. “Smarter” surface transportation refers to the promise of increased transportation efficiency resulting from individuals selecting the best available time, mode, and pattern of travel to optimize system efficiency in all modes.

The fundamental mandate of ITS could be stated as:

> *To enhance mobility and increase accessibility to destinations for travellers and commercial operations in a manner that is economically and environmentally sustainable.*

Although the term “economically and environmentally sustainable” is an apparent contradiction, ITS can be designed and deployed to act as a fulcrum to achieve a delicate balance between two competing aims. If viewed simply as a “product” to be deployed in the absence of a broader transportation and economic policy, ITS would be less able to take that role.

On a smaller scale, ITS America has established five basic ITS goals. Each goal has specific objectives that should be achieved by employing precise strategies. For example, for the goal “To Improve Safety”, one objective is to “reduce the frequency of accidents”, and the specific strategy is “*to reduce the number of impaired drivers*”.

The following list was developed by ITS America. The first level refers to goals, the second to objectives, and the third to strategies. The strategies/objectives in parentheses are strategies, or parts thereof, that are not officially integrated as ITS strategies/objectives according to ITS America. These additions were included at an ITS America Benefit-Cost Workshop at Newport Beach, California, in November 1994. Whether these revisions will remain in effect is as yet unknown. They are included here for evaluation.

Improve Safety

Reduce the frequency of accidents
Improve on-board vehicle system monitoring
Reduce the number of impaired drivers
Enhance driver performance
Enhance vehicle control capability
Improve traffic safety law enforcement
Smooth traffic flows
(Improve EMS/roadway services responsiveness)
(Redeploy attention of enforcement staff to violators)

Reduce severity of accidents, including fatalities, injuries, and property damage
Enhance driver performance
Enhance vehicle control capability
Improve EMS/roadway services responsiveness
Improve passenger protection (restraint)

(Reduce system incidents)
(Improve personal security of travellers and operators)

Improve Service Level

Increase capacity of the transportation system
Increase average vehicle occupancy
Increase vehicle capacity of highways
Match demand to available highway system capacity
Increase driver navigational effectiveness
(Reduce highway wear and tear)

Reduce congestion due to incidents
Improve the ability to respond to HAZMAT incidents
Improve incident management
Improve incident information to drivers/(travellers)

Improve transportation customer service
Improve transit information
Improve transit schedule (adherence)
Improve transit responsiveness
Improve service request responsiveness
Improve convenience of transportation payment

Reduce Energy and Environmental Impact

Reduce harmful emissions per unit of travel
Reduce vehicle miles travelled
Reduce emissions due to congestion
Improve pollution source identification
Smooth traffic/(vehicle) flow

Reduce energy consumption per unit of travel
Reduce vehicle miles travelled
Smooth traffic/(vehicle) flow
Reduce fuel wasted in congestion

Reduce new right-of-way requirements
Reduce vehicle miles travelled
(Smooth traffic/vehicle flow)
(Improve transit responsiveness)

(Reduce environmental impact of HAZMAT mishaps)

Enhance Productivity

Reduce costs incurred by fleet operators, operating agencies, and individuals
Reduce costs of regulating vehicles
Reduce cost of fee collection
Improve equity of fee collection
Improve vehicle and staff utilization
(Reduce unit operational costs)
(Enable innovative business practices for carriers)

Reduce travel time
Reduce time lost in inter-modal travel
Reduce delays of regulating vehicles
Reduce delay associated with congestion
Reduce time wasted due to navigational inefficiency
(Reduce unit operational delays)

Improve transportation, system management, and planning
Reduce cost of data collection
Improve quality of data collection

Improve Mobility

Enhance traveller security
Improve availability of communications devices
Reduce vehicle theft
Increase monitoring of transportation facilities/vehicles

Reduce travel stress
Improve traffic/(travel) information
Smooth traffic/(passenger) flows
Improve travel time predictability
(Reduce driver stress)

Improve accessibility to transportation
Improve transportation affordability
Improve quality of travel options information
Improve availability of alternative modes
Improve driver performance/(system reliability)
(Increase person trips)

This report proposes that ITS Canada introduce a sixth goal:

Provide Innovative Approaches to Infrastructure Financing

- Enable private operators to levy user charges
- Empower private investors to finance infrastructure investment
- Facilitate the creation of new road management companies

Although the ISTEA was created, in part, to invite private sector participation in future infrastructure investments, the pursuit of these partnerships is not included as an ITS goal. Highway 407 in Ontario is the first project in North America that will be built and operated by the private sector, in partnership with the provincial government. Automatic Vehicle Identification (AVI) systems using electronic payment technologies permit the private sector to manage its investment with minimal government participation. Without such technologies, public-private partnerships in transportation infrastructure renewal would be difficult to establish.

2.2 ITS: Policy Tool Kit and Consumer-Driven Technologies

Twenty-nine individual user services form the nucleus of ITS technology, which is composed of both consumer-driven technologies or products and government policy tool kits.

Each of these user services achieves one or more of the above-mentioned goals in some way. Some - collision avoidance systems, for example - can do so without government involvement, but others can only be effective if deployed by a jurisdiction to achieve a specific policy aim (see Appendix A). The potential value or benefits of ITS applications could be greatly enhanced if transportation jurisdictions choose to employ these technologies to support their specific transportation policies.

ITS literature contains no reference to the classification of user services as either a policy tool kit or a consumer product. However, a classification system is desirable to permit future analysts to develop focussed benefit-cost studies, and to simplify the evaluation of user services whose success will be driven more by consumer product acceptance than by government policy.

The success of government initiatives that encourage ITS product development through seed funding to the private sector is measured on the assumption that products such as air bags, anti-lock braking systems, and the proposed collision avoidance systems will yield substantial benefits in lives saved and injuries averted.

2.2.1 Policy Tool Kit: An Illustration

A good example of how governments can use ITS to effect transport policy is the Advanced Traffic Management Systems (ATMS) bundle, which has significant potential to improve the efficiency of our road network by applying variable user service charges to shift discretionary travel to non-peak hours and to increase the attractiveness of alternative modes and carpooling. The technology will soon be available, but its application depends totally on the affected transportation jurisdiction.

The difficulty for the benefit-cost analyst is to predict the client jurisdiction’s intended policy objective. If an analyst makes an erroneous assumption, the study results will not be relevant to policy makers. Thus each benefit-cost analysis must be defined by the specific policy objective that a client jurisdiction is striving to achieve.

Consider the Bay Area experience. In San Francisco, the Bay Area Congestion Pricing Task Force, a coalition of government, business, environmental, and public interest organizations, developed a demonstration program to introduce variable congestion pricing for the San Francisco-Oakland Bay Bridge. The proposal was to triple the manual toll collections to $3 (collections are made only at the entrance to San Francisco). It was estimated that this would reduce morning and evening traffic delays by 40 percent and 47 percent respectively, by eliminating 7 percent of the traffic. At the same time, it would trigger the release of a special $23 million federal grant to improve transit and ride-sharing alternatives in the Bay Bridge Corridor.

While many constituents agree with the proposed policy objective, state legislators are slow to bring the issue before the state assembly in Sacramento, where amendments would be required to increase the toll (3). This reluctance has been attributed to fear of a backlash from the public, who have voiced concern over this issue, despite the task force's proposal to exempt low-income motorists from the surcharge.

2.2.2 Consumer Product: An Illustration

Some ITS user services are being developed as consumer products. Here the role for the public sector is to provide industry-wide standards and coordination and to ensure that the products meet proper ergonomic standards for driving safety.[2] However, public acceptance of these products, while certainly promoted by government action, will depend entirely on the consumer.

An example is Route Guidance, information provided to the driver through an on-board navigation system. In the United States, several car rental companies are experimenting with this new service. The system carries digitized maps of metropolitan regions and, through the use of a Global Positioning System (GPS), the location of the automobile is displayed on a monitor. This locational knowledge helps motorists to select the most efficient route to the desired destination. The success of Route Guidance will largely depend on consumer acceptance and the perceived value that it offers. In U.S. metropolitan regions where digitized maps are available, consumers have demonstrated a willingness to pay a premium for this service.

The estimated time frame for Route Guidance is from five to 20 years. Although it is available today, the current system does not allow motorists to receive information about changing road conditions. Ultimately, Route Guidance will also provide up-to-the-minute information about relevant road conditions to help the motorist circumvent impending traffic bottlenecks or incidents. A fully mature system will rely on an operational intelligent transportation infrastructure to emit, receive, and process guidance information for the motorist.

[2] There are concerns that some products, primarily those related to the en-route travel information bundle, may distract motorists.

2.2.3 ITS: Product Maturity and Application for Transportation Policy

To facilitate benefit-cost analyses, the 29 user services can be categorized as either consumer products or public policy tools. Table 1 represents a first attempt at classification. It includes an estimation of the date when the user service technology will be fully deployable. Where a range is given, a gradual evolution of the technology is predicted.

2.2.4 Social Costs of Automobile Transport

Perhaps the greatest contribution of ITS to transportation and urban social issues is that it allows governments to incorporate the social costs of automobile transport with private costs to drivers (see Section 5).

In the 1960s, prominent urban social scientists such as Anthony Downs observed that motorists do not pay for the full cost of automobile transport because, in addition to the private costs of ownership and operation, drivers impose costs on society as a whole. In some jurisdictions, these negative side effects may well exceed the private cost of automobile transport. In a report to Transport Canada, Hans Blumenfeld identified four social costs:

- costs imposed on other movements - goods, services, transit vehicles, and pedestrians - by interference and by expanding all distances as a result of large land requirements for parking;
- costs imposed on the environment - air pollution, noise, damage to plant life, poor urban aesthetics, highway signage, and the deterioration of life in neighbourhoods subjected to increased traffic, new arteries, or new freeways;

  [In 1978 the environmental hazards of global warming attributed to automobiles were not known. If they had been, Hans Blumenfeld would no doubt have included that cost as well.]
- costs imposed on individuals lacking automobile access (see Section 3.3);
- costs imposed on both users and non-users - increased stress, as well as danger to life, limb, and property (4).

The term Automatic Vehicle Identification (AVI) dates back to the early sixties when urban social scientists assumed that motorists would change their travel behaviour (location decisions as well as selected mode) if they were made to pay the full cost of automobile transport. The absence of AVI technology and a lack of political willingness prevented these scientists from persuading government jurisdictions to convert social costs or the costs of negative side effects into private costs. ITS technology has now removed the first impediment.

2.3 ITS: Bundling of User Services and Benefit Framework

The 29 user services of ITS have been grouped into seven separate bundles or functional areas, each addressing specific transportation objectives related to broader goals. The addition of an eighth bundle, Border Crossing Control, is proposed here. Because ITS development in the United States and Canada is evolving rapidly, the bundles, user services, and goals are constantly being reviewed, re-justified, and modified. This process will continue as ITS gains broader acceptance. The bundles described in Section 2.3.1 will doubtless be modified over time.

Already, at the request of the railways, ITS America and ITS Canada are determining how ITS could be used to improve grade level crossings. The Transportation Association of Canada may sponsor an ITS study on the deployment of ITS at a grade level crossing, thus creating a need for an ITS benefit-cost study.

2.3.1 Bundles

The ITS bundles were recently revised. Those listed below replace the original functional areas: Advanced Traffic Management Systems (ATMS); Advanced Traveller Information Systems (ATIS); Commercial Vehicle Operations (CVO); Advanced Public Transit Systems (APTS); Advanced Vehicle Control Systems (AVCS); and Advanced Rural Transportation Systems (ARTS).

The differences are the elimination of ARTS, given the easy adaptation of ITS to rural conditions; the designation of electronic payment as a separate bundle; the addition of emergency management; and, in Canada, the addition of border crossing control.

TABLE 1
Classification of User Services

User Service	Time Frame	Product/Public Policy
Travel and Transportation Management		
1. En-Route Driver Information		
2. Route Guidance	5 to 10 years	Consumer Product
3. Traveller Services Information	5 to 20 years	Consumer Product
4. Traffic Control	5 to 10 years	Consumer Product
5. Incident Management	5 years	Government Tool Kit
6. Emissions Testing and Mitigation	5 to 10 years	Government Tool Kit
Travel Demand Management	5 years	Government Tool Kit
7. Demand Management & Operations		
8. Pre-trip Travel Information	10 to 20 years	Government Tool Kit
9. Ride Matching and Reservation	5 to 10 years	Consumer Product
Public Transportation Operations	5 to 20 years	Government Tool Kit
10. Public Transportation Management		
11. En Route Transit Information	5 to 10 years	Government Tool Kit
12. Personalized Public Transit	5 to 10 years	Consumer Product
13. Public Travel Security	5 to 10 years	Government Tool Kit
Electronic Payment	5 to 10 years	Government Tool Kit
14. Electronic Payment Services		
Commercial Vehicle Operations	5 years	Government Tool Kit
15. Comm. Vehicle Elect. Clearance		
16. Automated Roadside Safety	5 years	Government Tool Kit
Inspections	10 years	Government Tool Kit
17. On-Board Safety Monitoring		
18. Comm. Vehicle Admin Process	10 years	Government Tool Kit
19. HAZMAT Response	5 years	Consumer Product
20. Freight Mobility	5 to 10 years	Government Tool Kit
Emergency Management	5 to 10 years	Consumer Product
21. Emergency Notification and Personal		
Security	10 years	Government Tool Kit
22. Emergency Vehicle Management		
Advanced Vehicle Control &	5 years	Government Tool Kit
Safety Systems		
23. Longitudinal Collision Avoidance		
24. Lateral Collision Avoidance	10 to 20 years	Consumer Product
25. Intersection Collision Avoidance	10 to 20 years	Consumer Product
26. Vision Enhancement	10 to 20 years	Consumer Product
27. Pre-Crash Restraint Deployment	10 to 20 years	Consumer Product
28. Safety Readiness	5 to 10 years	Consumer Product
29. Automated Highway System	10 to 20 years	Consumer Product
	20 years +	Consumer Product

The resulting bundles are as follows:

- Travel and Transportation Management
- Travel Demand Management
- Public Transportation Operations
- Electronic Payment
- Commercial Vehicle Operations
- Emergency Management
- Advanced Vehicle Control and Safety Systems
- (Border Crossing Control - ITS Canada addition)

2.3.2 Relationship of Bundles to ITS Goals and Strategies

Travel and Transportation Management (1)

♦ En-Route Driver Information

Real-time information about road and weather conditions, incidents, construction, and transit schedules is provided to motorists en route, permitting them to select the best route.

The Province of Ontario's COMPASS includes one such application. It does not offer interactive communication, but warns motorists of impending traffic problems to permit them to bypass the problem areas. Since interactive communication is not yet available, information about traffic congestion on the road ahead is currently being transmitted to motorists via Changeable Message Signs (CMS).

♦ Route Guidance

On-board navigation systems, currently available from some car rental companies, suggest the most effective route to a selected destination. A critical component of the system is the interactive real-time information exchanged between a central control centre and the driver. Hand-held devices to transmit information to pedestrians and cyclists are also being developed. The foremost application to date is Travel Guide, a Province of Ontario initiative.

- Traveller Services Information

Referred to as ITS's "Yellow Pages" service, this commercial initiative carries paid advertisements for travel-dependent businesses such as tourist attractions, hotels, restaurants, and emergency and repair facilities. This trip planning service should be considered as a prime source of ITS revenue.

- Traffic Control

Traffic control refers to centres that manage vehicle movement on streets and highways. An illustrative analogy is an airport ground control tower, which ensures that the movements of vehicles and taxiing aircraft are conducted with no interference and maximum safety. The only difference between airport ground control and ITS traffic control is that while the former conveys mandatory directives, the latter will merely offer guidance, except in the case of closure and opening of lanes and exit and entrance ramps to highways.

Interactive communications between the traffic control centre and individual drivers are an important facet of this operation. Drivers will not only collect information, they will also be able to transmit information about road conditions to the traffic control centre, where it will be processed and transmitted to all drivers in the area - hence the term interactive communication.

- Incident Management

Primarily a surveillance function that monitors the movement of vehicular traffic, incident management is designed to reduce emergency response time for non-recurring congestion. Ontario's COMPASS, which includes a monitoring function, has reduced the duration of incidents, from occurrence to clearance, from 86 minutes to an average of 30 minutes. This has reduced the average delay per incident by 537 vehicle-hours or over 300 000 hours a year. In addition, over 200 accidents are averted every year because of CMS, and circulation speed has increased by 7 to 19 percent. With an actual cost to date of $33.6 million, the payback period is 3.5 years at an internal rate of return of 18 percent (5).

- Emissions Testing and Mitigation

This information service provides real-time data on air quality and permits authorities to evaluate the effectiveness of transportation pollution-control strategies. The ability to link this information with variable road pricing (Travel Demand Management) will permit authorities to charge motorists a fee related to an automobile's harmful effects on the environment.

Travel Demand Management

- Demand Management and Operations

Travel demand management and operations act as a tool that allows transportation managers and policy makers to effect travel behaviour changes that decrease the number of vehicles on the roads at one time. Whether the strategy is to promote carpooling or public transit, or to shift part of the traffic to non-peak hours, this tool is the most effective means of changing motorists' travel behaviour, and a key method of mitigating the environmental and social impacts of traffic congestion. Its deployment will allow authorities to use a "stick or carrot" approach. If used in isolation from other ITS initiatives, especially APTS, it will generally be relied upon as a punitive mechanism to discourage travellers who routinely choose the automobile.

- Pre-trip Travel Information

Real-time pre-trip information with estimated door-to-door travel times, transit schedules, and costs for each available mode and route, will help prospective travellers to select the most convenient mode and departure time, or perhaps to defer or cancel a journey. Commuting duration, unreliability, waiting times, and poor connections are the most important disincentives for prospective transit users. Having reliable information, it is assumed, will encourage travellers to change from individual automobiles to car pooling and public transit. This information could include other pertinent data, such as the emission levels generated by the use an automobile on a particular journey, or could be extended to deal with longer, less frequent trips.

This ITS component is a crucial element in a strategy to allow travellers to make the most efficient decisions about their trips from a time and cost perspective.

Ride Matching and Reservation

This service will provide real-time ride matching information and reservations to users in homes, offices, and other locations. The objective is to increase carpooling by matching a greater number of motorists to individuals seeking transportation.

Public Transportation Operations

One of the major negative outcomes of post-war urban development was the creation of low-density suburbs that make the provision of public transit cost-ineffective. To serve a community adequately, scheduled public transit transportation on fixed routes was required. Now, with the advent of interactive communication, public transit can be more efficiently deployed in response to service demands. In rural settings where citizens are unable to access automobile transport, applications may allow cost-effective public transit.

- Public Transportation Management

This service automates the operation, planning, and management of public transit systems. Mirroring the traffic control user service for roads, public transit management systems will provide real-time communication to drivers about schedule deviations, connections, and alternative route selections to increase the efficiency of the public transportation system.

- En-Route Transit Information

This real-time information helps passengers to make proper transfers and to modify their itinerary if necessary.

- Personalized Public Transit

In this user service, flexible public transit is offered to travellers who request personalized service, such as travel from door-to-door. A major beneficiary would be regions with dispersed populations, such as rural communities. In regions like Prince Edward Island, with no transit service between major towns and villages, personalized public transit may fill a need that is not met today. Such flexible transport could be provided by mini-vans or even contracted taxi firms, rather than by a typical large capacity bus.

- Public Travel Security

Operating in much the same way as incident management, this surveillance function is intended to provide physical security for public transit users. Surveillance systems with rapid response times are key to enhancing the security of the individual.

Electronic Payment

- Electronic Payment Services

Today, many people carry smart cards that allow them to place calls and send faxes when they are away from their offices and homes, without the need for cash. The convenience of this service facilitates and promotes communications.

A similar concept now being developed for transportation could be made available for all modes, including automobiles. In an automobile, a transponder tag would be inserted into the car to allow road and highway sensors to record road mileage. The technology would further permit authorities to introduce variable road pricing to effect travel behaviour changes. This mature technology has already been introduced on over 20 toll roads in the United States and is a key feature of the public-private sector partnership in the Highway 407 project in Ontario.

Commercial Vehicle Operations

- Commercial Vehicle Electronic Clearance

Composed of Automatic Vehicle Identification and Weigh-in-Motion technologies, this user service is designed to facilitate the clearance of heavy commercial vehicles at domestic and international border points. Applied to weight and customs inspections, the clearance system improves traffic flow and helps to ensure road safety.

Two important projects are under way in the United States and Canada: I-75 running from Ontario through the Ontario-Michigan border and cutting down through Ohio, Kentucky, and Tennessee; and the HELP Project on the western coast running through Mexico, Arizona, California, Oregon, Washington, British Columbia, and, eventually, Alberta and the prairie provinces.

- Automated Roadside Safety Inspections

Through the use of sensors and diagnostics, automated roadside safety inspections would check vehicle systems and driver alertness.

- On-Board Safety Monitoring

The railway industry employs "hot boxes" to detect wheel bearing failures that can lead to train derailments. A similar system is being developed to provide on-board monitoring of driver, cargo, and vehicle. The system would include interactive communication with a traffic control centre.

- Commercial Vehicle Administrative Processes

Today, carriers that cross several state and provincial jurisdictions must maintain credentials and satisfy requirements for each province and state. Not only can this lead to time delays due to incorrect permits, it also forces carriers to employ personnel to administer the extensive paperwork required. Electronic clearance can provide “one stop" administration services. It can also record statistics on fuel consumed, mileage covered, and tolls paid in each jurisdiction, to ease administrative tax burdens. This system can also allow jurisdictions to track and record the movements of cargo by carrier and shipper.

- Hazardous Material Incident Response

The ability to identify cargo in transit is a key achievement that will allow authorities to deter the illegal shipment of hazardous goods and to disseminate information to emergency response teams in case of an accident.

- Freight Mobility

Instantaneous communications between fleet dispatchers and drivers, coupled with real-time traffic information, will permit more cost-effective commercial trucking operations. Last-minute itinerary changes for pick-ups and time savings from automatic clearance and from rerouting to bypass traffic congestion will mean increased revenues and lower operating costs for carriers.

Emergency Management

- Emergency Notification and Personal Security

Vehicles and drivers would carry a device that emits signals after breakdowns and accidents, permitting response teams to locate and assist travellers in emergencies.

- Emergency Vehicle Management

Similar in function to on-board navigation systems, these interactive communication devices will allow emergency response teams to respond quickly when needed.

Advanced Vehicle Control and Safety Systems

Compared to the other bundles, Advanced Vehicle Control and Safety Systems are not yet technically mature and will not be operational for 20 years or more. However, continued development by the public and private sectors depends on anticipated and achievable benefits. For example, will these systems work? If they do, will the benefits be as great as anticipated?

- Longitudinal Collision Avoidance

Safety automation promises to help prevent head-on, rear-end, or backing collisions with other objects and pedestrians. Sensors would anticipate impending collisions and automatically assume emergency vehicle control.

- Lateral Collision Avoidance

Many collisions are due to unsafe lane changes. Sensor-emitted information could reduce blind spot hazards. Automatic systems could also be programmed to control the vehicle until the impending collision is avoided.

- Intersection Collision Avoidance

Similar systems to warn drivers of impending intersection collisions are being developed.

- Vision Enhancement for Crash Avoidance

The vision of drivers will be enhanced to improve detection of road and pedestrian hazards.

- Pre-Crash Restraint Deployment

This system will anticipate impending collisions and activate passenger safety systems before a collision occurs.

- Safety Readiness

This system will monitor roadside conditions and the alertness of the driver and issue a warning to the driver to avert an impending collision.

- Automated Highway System

This system, the most closely associated with ITS, is far off in the future. It will provide a fully automated, “hands-off” operating environment. Theoretically, such a system would eliminate collisions and substantially reduce traffic congestion.

Border Crossing Control

This bundle borrows several user services from other bundles to form a separate initiative for ITS applications. In anticipation of increased trade arising from the North

American Free Trade Agreement, the United States Department of Transportation launched a study to examine the ability of border crossing points to accommodate increased traffic. It urged the respective crossing authorities to examine the feasibility of using ITS technology to improve traffic capacity and to increase the effectiveness of border control (6).

The following user services have been selected:

- Route Guidance
- Traveller Information Services
- Pre-trip Travel Information
- Electronic Payment
- Commercial Vehicle Clearance
- Automated Roadside Safety Inspection
- Commercial Vehicle Administrative Process

This report includes a benefit-cost case study on the use of ITS at the Ontario-Michigan border crossing (see Section 4).

2.4 Assessment of Current Benefit-Cost Framework: Literature Review

This research included a literature review of a large selection of Canadian and American ITS benefit-cost studies. The review revealed several important points about the state of the art in ITS benefit-cost assessments, particularly in the United States:

- To date, ITS America has not developed a standard ITS benefit-cost framework, although the Federal Highways Administration did mandate MITRE Corp. to develop one (see Section 1).
- The absence of a standard framework has not prevented others from carrying out their own ITS benefit-cost studies, independently of the MITRE mandate.
- A significant impediment to compiling an effective benefit-cost study is the absence of empirical data.
- By relying almost exclusively on individual user benefits, many studies fail to consider benefits to other beneficiaries, such as the community or the transportation network.
- Many ITS applications, in particular CVO, are modest in capital cost and the benefits are very evident. In many instances, such as the HELP and I-75 programs, the

impediments are largely institutional and not financial or technical. As a result, future benefit-cost studies should underscore the benefits to the transportation jurisdictions, to foster their acceptance of this tool.

The review clearly indicated that most of the benefit-cost studies have tended to underestimate the benefits of ITS.

2.5 Development of a Benefit-Cost Framework for User Services

The MITRE Group’s benefit-cost framework links individual goals, objectives, and strategies (see Section 2.1) to each of the 29 user services that make up the ITS initiative. In November 1994 a large group of ITS benefit-cost specialists assembled to review and comment on the appropriateness of the proposed ITS framework.

2.5.1 Response by U.S. ITS Community

The draft framework has not been accepted in its entirety and further development has been decelerated, because ITS professionals, with their divergent interests, find it difficult to reach a consensus.

The difficulty in gaining universal acceptance reflects the very nature of ITS deployment itself. Transportation managers assess ITS according to its ability to solve the transportation problems of their individual communities and, even more narrowly, their departmental mandates. ITS deployment is primarily policy driven, and should not be viewed as a consumer product replicating the same transportation behavioural effect in every application. It is misguided to expect a single framework or template to suit each transportation environment across North America perfectly. A more effective way to view the framework is as a “benchmark item list” to test ITS deployment. For example, how effective has “Ride Matching and Reservations” been in increasing vehicle highway capacity? The item relates to a possible causal effect of ITS deployment, but the transportation jurisdiction must encourage that outcome as a community-wide objective, if it chooses to use this means of transportation management. “Ride Matching and Reservations” could also be used to improve accessibility to the transportation network, a different action item for that user service.

Some U.S. observers have viewed this lack of a consensus as a failure for the U.S. ITS initiative, but consensus should not be a goal for the Canadian ITS community. The framework is a good comprehensive mapping of likely outcomes of ITS deployment by individual user services. Canadian transportation jurisdictions must decide whether the likely outcomes are desirable.

2.5.2 Institutional Issues

The apparent inability to map out institutional issues that either impede or promote ITS deployment is another source of disagreement over the framework. Institutional barriers have become a major concern. ITS investigators specifically mentioned institutional impediments in the I-75 program (7). One school of thought argues that the framework should identify areas of institutional resistance or problem areas. Others believe that it should be oriented towards operational tests and that issues of an institutional nature should be excluded.

Within a narrow definition of ITS beneficiaries, where the benefits and costs are exclusively targeted to users, it would be very difficult to map institutional concerns adequately. A more comprehensive framework, which identifies benefits and costs to beneficiaries other than users, would allow analysts to link potential institutional issues to benefits and costs related to specific sectors, such as transportation infrastructure managers (i.e., government).

2.5.3 Social Costs

The issue of disadvantages or social costs generated the greatest commentary at the November 1994 meeting. In a benefit-cost ratio, the variable on the right side of the equation is expected to reflect not only monetary costs for things like capital investment, but also the negative side effects that may arise and should be accounted for.

It was proposed that further development of the ITS benefit-cost framework be based on a dynamic model where effects that produce positive results for a particular goal are also interpreted and tallied as negative outcomes for other goals. This traceability, it was argued, would permit future benefit-cost analysts to assess the negative side effects, as well as the benefits, of successful applications.

These situations would most aptly apply to seemingly conflicting goals. A case in point is the third goal of “reducing energy and environmental impact” and the fifth goal of “increasing mobility”. Again the resolution of the conflict will be determined by the specific policy objective that a transportation jurisdiction is striving to achieve.

Another example of a disadvantage is seen in the work of Dr. Patricia Waller’s Societal Implications group at the University of Michigan. Their interpretation of ITS is predominantly influenced by the willingness of governments to use travel demand management as a means to lessen the demand for transportation through aggressive variable pricing. The group is concerned about those segments of society that depend on automobile transport, but are least able to support higher charges.

In a 1978 report for Transport Canada, Hans Blumenfeld examined the role of the automobile in our cities. He identified a segment of our population that has become even more marginalized in the age of the automobile. To those who permanently or temporarily are not able to use a car, primarily the poor and the infirm, the social costs of the automobile age are substantial.

> *Their mobility has been catastrophically reduced by the vast extension of distances by an automobile-dominated settlement pattern and by the sharp reduction of transit services because of loss of customers to the automobile (4).*

The Societal Implications group fears that those deprived of automobile transportation will experience substantial hardships and fewer choices of urban activities. Work or residence location may change, retail products may cost more, and access to medical care and education may be restricted, all because accessibility to urban activities is reduced.

Although ATMS can affect this population segment negatively, other ITS initiatives like ATIS and APTS could mitigate these negative social costs by improving accessibility to the transportation network. The extent to which a balance is achieved will depend very much on the policy objectives of the transportation jurisdiction.

3. DEVELOPMENT OF A COMPREHENSIVE ITS BENEFIT-COST MODEL

The present study identifies areas where future benefit-cost studies could better reflect the potential of ITS to enhance mobility in an economically and environmentally sustainable manner. Given that most past studies have underestimated benefits because of their narrow focus, a more comprehensive framework incorporating previously ignored benefits has been developed.

A major difficulty with ITS benefit-cost studies in North America is that transportation analysts follow the traditional approach, where congestion relief and safety enhancement are the guiding principles for transportation infrastructure investment. This approach produces a very limited scope of analysis and fails to address the underlying economic forces that are positively affected by a properly functioning transportation system and negatively affected by system shortcomings. To date, benefits of this third order have not been given due consideration (see Section 3.4). These benefits are derived by increasing or, in some rare cases of unsustainable congestion, maintaining accessibility to urban activities for private citizens and businesses.

3.1 Goal-Oriented Benefit-Cost Studies

To develop a comprehensive benefit-cost study of an ITS application, the analyst must understand the policies, goals, and objectives of the particular transportation jurisdiction. In some instances, such as the decision to award the construction and operation of Highway 407 in Ontario to a private consortium, ITS is not a central objective, but a means of establishing a public-private sector partnership. Such background provides the analyst with a broader vision of how the ITS application is linked to an overall policy objective.

In 1993 the U.S. Department of Transport Federal Highway Administration invited four groups to deliver an ITS architecture plan. An important component of the submission was a benefit-cost analysis; however, no ITS policy objectives were issued. In the absence of specific policy guidelines about the effected transportation change, applicants were forced to make their own statements/judgments. Some emphasized public transport, while others stressed methods of squeezing more cars onto a road network with limited capacity. The resulting plans had little common ground for comparing their relative benefit-cost advantages and disadvantages (see Appendix A).

When the candidate ITS application is primarily a consumer-driven product, the analyst should be beware of allocating arbitrary benefits that ignore perceived consumer values, which are based as much, or more, on perception as on reality. An example is the in-vehicle navigation systems currently marketed by AVIS Rental Car in a successful commercial venture. For a $5 premium, consumers have opted for these ATIS-equipped vehicles because the perceived value of increased safety and reliability is high. A standard benefit-cost analysis may have underestimated this value by using actual rather than perceived consumer benefits (see Section 5 for an illustration of this principle).

3.2 User Groups

One factor leading to underestimation of ITS benefits is the tendency of analysts to exclude secondary and tertiary beneficiaries of an ITS application. This report identifies four beneficiaries for evaluation (see Section 4.3):

- Individual transportation users
- Transportation infrastructure providers and managers
- The community
- Potential private investors/ITS technology suppliers

3.3 Proposed Comprehensive ITS Benefit-Cost Framework

The ITS benefit-cost framework developed by MITRE has been modified for this report to classify beneficiaries according to the four principal client groupings.

All 29 user services are linked to individual goals and objectives. In every instance, primary and secondary benefits are identified. Primary benefits are allocated to the principal beneficiary, which in turn spins off secondary benefits. However, for the secondary benefits to be realized, ITS applications must first effect a primary benefit. This classification should not be interpreted to mean that secondary benefits are less significant than primary benefits. In some areas such as “increasing mobility”, where the primary benefits accrue to individual users, the spin-offs to the outlying community can provide more substantial benefits. A third category is included to illustrate how private sector participation can be attracted to satisfy the relevant client grouping (see Table 2).

TABLE 2 - ITS Benefit-Cost Framework

MAPPING OF USER SERVICES TO ITS STRATEGIC GOALS ACCORDING TO BENEFICIARY	TRAVEL AND TRANSPORTATION MANAGEMENT																							
	1.1 En-Route Driver Information				*1.2 Route Guidance*				*1.3 Traveller Information Services*				*1.4 Traffic Control*				*1.5 Incident Management*				*1.6 Emissions Testing and Mitigation*			
	User	System	Comm.	Private	User	System	Comm.	Private	User	System	Comm.	Private	User	System	Comm.	Private	User	System	Comm.	Private	User	System	Comm.	Private
A Improve Safety																								
1 Reduce the frequency of accidents	B1	B2		PS	B1	B2		PS					B1	B2		PS	B1	B2		PS				
2 Reduce severity of accidents, including fatalities, injuries, property damage	B1	B2		PS	B1	B2		PS					B1	B2		PS	B1	B2		PS				
3 Reduce system incidents	B1	B2		PS	B1	B2		PS					B1	B2		PS	B1	B2		PS				
B Improve Service Level (Efficiency)																								
1 Increase capacity of the transportation system	B2	B1	B2	PS	B2	B1	B2	PS					B2	B1	B2	PS								
2 Reduce congestion due to incidents	B2	B1	B2	PS	B2	B1	B2	PS					B2	B1	B2	PS								
3 Improve transportation customer service	B1		B2	PS	B1		B2	PS					B1		B2	PS								
C Reduce Energy and Environmental Impact																								
1 Reduce harmful emissions per unit of travel		B2	B1	PS		B2	B1	PS		B2	B1	PS		B2	B1	PS		B2	B1	PS		B2	B1	PS
2 Reduce energy consumption per unit of travel		B2	B1	PS		B2	B1	PS		B2	B1	PS		B2	B1	PS		B2	B1	PS		B2	B1	PS
3 Reduce new right-of-way requirements		B2	B1	PS		B2	B1	PS		B2	B1	PS		B2	B1	PS		B2	B1	PS				
4 Reduce environmental impact of HAZMAT mishaps		B2	B1	PS		B2	B1	PS		B2	B1	PS		B2	B1	PS		B2	B1	PS				
D Enhance Productivity																								
1 Reduce costs to fleet operators, operating agencies, and individuals													B1		B2	PS	B1		B2	PS				
2 Reduce travel time	B1		B2	PS	B1		B2	PS	B1		B2	PS	B1		B2	PS	B1		B2	PS				
3 Improve transportation system management and planning		B1	B2	PS										B1	B2	PS								
E Improve Mobility																								
1 Enhance traveller security									B1		B2	PS	B1		B2	PS	B1		B2	PS				
2 Reduce travel stress	B1		B2	PS	B1		B2	PS	B1		B2	PS	B1		B2	PS	B1		B2	PS				
3 Improve accessibility to transportation	B1		B2	PS	B1		B2	PS	B1		B2	PS	B1		B2	PS								
F Provide Innovative Approaches for Infrastructure Financing																								
1 Enable private operators to levy user charges																								
2 Empower private investors to finance infrastruct. investment														B1	B2	B1		B1	B2	B1				
3 Facilitate the creation of new road management companies														B1	B2	B1		B1	B2	B1				

LEGEND

B1 PRIMARY BENEFICIARY

B2 SECONDARY BENEFICIARY

PS PRIVATE SECTOR SUPPLIER INTEREST

Adapted from the MITRE framework developed by D. Shank and R. Bolczak,
and published in the Proceedings of the November 1994 meeting of ITS America.

TABLE 2 - ITS Benefit-Cost Framework (cont'd)

MAPPING OF USER SERVICES TO ITS STRATEGIC GOALS ACCORDING TO BENEFICIARY	TRAVEL DEMAND MANAGEMENT											
	2.1 Pre-trip Travel Information				*2.2 Ride Matching Reservation*				*2.3 Demand Management*			
	User	System	Comm.	Private	User	System	Comm.	Private	User	System	Comm.	Private
A Improve Safety												
1 Reduce the frequency of accidents	B1	B2		PS								
2 Reduce severity of accidents, including fatalities, injuries, and property damage	B1	B2		PS					B1	B2		PS
3 Reduce system incidents									B1	B2		PS
B Improve Service Level (Efficiency)												
1 Increase capacity of the transportation system	B2	B1	B2	PS	B2	B1	B2	PS	B2	B1	B2	PS
2 Reduce congestion due to incidents	B2	B1	B2	PS					B2	B1	B2	PS
3 Improve transportation customer service	B1		B2	PS	B1		B2	PS				
C Reduce Energy and Environmental Impact												
1 Reduce harmful emissions per unit of travel		B2	B1	PS		B2	B1	PS		B2	B1	PS
2 Reduce energy consumption per unit of travel		B2	B1	PS		B2	B1	PS		B2	B1	PS
3 Reduce new right-of-way requirements		B2	B1	PS		B2	B1	PS		B2	B1	PS
4 Reduce environmental impact of HAZMAT mishaps												
D Enhance Productivity												
1 Reduce costs incurred by fleet operators, operating agencies, and individuals												
2 Reduce travel time												
3 Improve transportation system management and planning												
E Improve Mobility												
1 Enhance traveller security												
2 Reduce travel stress	B1		B2	PS	B1		B2	PS				
3 Improve accessibility to transportation	B1		B2	PS	B1		B2	PS				
F Provide Innovative Approaches for Infrastructure Financing												
1 Enable private operators to levy user charges												
2 Empower private investors to finance infrastructure investment												
3 Facilitate the creation of new road management companies												

LEGEND

B1 PRIMARY BENEFICIARY

B2 SECONDARY BENEFICIARY

PS PRIVATE SECTOR SUPPLIER INTEREST

TABLE 2 - ITS Benefit-Cost Framework (cont'd)

	MAPPING OF USER SERVICES TO ITS STRATEGIC GOALS ACCORDING TO BENEFICIARY	PUBLIC TRANSPORT OPERATIONS															
		3.1 Public Transport Management				*3.2 En-Route Transit Information*				*3.3 Personalized Public Transit*				*3.4 Public Travel Security*			
		User	System	Comm.	Private	User	System	Comm.	Private	User	System	Comm.	Private	User	System	Comm.	Private
A	**Improve Safety**																
1	Reduce the frequency of accidents																
2	Reduce severity of accidents, including fatalities, injuries, and property damage																
3	Reduce system incidents																
B	**Improve Service Level (Efficiency)**																
1	Increase capacity of the transportation system	B2	B1	B2	PS	B2	B1	B2	PS	B2	B1	B2	PS				
2	Reduce congestion due to incidents	B2	B1	B2	PS	B2	B1	B2	PS	B2	B1	B2	PS				
3	Improve transportation customer service	B1		B2	PS	B1		B2	PS	B1		B2	PS				
C	**Reduce Energy and Environmental Impact**																
1	Reduce harmful emissions per unit of travel		B2	B1	PS		B2	B1	PS		B2	B1	PS				
2	Reduce energy consumption per unit of travel		B2	B1	PS		B2	B1	PS		B2	B1	PS				
3	Reduce new right-of-way requirements		B2	B1	PS		B2	B1	PS		B2	B1	PS				
4	Reduce environmental impact of HAZMAT mishaps		B2	B1	PS		B2	B1	PS		B2	B1	PS				
D	**Enhance Productivity**																
1	Reduce costs incurred by fleet operators, operating agencies, and individuals	B1		B2	PS	B1		B2	PS	B1		B2	PS				
2	Reduce travel time	B1		B2	PS	B1		B2	PS	B1		B2	PS				
3	Improve transportation system management and planning		B1	B2	PS		B1	B2	PS		B1	B2	PS				
E	**Improve Mobility**																
1	Enhance traveller security													B1		B2	PS
2	Reduce travel stress	B1		B2	PS	B1		B2	PS	B2		B2	PS	B1		B2	PS
3	Improve accessibility to transportation	B1		B2	PS	B1		B2	PS	B2		B2	PS	B1		B2	PS
F	**Provide Innovative Approaches for Infrastructure Financing**																
1	Enable private operators to levy user charges																
2	Empower private investors to finance infrastructure investment																
3	Facilitate the creation of new road management companies																

LEGEND

B1	PRIMARY BENEFICIARY
B2	SECONDARY BENEFICIARY
PS	PRIVATE SECTOR SUPPLIER INTEREST

TABLE 2 - ITS Benefit-Cost Framework (cont'd)

MAPPING OF USER SERVICES TO ITS STRATEGIC GOALS ACCORDING TO BENEFICIARY	ELECTRONIC PAYMENT			
	4.1 Electronic Payment			
	User	System	Comm.	Private
A Improve Safety				
1 Reduce the frequency of accidents	B1		B2	PS
2 Reduce severity of accidents, including fatalities, injuries, and property damage				
3 Reduce system incidents				
B Improve Service Level (Efficiency)				
1 Increase capacity of the transportation system	B2	B1	B2	PS
2 Reduce congestion due to incidents				
3 Improve transportation customer service	B1		B2	PS
C Reduce Energy and Environmental Impact				
1 Reduce harmful emissions per unit of travel		B2	B1	PS
2 Reduce energy consumption per unit of travel		B2	B1	PS
3 Reduce new right-of-way requirements				
4 Reduce environmental impact of HAZMAT mishaps				
D Enhance Productivity				
1 Reduce costs incurred by fleet operators, operating agencies, and individuals	B1		B2	PS
2 Reduce travel time	B1		B2	PS
3 Improve transportation system management and planning		B1	B2	PS
E Improve Mobility				
1 Enhance traveller security				
2 Reduce travel stress	B1		B2	PS
3 Improve accessibility to transportation	B1		B2	PS
F Provide Innovative Approaches for Infrastructure Financing				
1 Enable private operators to levy user charges		B1	B2	B1
2 Empower private investors to finance infrastructure investment		B1	B2	B1
3 Facilitate the creation of new road management companies		B1	B2	B1

LEGEND

B1 PRIMARY BENEFICIARY

B2 SECONDARY BENEFICIARY

PS PRIVATE SECTOR SUPPLIER INTEREST

TABLE 2 - ITS Benefit-Cost Framework

MAPPING OF USER SERVICES TO ITS STRATEGIC GOALS ACCORDING TO BENEFICIARY	COMMERCIAL VEHICLE OPERATIONS																							
	5.1 Commercial Vehicle Clearance				*5.2 Automated Roadside Safety Insp.*				*5.3 On-Board Safety Monitoring*				*5.4 Commercial Veh. Administrative Proc.*				*5.5 Hazardous Material Incident Response*				*5.6 Commercial Fleet Management*			
	User	System	Comm.	Private	User	System	Comm.	Private	User	System	Comm.	Private	User	System	Comm.	Private	User	System	Comm.	Private	User	System	Comm.	Private
A Improve Safety																								
1 Reduce the frequency of accidents	B1	B2		PS	B1	B2		PS	B1	B2		PS	B1	B2		PS					B1	B2		PS
2 Reduce severity of accidents, including fatalities,injuries, and property damage	B1	B2		PS	B1	B2		PS	B1	B2		PS					B1	B2		PS	B1	B2		PS
3 Reduce system incidents	B1	B2		PS	B1	B2		PS	B1	B2		PS												
B Improve Service Level (Efficiency)																								
1 Increase capacity of the transportation system	B2	B1	B2	PS																	B2	B1	B2	PS
2 Reduce congestion due to incidents																	B2	B1	B2	PS	B2	B1	B2	PS
3 Improve transportation customer service																					B1		B2	PS
C Reduce Energy and Environmental Impact																								
1 Reduce harmful emissions per unit of travel		B2	B1	PS																		B2	B1	PS
2 Reduce energy consumption per unit of travel		B2	B1	PS																		B2	B1	PS
3 Reduce new right-of-way requirements		B2	B1	PS																		B2	B1	PS
4 Reduce environmental impact of HAZMAT mishaps		B2	B1	PS																		B2	B1	PS
D Enhance Productivity																								
1 Reduce costs incurred by fleet operators, operating agencies, and individuals	B1		B2	PS	B1		B2	PS					B1		B2	PS					B1		B2	PS
2 Reduce travel time	B1		B2	PS	B1		B2	PS													B1		B2	PS
3 Improve transportation system management and planning		B1	B2	PS																				
E Improve Mobility																								
1 Enhance traveller security	B1		B2	PS																				
2 Reduce travel stress	B1		B2	PS																	B1		B2	PS
3 Improve accessibility to transportation																								
F Provide Innovative Approaches for Infrastructure Financing																								
1 Enable private operators to levy user charges		B1	B2	PS																				
2 Empower private investors to finance infrastructure investment		B1	B2	PS																				
3 Facilitate the creation of new road management companies																								

LEGEND

B1 PRIMARY BENEFICIARY

B2 SECONDARY BENEFICIARY

PS PRIVATE SECTOR SUPPLIER INTEREST

TABLE 2 - ITS Benefit-Cost Framework (cont'd)

MAPPING OF USER SERVICES TO ITS STRATEGIC GOALS ACCORDING TO BENEFICIARY	EMERGENCY MANAGEMENT							
	E.1 Emergency Notification & Personal Security				*E.2 Emergency Vehicle Management*			
	User	System	Comm.	Private	User	System	Comm.	Private
A Improve Safety								
1 Reduce the frequency of accidents								
2 Reduce severity of accidents, including fatalities, injuries, and property damage	B1	B2		PS	B1	B2		PS
3 Reduce system incidents								
B Improve Service Level (Efficiency)								
1 Increase capacity of the transportation system								
2 Reduce congestion due to incidents	B2	B1	B2	PS	B2	B1	B2	PS
3 Improve transportation customer service	B1		B2	PS	B1		B2	PS
C Reduce Energy and Environmental Impact								
1 Reduce harmful emissions per unit of travel								
2 Reduce energy consumption per unit of travel								
3 Reduce new right-of-way requirements								
4 Reduce environmental impact of HAZMAT mishaps								
D Enhance Productivity								
1 Reduce costs incurred by fleet operators, operating agencies, and individuals								
2 Reduce travel time								
3 Improve transportation system management and planning								
E Improve Mobility								
1 Enhance traveller security	B1		B2	PS				
2 Reduce travel stress								
3 Improve accessibility to transportation								
F Provide Innovative Approaches for Infrastructure Financing								
1 Enable private operators to levy user charges								
2 Empower private investors to finance infrastructure investment								
3 Facilitate the creation of new road management companies								

LEGEND

B1 PRIMARY BENEFICIARY

B2 SECONDARY BENEFICIARY

PS PRIVATE SECTOR SUPPLIER INTEREST

TABLE 2 - ITS Benefit-Cost Framework (cont'd)

	MAPPING OF USER SERVICES TO ITS STRATEGIC GOALS ACCORDING TO BENEFICIARY	ADVANCED VEHICLE CONTROL AND SAFETY SYSTEMS																											
		7.1 Longitudinal Collision Avoidance				*7.2 Lateral Collision Avoidance*				*7.3 Intersection Collision Avoidance*				*7.4 Vision Enhanc. for Crash Avoidance*				*7.5 Safety Readiness*				*7.6 Pre-Crash Restraint Deployment*				*7.7 Automated Highway System*			
		User	System	Comm.	Private	User	System	Comm.	Private	User	System	Comm.	Private	User	System	Comm.	Private	User	System	Comm.	Private	User	System	Comm.	Private	User	System	Comm.	Private
A	**Improve Safety**																												
1	Reduce the frequency of accidents	B1	B2		PS	B1	B2		PS	B1		B2	PS	B1	B2		PS	B1	B2		PS					B1	B2		PS
2	Reduce severity of accidents, including fatalities, injuries, and property damage	B1	B2		PS	B1	B2		PS	B1		B2	PS	B1	B2		PS	B1	B2		PS	B1	B2		PS	B1	B2		PS
3	Reduce system incidents	B1	B2		PS	B1	B2		PS	B1		B2	PS	B1	B2		PS	B1	B2		PS					B1	B2		PS
B	**Improve Service Level (Efficiency)**																												
1	Increase capacity of the transportation system	B2	B1	B2	PS	B2	B1	B2	PS	B2	B1	B2	PS	B2	B1	B2	PS	B2	B1	B2	PS					B2	B1	B2	PS
2	Reduce congestion due to incidents	B2	B1	B2	PS	B2	B1	B2	PS	B2	B1	B2	PS	B2	B1	B2	PS	B2	B1	B2	PS					B2	B1	B2	PS
3	Improve transportation customer service																												
C	**Reduce Energy and Environmental Impact**																												
1	Reduce harmful emissions per unit of travel		B2	B1	PS																						B2	B1	PS
2	Reduce energy consumption per unit of travel		B2	B1	PS																						B2	B1	PS
3	Reduce new right-of-way requirements						B2	B1	PS																		B2	B1	PS
4	Reduce environmental impact of HAZMAT mishaps																												
D	**Enhance Productivity**																												
1	Reduce costs incurred by fleet operators, operating agencies, and individuals																												
2	Reduce travel time																									B1		B2	PS
3	Improve transportation system management and planning																												
E	**Improve Mobility**																												
1	Enhance traveller security																												
2	Reduce travel stress																									B1		B2	PS
3	Improve accessibility to transportation	B1		B2	PS	B1		B2	PS	B1		B2	PS	B1		B2	PS									B1		B2	PS
F	**Provide Innovative Approaches for Infrastructure Financing**																												
1	Enable private operators to levy user charges																												
2	Empower private investors to finance infrastructure investment																												
3	Facilitate the creation of new road management companies																												

LEGEND

B1	PRIMARY BENEFICIARY
B2	SECONDARY BENEFICIARY
PS	PRIVATE SECTOR SUPPLIER INTEREST

TABLE 2 - ITS Benefit-Cost Framework (cont'd)

MAPPING OF USER SERVICES TO ITS STRATEGIC GOALS ACCORDING TO BENEFICIARY — **BORDER CROSSING CONTROL**

		1.2 Route Guidance				*1.3 Traveller Information Services*				*2.1 Pre-trip Travel Information*				*4.1 Electronic Payment*				*5.1 Commercial Vehicle Clearance*				*5.2 Automated Roadside Safety Insp.*				*5.4 Commercial Veh. Administrative Proc.*			
		User	System	Comm.	Private	User	System	Comm.	Private	User	System	Comm.	Private	User	System	Comm.	Private	User	System	Comm.	Private	User	System	Comm.	Private	User	System	Comm.	Private
A	**Improve Safety**																												
1	Reduce the frequency of accidents	B1	B2		PS					B1	B2		PS	B1		B2	PS	B1	B2		PS	B1	B2		PS	B1	B2		PS
2	Reduce severity of accidents, including fatalities, injuries, and property damage	B1	B2		PS					B1	B2		PS					B1	B2		PS	B1	B2		PS				
3	Reduce system incidents	B1	B2		PS													B1	B2		PS	B1	B2		PS				
B	**Improve Service Level (Efficiency)**																												
1	Increase capacity of the transportation system	B2	B1	B2	PS					B2	B1	B2	PS	B2	B1	B2	PS	B2	B1	B2	PS								
2	Reduce congestion due to incidents	B2	B1	B2	PS					B2	B1	B2	PS																
3	Improve transportation customer service	B1	B2	B2	PS					B1	B2	B2	PS	B1	B2	B2	PS												
C	**Reduce Energy and Environmental Impact**																												
1	Reduce harmful emissions per unit of travel		B2	B1	PS		B2	B1	PS		B2	B1	PS		B2	B1	PS		B2	B1	PS								
2	Reduce energy consumption per unit of travel		B2	B1	PS		B2	B1	PS		B2	B1	PS		B2	B1	PS		B2	B1	PS								
3	Reduce new right-of-way requirements		B2	B1	PS		B2	B1	PS		B2	B1	PS						B2	B1	PS								
4	Reduce environmental impact of HAZMAT mishaps		B2	B1	PS		B2	B1	PS										B2	B1	PS								
D	**Enhance Productivity**																												
1	Reduce costs incurred by fleet operators, operating agencies, and individuals													B1		B2	PS	B1		B2	PS	B1		B2	PS	B1		B2	PS
2	Reduce travel time	B1		B2	PS	B1		B2	PS					B1		B2	PS	B1		B2	PS	B1		B2	PS				
3	Improve transportation system management and planning				PS										B1	B2	PS		B1	B2	PS								
E	**Improve Mobility**																												
1	Enhance traveller security					B1		B2	PS									B1		B2	PS								
2	Reduce travel stress	B1		B2	PS	B1		B2	PS	B1		B2	PS	B1		B2	PS	B1		B2	PS								
3	Improve accessibility to transportation	B1		B2	PS	B1		B2	PS	B1		B2	PS	B1		B2	PS												
F	**Provide Innovative Approaches for Infrastructure Financing**																												
1	Enable private operators to levy user charges														B1	B2	B1		B1	B2	PS								
2	Empower private investors to finance infrastructure investment														B1	B2	B1		B1	B2	PS								
3	Facilitate the creation of new road management companies														B1	B2	B1												

LEGEND

B1	PRIMARY BENEFICIARY
B2	SECONDARY BENEFICIARY
PS	PRIVATE SECTOR SUPPLIER INTEREST

By allocating primary and secondary benefits, a discernible pattern emerges:

- The pattern is influenced more by the specific goals and objectives than by individual user services.
- In most instances, a user service effects a primary and a secondary benefit to the transportation user, the transportation infrastructure provider/manager, and the community.
- For “improve safety”, the primary beneficiary is the individual user, and the community is the secondary beneficiary.
- For “improve service levels”, the primary beneficiary is predominantly the transportation infrastructure provider/manager, followed by the community and the individual user.
- For “reduce energy and environmental impact”, the primary beneficiary is the community, followed by the transportation infrastructure provider.
- For “enhance productivity”, the individual traveller receives the primary benefits, followed by the community.
- For “improve mobility”, the primary beneficiary is the individual user, and the community is the secondary beneficiary.
- For electronic payment, where the goal is “to provide innovative approaches for infrastructure financing”, the primary beneficiaries are both the transportation infrastructure provider/manager and the private sector.
- In many instances, the secondary beneficiary is the community, which benefits from the incremental improvement in economic activity and quality of life achieved from an ITS application.

3.4 ITS Benefit-Cost Model: First, Second, and Third Order Benefits

Traditional methods of evaluating transportation projects have concentrated on safety improvements and congestion relief. This approach produces a very limited scope for benefit-cost analyses of ITS in that it fails to link mobility enhancements to improved economic performance.

In 1994 the Transportation Association of Canada published *A Primer on Transportation Investment and Economic Development* by Dr. David Lewis of Hickling, who stressed the urgency for analysts to develop better research tools that can assess how improvements in the transportation infrastructure can effect incremental productivity gains in the economy. For example, will transportation improvements lower the cost of goods or will they improve industrial productivity? The Primer’s underlying assumption is that a combination of reduced costs and increased productivity should encourage or facilitate economic growth, and present the positive signals required to attract industrial investment to Canada (8).

The implication for ITS analyses is quite clear. What are the economic effects of ITS programs that enhance mobility? Unfortunately, current efforts in North America are geared toward traditional benefit-cost analyses and ignore the substantive issues of economic incremental changes that are a direct result of ITS initiatives.

Decreased costs or productivity gains refer to improvements in economic performance brought about by ITS. However, it should also be possible to demonstrate the need for ITS deployment if its implementation arrests the escalating costs of goods and the declining levels of productivity that are directly attributed to ever-increasing levels of congestion. As a result, when benefit-cost analysts forecast changes generated by ITS, an accurate approach would be to estimate, for net comparison purposes, the deterioration of the transportation network and the resulting changes in economic productivity if ITS is not deployed.

3.4.1 Dynamic Model of Client-ITS Relationship

ITS exerts influence on the transportation market and clients draw benefits from ITS applications at three levels.

First Level of Client-ITS Relationship: The Traveller

At the first (or micro) level travellers make individual decisions about if, when, and how to travel. The quality of decisions taken depends on the quality of information available and the decision maker's ability to absorb and make intelligent use of it. At this level, the beneficiaries are the individual users, and the benefits are of the first order. Such benefits are measured in reduced travel times, reduced stress, and improved reliability. Most benefit-cost studies have concentrated on these benefits.

Second Level of Client-ITS Relationship: The Transportation Network

The next (or macro operations) level involves management of the overall transportation network. Decisions about transportation deployment and capacity adjustments are based on real-time information about the performance of the transportation system. Transportation managers also receive information about travel conditions transmitted by individual users and, after processing all available information, advise transportation users on the most efficient modes and travel routes. The objective of ITS deployment at this level is to achieve maximum efficiency and reliability in the transportation system. These second order benefits would be quantified as measures of efficiency in optimizing the performance of the transportation network and reducing harmful environmental effects.

Demonstration of First and Second Order Benefits

Traditional traffic demand modelling can be employed to measure how effectively ITS deployment achieves targeted benefits for the traveller, the transportation network, and the environment. Vehicle miles travelled, commuting time, mode of choice, reduction of emissions, and passengers transported are comprehensive units to measure. Within this framework, the inability to assess trips not taken because of the cost of transportation need not be considered. Hard numbers relating how effectively ITS influences travel behaviour can also be delivered by conventional modelling techniques.

Third Level of Client-ITS Relationship: The Affected Regional Economy

At the highest level of the hierarchy, the macro economic stage, the benefits of ITS deployment are measured in economic and social equity terms. Improvements in the transportation network are directly related to economic performance at a metropolitan, regional, provincial, or national level. The ability to link transportation innovations to economic performance therefore becomes as important as demonstrating that transportation advancements are technically feasible and are effective in changing travel behaviour.

Demonstration of Third Order Benefits

Although the linkage between mobility and economic development is well accepted, it is not well understood or easily quantifiable. Mobility can be understood as accessibility for individuals and businesses to employment, housing, labour, and markets. To the extent that improved transportation systems increase accessibility, the economic value of that incremental change must be assessed to evaluate the relative benefits and costs of ITS deployment. At this macro level, the implications of industrial restructuring, discussed in Dr. Lewis's paper, become more evident.

The Application of a Canadian ITS Benefit-Cost Model

The identification and quantification of first and second order benefits are essential for the majority of ITS benefit-cost analyses. This approach is fairly straightforward using conventional traffic-demand modelling techniques.

However, the interpretation of those results must be tempered by the knowledge that third order benefits may not have been quantified, although the linkage between economic productivity and transportation may be clear. For example, a study by Marshall Macklin Monaghan in May 1994 (9) found that AVI deployment (a $7.88 million investment) to facilitate Ontario-Michigan border crossings produced only marginal benefits to individuals and transportation infrastructure managers. By weighing likely benefits to the community at large and to the automotive industry, however, the benefits of improved traffic flows become more evident, and it is clear that they have been understated in the study (see Section 4). An extensive third order benefit study may not be necessary if the proposed ITS cost is modest and the linkage between accessibility and economic performance is well accepted.

In instances where ITS is primarily impeded by institutional rather than financial barriers, an acknowledgment of third order benefits, however difficult to measure, may be sufficient to decrease or eliminate the institutional impediments preventing full cooperation.

But if the cost of an ITS application (automated highway system or other transportation enhancements such as high speed rail) represents a very significant public sector investment, an attempt to identify and quantify third order benefits is necessary to allow government jurisdictions to make an informed decision.

The high-speed rail investigations undertaken in North America since the early 1980s have, without exception, concentrated on first and second order benefits. If ITS proceeds in the same manner, it too will run the risk of becoming less relevant, not because the technologies are immature or ineffective in changing travel behaviour, but because ITS will fail to demonstrate how much more mobile our society could become and how increased accessibility leads to gains in economic productivity. The sobering reality is that no academic institution, private consulting group, or government-sponsored agency in North America has taken the initiative to research third order benefits.

3.5 Canadian ITS Applications/Programs and Benefit-Cost Analysis: Some Observations

3.5.1 Electronic Payment

Highway 407

Fiscal constraints, acceleration of road construction, public/private road construction, and the introduction of a user-payment concept led to the creation of North America's first privately built and managed highway.

The 69 km Highway 407 in Ontario is designed to include an electronic toll collection system that will not interfere with normal highway operations (manual tolling impedes traffic flows). Electronic tolling will also permit the introduction of other ITS applications aimed at improving road efficiencies. On off/on ramps transponder-equipped vehicles will be detected by AVI readers and those without transponders by video identification. Billing and collection will be handled by the telephone company, which will include road charges on monthly bills. Motorists will have the choice of pre-payment, post-payment, or anonymous cash accounts.

The value of the electronic payment technology will be enhanced by the Province of Ontario's decision to do two things: first, to implement a road consumption charge; and second, to seek out private sector partnerships for financing, construction, and management of this $1 billion investment. If the province had chosen to go it alone and not to impose user charges, the value of the technology would have been limited. In the United States, about 20 tolling collection agencies have introduced some form of electronic payment, generally because, in instances where renewed capital investment was not required, it reduces operational costs by replacing personnel with AVI readers and automated billing systems.

The assessment of benefits and costs for electronic tolling should reflect the mandate for the proposed service as either a means of lowering toll-collection operating costs or a technology to enable private/public sector partnership.

3.5.2 Commercial Vehicle Operations - HELP Project

The Heavy Vehicle Electronic License Plate identification system (HELP) was developed by the Arizona and Oregon Departments of Transportation to identify, classify, and weigh commercial vehicles on highways. Today HELP has expanded to include 15 states and the Province of British Columbia, and is expected to include other western provinces soon.

The greatest impediment to the installation of a commercial vehicle operation (CVO) system, whether HELP or the I-75 Program, is institutional rather than technical. Not enough work has been done to identify the benefits that CVO would generate for individual states and provinces. CVO's major selling point for truckers is that it offers significant economies in the administrative paperwork required from each transportation jurisdiction. The difficulty has been the reluctance of these jurisdictions to adopt universally accepted standards. Unless CVO benefits to the respective transportation jurisdictions can be demonstrated, there is little motivation to proceed with such systems.

Enforcement Value of CVO

By far the greatest benefit to infrastructure managers/providers lies in the enforcement value of CVO applications. An Oregon Department of Transportation study report states:

> *Pavement damage due to the number of and weights of axle loads can be expressed as a function of the number of axles which use a road times the axle load to the power of 4.5 (10).*

According to this methodology, doubling the axle load increases the damage by a factor of 23. To estimate the savings in maintenance costs, the benefit-cost analyst would have to determine and correlate projected savings with the reduced number of non-compliant trucks. The problem is that no jurisdiction in North America is fully aware of the number of non-compliant trucks on the roads. In Oregon, the highway patrol reports that 65 percent of the observed infractions of commercial truck weight occur when Ports of Entry are closed.

Competitive Value of CVO

Exceeding commercial weight limitations is done not simply to increase revenues and lower costs (fewer trucks needed) but, quite often, to stay in business. Competition in the trucking industry has become so fierce since deregulation that a change in the operating costs or revenue stream of a competitor forces a trucking company to respond in kind or else go out of business. If carriers could be assured that CVO can regulate the industry to highway standards with near perfect efficiency, the motivation to exceed limits would decrease considerably. Maintaining level playing fields is a key rationale to persuade carriers to respect weight limits. Again, because the prevalence of the problem is unknown, the significance of this industrial benefit cannot be estimated or quantified.

Social Cost of Effective CVO Applications

Although there is no valid excuse for carriers who exceed weight limits, no empirical data is available to determine the savings to the consumer derived from shipping goods illegally. The feeling in the industry is that carriers of perishable goods and other primary resources, such as timber, are the most frequent offenders. It stands to reason that higher operating costs will result from effective CVO applications. We currently have no way of knowing whether, or how much, the cost of those consumer goods will be raised in response to effective enforcement.

Regulator of Inter-Modal Freight Competition

The reason most often cited by Canada's railway companies, to obtain more favourable tax concessions, is that trucking companies enjoy an unfair advantage because they do not pay their fair share of infrastructure costs. An equalized allocation of operating costs, the railways argue, would permit the railway industry to maintain its own high standards of right-of-way maintenance.

ITS would allow weights and distance to be traced for every commercial truck movement in a CVO-equipped jurisdiction. This would help the federal government to determine whether or not the railways' arguments have substance.

3.5.3 Travel and Transportation Management (ATIS)

Although the public sector has played a significant role in ATIS development, its successful deployment will depend very much on the commercial appeal of the product to the consumer. For this reason, ATIS is primarily consumer driven and not policy driven. This value-added service will be extremely difficult for conventional benefit-cost analysts to evaluate. Consumer-driven strategies market the perceived value of products rather than the actual value, while more traditional benefit-cost analysis strives to assess actual values, not those altered by perception.

The American-based AVIS rental car company has become very successful in attracting consumers to its added value on-board navigation systems, originally tried out in San Jose, California, in 1992 and since modified and introduced into San Francisco and New York (see Section 3.1). AVIS plans to introduce the same service in other large metropolitan regions. In Canada, we have several large cities that could host a similar application.

One Canadian application of ATIS is *Travel Guide*, a Ministry of Transportation of Ontario (MTO) and private sector joint venture to design and market a product that provides pre-trip travel advice, route guidance, and en-route travel information in real time.

Another important application of ATIS is to offer elderly and disabled persons greater mobility. By the year 2005, 33 percent of the Canadian adult population will be aged over 65. Of all the ITS applications, ATIS offers the greatest opportunities to this group. Seventy-eight percent of the elderly and disabled community find that the lack of reliable pre-trip information represents a major impediment to travel. Thus, the provision of such information should greatly increase their mobility and their access to both urban and rural activities.

By providing them with access to the economy, as workers and consumers of goods and services, increasing mobility for elderly and disabled persons could provide substantial third order benefits to the community at large. When an individual has access to employment, society gains by transforming someone dependent on society to one who contributes to the overall wealth of society. More work will be required to assess the effects of this increased mobility on economic performance.

3.5.4 Travel Demand Management – COMPASS and SGAP

COMPASS and SGAP (Le système de gestion de la circulation autoroutière de Montréal) are specific travel demand management applications using real-time information to detect highway incidents that impede traffic flows and to improve the response time of crews correcting such traffic barriers. Changeable message signs are used to alert oncoming vehicles of delays, allowing drivers to take alternative routes to bypass the obstruction.

MTO traffic engineers point out that the COMPASS evaluations were restricted to roadways that were provincially administered and excluded municipal or Metro Toronto roads. In the case of Highway 401, where the collector lanes parallel the highway, very little diverted traffic is rerouted onto non-provincial roads.

However, this does not necessarily hold for other ATMS applications. A case in point is the SGAP application. The Décarie expressway and the elevated Highway 40 have no collector roads. Diverted traffic would funnel onto local roads, thereby increasing congestion and having negative side effects for other vehicles and affected neighbourhoods. To assess the full value of this ATMS application, the net costs of the diverted traffic would have to be assessed and entered into the right side of the benefit-cost equation.

3.5.5 Public Transportation Operations - Automatic Vehicle Location and Control

The Ottawa-Carleton public transit company is spending $20 million to improve the punctuality and schedule adherence of the transit system via on-line two-way communication with its bus drivers. Tracking will be done by stationary sensors that can detect transponder-equipped buses while they are in motion. Locational information will be provided by GPS. Other features include smart cards, electronic fare collection, and passenger counting (11).

The principal objective of this project is to improve the reliability of public transport, thus encouraging patronage and, it is hoped, accelerating a shift from the use of automobiles.

In the Air Canada/CP Rail High Speed Train (HST) Study, empirical data revealed that under optimal conditions regarding station location, convenience, and cost, a full quarter of the motorists interviewed would have used HST. The greatest single deterrent to achieving the mode shift was the perceived and real inconvenience of making not only one modal shift for intercity transport but also another for intra-urban transport. Once the station locations were imposed in the traffic model, those prepared to use HST rather than an automobile fell to 1 percent (12).

In *Edge City*, Joel Garreau defines the difficulties of public transportation. A commuter, he says, will rarely put up with more than one connection or mode change (13). Although the resistance is not explained, others have indicated that public transit faces four major handicaps:

- The walk to and from the transit station or stop
- Time spent waiting for the vehicle
- Transfer between vehicles
- Time spent stopping for embarking and disembarking passengers (4)

The development of systems that can transmit accurate and reliable information to minimize these handicaps represents the single greatest opportunity for Advanced Public Transit Systems (APTS) professionals to achieve a significant shift from the use of automobiles. An APTS application within a High Speed Train project could achieve a substantially greater shift than the currently estimated 1 percent achieved by traffic modelling forecasts in North America.

3.5.6 Policy Impact of ITS and Private-Public Sector Partnerships

Although the scope of this study did not extend to a full discussion of the implications to transport policy of the deployment and development of ITS applications, three emerging issues are identified here:

- Impact of Transportation Policy on Travel Demand

Government policies either directly (the funding of alternative transportation modes) or indirectly (land-use zoning encouraging development) affect the demand for transportation. To limit risk, private investors will encourage governments to adopt transportation policies that favour their interests. In the case of a privately owned highway, for example, should government be expected to encourage land development and to limit the role of public transportation to attract private investment participation?

- Profit Margin and Access to Capital

Returns on transportation investment will have to compete for investment capital with other business ventures that can offer returns of 12 to 15 percent or more. To access that capital, will governments be in a position to act as a guarantor to achieve a sufficient return on investment or will transportation users be expected to provide that profit margin? Given that demand is elastic to price fluctuations, if transportation users are expected to provide returns on investment in the order of 15 percent, what negative third order cost to the community will be created as a result of reducing accessibility?

- Privacy

While private industry can provide assurances that the tracking of movements to permit billing will be kept confidential, the government, through regulation, must ensure that this confidentiality is, in fact, respected. In addition, some debate over the extent to which government departments, or even police forces, can access this information will be required. In the United States, ITS America has devoted considerable resources to this issue.

3.5.7 Telecommuting and ITS

The Fourth Annual IVHS America meeting held in Atlanta, Georgia, in 1994, featured a ground-breaking paper suggesting that, far from viewing telecommuting as a competitor to ITS, transportation planners should consider the possibility of forging a symbiotic ITS-telecommuting relationship (14).

To some extent, the goals of telecommuting and ITS are the same: fewer commuters on the road. In 1990 President Bush said that if only 5 percent of LA commuters telecommuted one day a week, they would save 205 million VMTs each year and keep 47 000 t of pollutants from entering the atmosphere. Isolated from each other, ITS and telecommuting initiatives may reduce VMTs and improve road network capacity far less than if the two were deployed in tandem.

This is yet another factor that should be considered in the planning of ITS implementation.

4. CASE STUDY 1 - WINDSOR-DETROIT BORDER CROSSINGS

4.1 Background

The Free Trade Agreement (FTA) with the United States and the North American Free Trade Agreement (NAFTA) have fundamentally altered the economic relationship between Canada, the United States, and Mexico. More goods and services will be exchanged and the movement of people across the borders will increase. All of this will test the ability of Customs and Immigration (C&I) officials to facilitate border crossings without sacrificing control of admission of goods and people. Skillfully deployed, ITS can enable C&I officials to accommodate growing travel demands with greater efficiency. Its objective is to make the border an invisible frontier.

This case study is a test case that employs the ITS benefit-cost framework developed in this report to provide a more comprehensive assessment of ITS applications. It is an illustration, and the results should not be interpreted as definitive findings, but as an indication of how a comprehensive study could be developed.

4.1.1 Some Facts, Figures, and Trends

- The eastern border, from the Great Lakes to Maine, is 3 400 km long and has
- 88 border crossings
- 63 million people reside in the states and provinces on the eastern border
- The United States and Canada constitute the world's largest bi-national trading partnership, with $189 billion in trade annually. An estimated 80-85 percent of this trade passes through the eastern border (40 percent across the Ontario-Michigan border crossings)
- Approximately 80-95 percent of U.S.-Canada trade uses eastern coalition border crossings
- 200 000 vehicles cross the eastern border daily
- The Ontario-Michigan border crossings link Interstates 69, 75, and 94 with Ontario Highway 401 and 402. Trucks on this corridor travel an estimated 330 million km every year through Michigan between eastern Canada and other U.S. states
- International traffic between the United States and Canada has been growing rapidly and is expected to continue to do so
- Border crossing facility needs costing $1.2 billion have been identified

- Additional needs associated with the international highway, railway, and marine corridors, totalling nearly $6 billion, have been identified
- The Ambassador Bridge had the highest volume of any single crossing, with 8.2 million vehicles annually in 1992, followed by the Fort Erie Peace Bridge with 8.1 million
- Efficient border-crossing operations require adequate levels of staffing and capital resources for U.S. and Canadian inspection services (15)

The Marshall Macklin Monaghan Study, 1994

Many of the documented benefits and costs used here have been drawn from the Marshall Macklin Monaghan report (May 94), which also proposes a framework (9). The significant contribution of this work is acknowledged. The report will hereafter be referred to as the MMM 94 study. In this case study, however, a broader range of benefits is included. One of the difficulties in using such a range is the absence of empirical data. Research aimed at data collection and improvement of analytical tools is needed.

The MMM 94 study documented a 40 percent increase in vehicle border crossing traffic between Michigan and Ontario during the 1980s. Given the structural change in the economic relationship between Canada and the U.S., growth in the next 10 years could be significantly greater than the growth prior to the implementation of FTA and NAFTA.

In Europe, the strengthening of the Economic Community through the Maastricht Treaty has forced its members to address transportation infrastructure needs. While the effects on traffic flows between member countries have not been scientifically predicted, the urgent need to upgrade transportation links between European member states is nonetheless recognized (16).

4.1.2 Capacity Constraints: Physical and Operational

Most Canada-United States border crossings are land crossings. However, in the Great Lakes Region, border crossings are fixed on bridges or in tunnels. When capacity becomes constrained, upgrades to land crossings are more economical and less problematic than bridge or tunnel capacity upgrades. As a result, ITS applications that extend the operational life of bridge and tunnel crossings would offer significantly greater benefits than those that improve land crossings.

This case study considers the deployment of ITS technologies to increase the operational life of the Windsor-Detroit Tunnel. The tunnel is one of three border crossings between Ontario and Michigan, the others being the Ambassador Bridge and the Blue Water Bridge.

In this study, roadbed capacity refers to the physical vehicle capacity of the bridge. Operational capacity refers to the vehicle capacity when toll collections and C&I processing impede traffic flow. Improvements to these procedures would increase the operational capacity of the border crossings without the need for physical upgrades.

Current operational capacity, with toll collections and adequate C&I staffing for primary screening, allows 900 vehicles (auto and trucks) an hour to pass through the border; however, the bridge is physically capable of handling some 1 300 vehicles an hour, according to the Windsor-Detroit Tunnel Corporation. Thus the border crossing limits the efficiency rating of the tunnel to approximately 69 percent.

The MMM 94 study states that deployment of ITS technologies would contribute significantly to making a “virtually seamless and transparent border for both commercial and private passenger movements”. This study estimated that a single automated toll collection lane can accommodate 900 to 1 200 vehicles, a threefold improvement over manual collections. Furthermore, an AVI (automatic vehicle identification) lane could increase the rate of C&I primary processing from 120 autos and 60 trucks an hour to over 900 vehicles combined. Adding a second automated lane for both AVI and toll collections would match operational capacity to the physical limits of the Windsor-Detroit Tunnel.

4.2 Objective of Intelligent Transportation Systems

For border crossings, the broad objective of ITS is to match operational bridge capacity to roadbed capacity. Failure to accomplish this may lead to one of two scenarios in response to increasing traffic demand:

- Additional investment capital may be allocated to upgrade the physical capacity of the bridge by twinning spans or increasing the number of traversing lanes. This may be an unsatisfactory solution, given the built-in inefficiency of the crossing.
- Infrastructure managers may refrain from increasing the physical capacity of the border crossings and thus negatively affect the free movement of goods and passengers between the two countries. This restrained mobility would affect economic growth in the area. In addition, because of impeded crossing demand, infrastructure managers would lose revenue.

4.3 Beneficiaries of Improved Border Crossing Efficiency

The beneficiaries of ITS applications designed to increase the efficiency of border crossings can be broadly grouped as follows:

- Users: both travellers and carriers
- Infrastructure operators or owners (private and public sector)
- The community at large
- Private sector suppliers for ITS

4.3.1 Users (First Order Benefits)

First order benefits to users would include more reliable and convenient border crossings. Measurements of these benefits would be reduced or eliminated queuing times for C&I processing and toll collections. These benefits have already been identified and quantified in the MMM 94 study.

Users include commercial vehicles, typically trucks, and private vehicles. The ultimate benefits for these sub-groups are somewhat similar: access to markets and resources. Greater freedom to choose increases the accessibility range of the traveller. In contrast, restrained mobility reduces accessibility. For commercial enterprises, decisions on industrial locations will be influenced by the ease or difficulty of crossing the border and, in turn, by the range of access.

4.3.2 Infrastructure Owners and Operators (Second Order Benefits)

Bridge and Tunnel Operators

The Windsor-Detroit Tunnel Corporation is a private tunnel operator relying on toll collections for revenue. The private bridge operators for the Blue Water and Ambassador bridges also rely on toll collections for operating revenues.

Benefits to these operators include more efficient and less labour-intensive toll collections (9). However, a major benefit of increasing the productivity of the border crossings by matching operational and physical roadbed capacities would be that capital investment for capacity upgrades could be deferred for several years. The combined effect of lower operating costs and increased operating revenues in the absence of capital outlay would produce significant earnings for the operators.

Although both bridges and the Windsor-Detroit Tunnel are privately operated, only the Ambassador Bridge is privately owned. With private operations, a competitive market for attracting revenue vehicle traffic is in place. This has not promoted cooperation among the infrastructure operators to develop system-wide improvements. Empirical data to substantiate findings of congestion or to forecast demand/capacity ratios are often very difficult to obtain.

C&I

Earlier studies of border crossings and the effects of ITS on C&I have concentrated on productivity improvements in terms of reduced manpower requirements and increased processing rates per inspector. While these would be an important achievement in this time of constrained operating budgets, more effective control of the admission of people and goods into Canada would be equally valuable. Both types of benefits will be explored here.

Government

When examining the benefits of ITS applications, three levels of government on both sides of the border must be considered. Only the federal government will be considered in this section. The federal government is responsible for international border crossings and has two specific mandates:

- first, to facilitate cross border traffic of goods and travellers, thereby promoting economic trade and development;
- second, to interdict the entry of contraband goods and ineligible persons into the country.

The imposition of border crossing controls would appear to hinder the passage of goods and travellers. ITS does not eliminate this apparent contradiction, but it does minimize its manifestation in terms of impeded traffic flows and unreliable controls.

ITS would allow the federal government to exercise both of its mandates with the utmost efficiency.

Benefits to government also include increased economic activity, which is addressed under third order benefits to the community. The location of that activity is, however, more important at the provincial/state and local levels.

4.3.3 The Community (Third Order Benefits)

For a community, ITS offers the third order benefit of greater economic activity or development. More efficient transportation increases accessibility for both residents and businesses. For commercial shippers, increased accessibility to markets and resources makes them and the businesses they serve more competitive. In much the same way, for individuals, increased accessibility broadens their choice of housing, employment, shopping, education, and other urban pursuits.

For the past 35 years the primary emphasis in intracity traffic demand modelling has been to relieve congestion on our busy freeways. By reacting primarily to transportation problems, analysts and planners have tended to neglect the development of analytical techniques that would indicate how transportation innovations can increase accessibility. In the debate over ITS, undue emphasis is placed on congestion relief and too little consideration is given to increased accessibility/mobility. If congestion relief is the only objective of all transportation investment, one assumes that no improvement in mobility is warranted or possible. In the course of developing ITS benefit-cost studies, analysts must question that assumption, which is, I believe, incorrect.

Mobility and Economic Development

While the linkage between transportation or mobility and the regional economy is well accepted, it is poorly understood. Little work has been done to measure this linkage to permit policy makers to assess the net benefit of an improved transportation infrastructure and the cost of a deteriorated one.

In the United States, the Transportation Research Board has issued a request for proposals for an economic study that will link mobility to economic activity. A copy of the terms of reference is included in Appendix B. Transport Canada officials would be well advised to monitor the progress of this research. If the results prove promising, similar exercises could be completed in Canada. That linkage can then be used as input into a comprehensive decision-making model.

The implication is clear: to gauge the full impact of ITS, an economic assessment of expected increased or decreased mobility is central to the success or failure of individual programs.

4.4 Other Factors

4.4.1 Industrial Restructuring Analysis

A Transportation Association of Canada study recommends that investigators should include other parameters to assess the value of major transportation projects when preparing a benefit-cost analysis on transportation investment projects. One parameter of special significance is industrial restructuring analysis.

> *In appraising the rate of return of many prospective transportation policy and investment possibilities, it is sufficient to estimate the savings in vehicle operating costs and the value of time savings as the principal investment benefits only when there is no significant change in the production process and logistics of firms in response to the investment. Failure to account for such economies or operational changes can lead to an understatement of the impacts of transportation investment on productivity and economic growth (8).*

This statement reinforces the point that considering congestion relief as the primary source of ITS benefits limits the scope of an analysis. In many instances where the application of ITS can lead to enhanced mobility, the value of the resulting increase in accessibility should be closely examined to measure its effects on productivity and economic growth. The same logic can be applied in reverse. If a transportation network no longer satisfies the need for mobility, that reduction must be examined in the same manner. The principle of industrial restructuring represents an important yardstick to measure not only ITS applications, but also other transportation projects, on the basis of increasing or maintaining accessibility for individuals and businesses.

4.4.2 Automated Border Crossings: Deferring Capital Investment

This case study recognizes deferred capital investment as a significant potential benefit. If automated border crossings postpone capital investment for several years, significant savings can be achieved. The Transportation Association of Canada report underlined the need to develop better benefit-cost analytical tools to determine the optimal timing for transportation investments:

> *Though critical to economic success, the right timing for policies and investments is often overlooked in transportation investment planning. In practice, the net present value principle should be applied to establish both whether a policy or investment proposal promotes productivity and growth and when the economically appropriate time to invest occurs ... Transportation executives need to be aware that the optimal year to commission an investment is the start-date that maximizes the project's net*

present value. Alternatively, the first year benefit ratio, defined as the sum of all benefits accruing after construction divided by all costs incurred to date, including the interest paid during the construction period, expressed as a percent, could be used to indicate timing. If the value is more than the minimum required rate of return, then the project could be considered overdue. Alternatively, if the ratio is less than the minimum required rate of return, then the policy or investment may be said to be premature (8).

The application of ITS technology will allow transportation managers to better manage the optimal timing of capital investment upgrades.

4.5 Border Crossing Traffic Trends

The MMM 94 study recorded a 40 percent increase in traffic at the Ontario-Michigan border crossings during the 1980s. This represents a growth rate of under 4 percent a year. By extrapolation, a similar increase would be expected in the nineties. However, given the emergence of NAFTA, past trends based on economic trade are no longer a reliable basis for predicting travel behaviour.

A U.S. Department of Transportation Federal Highway Administration report to Congress assessed the capability of border crossings to accommodate increased trade as a result of NAFTA (6). The report recognizes the unique ability of ITS technology to increase both capacity and the efficiency of border control.

4.5.1 Canadian-U.S. Free Trade and Traffic Increase: 1989 to 1992

For 1989 to 1992, the report documented an annual growth rate of 10.2 percent for vehicles (10.5 percent for passenger vehicles and 7.5 percent for commercial vehicles) crossing the Canadian-U.S. border. The Ontario-Michigan frontier traffic grew at similar rates: 10.1 percent for vehicles; 10.6 percent for passenger vehicles; and 7.2 percent for commercial vehicles. This growth rate, occurring during the initial Free Trade Agreement between Canada and the United States, may be a good indicator of future traffic activity at border crossings.

4.5.2 1992-1997 Commercial Vehicle Forecasts

The Report to Congress also forecast Canadian-U.S. commercial traffic activity from 1992 to 1997. Three rates were calculated using three different trend indicators. The first, forecasting a 4 percent annual rate, was based on past empirical data. The second, forecasting an annual growth rate of 5.1 percent, was derived by applying trade projections to traffic forecasts. The last estimate, which forecasts an annual growth rate of 6.8 percent, used the commodity-specific rates of growth in shipments for each frontier to generate 1997 estimates.

4.5.3 1992-1997 Passenger Vehicle Forecasts

Given the volatility of the currency exchange rate and other variables, forecasts of passenger traffic were not included in the Report to Congress. However, for this study, it is realistic to expect that the number may not match the 10.6 percent average annual growth rate for passenger traffic that occurred between 1989 and 1992. To be conservative, an annual growth rate of 8.5 percent will be used.

4.5.4 Hazards of Long-Run Traffic Projections

Long-run growth projections are difficult to fix accurately because of unforeseen economic factors. For example, although growth rates from 1989 to 1992 were impressive, recent figures have shown a steep decline. On the Blue Water Bridge, traffic fell by 14.7 percent from 1992 to 1994. In 1993 traffic in the Windsor-Detroit Tunnel declined by 12 percent from the previous year. Traffic data for the Ambassador Bridge is not available.

4.6 ITS Benefits and Costs for Border Crossings

All of the cost and some of the benefit estimates for ITS applications used here were obtained from the MMM 94 study.

4.6.1 Users (First Order Benefits)

Passenger Vehicles

Direct benefits to passengers flow directly from time savings. The MMM 94 study estimated the value of time at $9 an hour, which was acknowledged to be a crude measure.

- Costs

Costs for passenger vehicles are the out-of-pocket costs for the purchase of an AVI tag ($94) and annual registration in the PACE program ($10), for a total of $104 for one year or $57 a year for two years, minus interest costs for the tag.

♦ Benefits

The decision to purchase an AVI tag depends on whether the annual time savings will be worth more than the annual costs.

The MMM 94 study assumed that each traveller would save an average of two minutes a trip. They further tallied the total number of hours saved and placed a $9 an hour value on the time savings. According to their aggregate calculation for all auto crossings, the benefit-cost ratio was .56 after the first year and 2.5 after 5 years.

♦ Case Study Perspective of Benefit-Cost

This case study approaches the same benefit from another perspective.

The 18.9 million vehicle crossings (both ways) are, in reality, 9.45 million vehicles that cross the border twice: an outbound and an inbound trip.

Daily Commuters

In 1992, 28 percent of the traffic crossings were made by daily (230 days) commuters, each generating some 46 trips a year (230´2). Using the same time savings (2 minutes) and assuming a $9 an hour value for time, the monetary benefit would be $138 for a benefit-cost ratio of 1.33.

Weekly Commuters

For weekly travellers, who constitute 33 percent of the traffic, the time savings would be 200 minutes for an annual net benefit of $30, a benefit-cost ratio of .29.

Other Travellers

Savings for those travelling monthly (21 percent) or quarterly (4 percent), would be insignificant. A full quarter of the 9.45 million vehicle drivers (4.725) would likely not entertain the purchase of the AVI tags for the sole purpose of crossing the Ontario-Michigan border.

Closer examination of the pattern of weekly and daily commuters indicates that accrued benefits may be significantly greater than first calculated. The real value of time savings is very arbitrary and depends on many factors. A more accurate estimate of time savings would be to calculate the probability of travellers encountering a major traffic delay. For daily commuters, the probability would be quite high and the effect of such delays could become very significant. For example, on what percentage of the 460 trips would they encounter delays of more than 15 minutes, 30 minutes, or 1 hour?

In reality, a two-minute time saving is not sufficient, even on a daily basis, to encourage AVI and PACE participation. However, the approach that mobile phone companies use to sell automobile communications devices could be effective: "Chances are you won't need it, but won't it be comforting to know that it is yours if you do." This approach could appeal to most daily commuters and even to a significant number of weekly commuters.

The point is that traditional benefit-cost studies cannot be relied upon to truly reflect consumer acceptance of new technology. Producers of consumer-led technologies often rely on both tangible and intangible variables to market their products.

Commercial Vehicles

The MMM 94 study found a very substantial benefit-cost ratio for commercial vehicles, in the order of 4.06 after the first year alone. However, a distinction between benefits to carriers and benefits to shippers would further illuminate the true benefits of ITS to manufacturers. The study limited the examination to carriers and excluded the value to shippers. This case study examines that value.

- ♦ A Look at the Automotive Industry and Transportation Requirements

The automotive industry and its "just-in-time" inventory system depends heavily on quick and reliable transportation across the international borders between Mexico and the U.S. and the U.S. and Canada. According to Irving Rubin, the Transportation Commissioner for Michigan Department of Transportation, the more efficient the transportation system, the wider the distribution of manufacturing and labour that the automotive industry can adopt.

It is not uncommon for a single automobile part to cross an international border five times or more. Parts manufactured in the U.S. are often sent down to Mexico for further manufacturing and returned to the U.S. for final preparation before being shipped to Canada for auto assembly. The assembled automobiles are then transported back to American and Mexican markets. If border crossings become unreliable, the manufacturing and distribution process would have to be adjusted to limit the number of border crossings, effectively influencing the industry to consolidate manufacturing in as few locations as possible. If this were to occur, an emerging negative side effect of strained border crossing capacity could be lost jobs and decreased regional economic activity.

"Just-in-time" shipping has had a major impact on the manufacturing process and on transportation logistics. The MMM 94 study revealed that many shippers routinely add one hour at the border to account for processing time. That study assigned a value of $38 for one hour of time saved. While this may reflect the value of trucking operations, it severely underestimates the value of the commodity shipped. More empirical data will be needed to separate the value of trucking costs saved from the time value of manufactured goods.

4.6.2 Transportation Infrastructure Owners/Operators (Second Order Benefits)

The major benefit of ITS to transportation owners/operators is the ability of this technology to improve border crossing efficiency by narrowing the gap between operational and roadbed capacities. The Windsor-Detroit Tunnel operations provide an example of how ITS can improve traffic efficiency for the operator.

Windsor-Detroit Tunnel

- Costs

The one-time cost for system hardware and project management for all three border crossings is estimated to be $7.88 million. It can be assumed, then, that the implementation of ITS at each site would cost $2.63 million (9).
Hardware system costs would include the following items:

- AVI readers
- AVI antennas
- Plaza computer
- In-road sensors
- In-booth alarm signals
- External message signs

Administration costs were assumed by the MMM 94 study to be marginal.

- Benefits

According to the Windsor-Detroit Tunnel authorities, the physical capacity of the tunnel is 1 300 vehicles an hour for each of the two traffic lanes. Toll collections and C&I primary screening decrease the capacity to 900 vehicles per hour, an efficiency rating of 69 percent.

♦ Projected Traffic Levels

Currently, peak hour volumes approach 800 vehicles approximately 30 times a year. In Table 3 the traffic volumes are forecasted to the year 2005. Annual growth rates of 8.5 percent and 5 percent are assumed.

TABLE 3
Traffic Growth Projections and Capacity Analysis
Windsor-Detroit Tunnel 1994-2005

Year	Vehicles (8.5% Growth)	Vehicles (5% Growth)
1994	800	800
1995	868	840
1996	942 (Operational Gridlock)	882
1997	1 022	926 (Operational Gridlock)
1998	1 109	972
1999	1 203	1 021
2000	1 305	1 072
2001	Roadbed Gridlock	1 125
2002	Roadbed Gridlock	1 182
2003	Roadbed Gridlock	1 240
2004	Roadbed Gridlock	1 303
2005	Roadbed Gridlock	Roadbed Gridlock

♦ Capacity Analysis

According to this forecast and using an annual growth rate of 8.5 percent, the Windsor-Detroit Tunnel will meet operational roadbed capacity in 1996, five years before it would meet the physical roadbed capacity. With an annual growth rate of 5 percent, the capacity of the tunnel would be extended a further eight years. This capacity analysis is not a precise calculation, but is used to demonstrate how the application of ITS can extend the lifespan of transportation infrastructure.

Benefits include deferred capital investment and increased productivity.

- Deferred Capital Investment

The direct benefit to the operator is the deferment of additional investment to upgrade capacity that would become necessary if ITS were not used to facilitate C&I primary screening. The value of that benefit is the interest on the capital investment that is deferred for several years.

- Traffic Diversion Effected by Congestion

Because the Ambassador Bridge, the Windsor-Detroit Tunnel and, to a lesser extent, the Blue Water Bridge are in close proximity, the manifestation of congestion at a particular crossing may not be discernible until two or all three infrastructures meet operational or roadbed capacity, because travellers can easily select the most convenient and reliable river border crossing point. If the Windsor-Detroit Tunnel is predictably congested at certain times of the day, some traffic would be diverted to the Ambassador or the Blue Water Bridge. In this scenario, the border traffic flow would not indicate a congestion problem because the system would accommodate the traffic at alternative points. The cost to the tunnel operator, which would not be observed, would be lost traffic and revenue. The calculation of that revenue diversion (loss) would entail detailed traffic simulation studies.

Future ITS studies should explore means of further improving capacity. ATMS, for example, could be used to effect changes in travel behaviour, staggering some peak hour traffic into non-peak hour times. This would further prolong the operational lifespan of the three border crossings. Traffic simulations to determine the effect of using variable toll charges would be required to estimate the benefits of ATMS applications.

- Benefit-Cost Ratio

On the basis of a capital outlay of $2.63 million, are the benefits sufficiently large to justify the implementation of ITS at the individual border crossings?

If only the deferred capital investment is considered, the annual savings in interest costs are substantial. For example, according to the Windsor-Detroit Tunnel Corporation, the only way to upgrade capacity would be to build another tunnel, at an estimated cost of approximately $250 million. If interest-bearing bonds were sold to private investors, at a compound rate of 8 percent, the annual interest cost would be about $20 million. At an annual traffic growth rate of 8.5 percent, congestion at the Windsor-Detroit Tunnel would be delayed five years. It would be further delayed by eight years if the annual growth rate were 5 percent.

Costs are fixed at $2.63 million for hardware acquisition and project management. Annual maintenance costs are assumed to be roughly 10 percent of fixed costs, for a total of $.263 million. For five years and eight years, the maintenance costs would total $1.32 million and $2.1 million respectively, for a combined cost of $3.95 million and $4.73 million.

The benefit-cost ratio shown in Table 4 only includes benefits from deferred capital investment and excludes savings in toll collections and recovered toll revenue that would have been diverted to the Ambassador or Blue Water Bridge due to congestion. Based on this evidence, ITS applications would provide favourable benefit-cost ratios for individual bridge and tunnel operators.

TABLE 4
Windsor-Detroit Tunnel Corporation Benefit-Cost Ratio
Deferred Capital Upgrade (Cdn$ millions)

	8.5% Annual Traffic Increase	**5% Annual Traffic Increase**
Benefits	$100	$140
Costs	$3.95	$4.73
Benefit-Cost Ratio	**25.3:1**	**33.8:1**

According to this analysis, the cost of ITS may be more appropriately allocated to the Windsor-Detroit Tunnel Corporation than to C&I, as suggested by the MMM 94 study.

- Recovered Revenues

Although it may not be realistic to expect the operators to twin the tunnel to meet increasing traffic levels, the above analysis was performed as an illustration. A more relevant benefit-cost ratio may be to examine how diverted traffic would affect the Tunnel Corporation through lost revenues.

The latest available figures indicate that 3 294 558 vehicles passed through the tunnel in 1993, generating revenues of U.S. $5 916 526 (only one-way traffic recorded) (17). Two-way traffic at Canadian currency rates (1.37) brings the total revenue to $16 211 281. Assuming an annual growth rate of 8.5 percent, the revenue ceiling would be $20 706 493 in 1995; under a growth rate of 5 percent it would be $19 704 913 in 1996 (discrepancy attributed to traffic growth projection listed in Table 3).

The benefit-cost ratio in Table 5 compares recovered revenues made possible by increasing capacity through the implementation of AVI equipment with the average annual cost for ownership and maintenance over an estimated 10-year lifespan. Peak-hour congestion is assumed to occur twice a day: three hours in the morning and three hours in the afternoon. As a result, only a quarter of the savings are considered. If a more conservative estimate, say four peak hours, were used, the benefit-cost ratio would be reduced by 33 percent and the results would still be favourable.[3]

TABLE 5
Windsor-Detroit Tunnel Corporation Benefit-Cost Ratio
Recovered Traffic Revenues- Cost of AVI Equipment and Maintenance
1996-2007 (Cdn$ millions)

Year	Cost[4]	Recovered Revenue 8.5% Growth	B/C Ratio	Recovered Revenue 5% Growth	B/C Ratio
1996	.526	.406	**.77**		
1997	.526	.846	**1.61**	.235	**.45**
1998	.526	1.323	**2.52**	.481	**.91**
1999	.526	1.840	**3.50**	.740	**1.41**
2000	.526	2.403	**4.57**	1.011	**1.92**
2001	.526	2.403	**4.57**	1.296	**2.46**
2002	.526	2.403	**4.57**	1.596	**3.03**
2003	.526	2.403	**4.57**	1.910	**3.63**
2004	.526	2.403	**4.57**	2.240	**4.26**
2005	.526	2.403	**4.57**	2.240	**4.26**
2006	.526			2.240	**4.26**

Customs and Immigration

- Costs

Excluding the Automated Toll Collection system valued at $2.015 million, the MMM 1994 Study allocated all hardware and project management costs ($5.865 million) to C&I. This case study suggests that a strong argument can made for allocating some of the costs for the AVI system to the tunnel and bridge operators. As was shown in the previous section, the returns on initial capital outlay can be very significant for operators.

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3 Interest costs were not estimated.

4 The annual cost of $526 000 includes cost of ownership over a 10-year period and annual maintenance cost estimated at 10 percent.

If this arrangement were to become the basis of future private-public sector partnerships, no capital costs would fall to C&I. In this case, what would be the costs of ITS to C&I? The cost, if any, would be the difference in operational costs of providing manual primary screening without ITS and the operational cost of electronic screening. According to the MMM 94 study, the operating savings are considerable.

♦ Benefits

The MMM 94 study identified several benefits:

- Increased third-party (user) data entry
- Automation of records
- Reduced inspection hours
- Improved management information
- Improved customer service

This case study groups and examines the benefits in relation to improved productivity and more effective border control.

Canadian C&I has already introduced some form of electronic screening, based on Electronic Data Exchange (EDI), to automate primary screening. Plans do not include full automation, and the booths will continue to be manned. However, C&I officials hope to improve productivity and to enable border inspectors to exercise more effective border control.

♦ Improved Productivity

Border inspections include primary screening, where every vehicle is processed; and secondary inspection, a second more thorough screening, which may include physical inspection of vehicle contents and interviews with passengers. Typically, for bridge and land crossings, primary screening occurs on the traffic lane and secondary screening is done on sites adjacent to the traffic lanes, to avoid obstructing the traffic flow.

According to the MMM 94 study, an express electronic lane can process over 900 vehicles an hour, compared to the 120 cars and 60 trucks that an inspector can handle. This major improvement (by a factor of 6.5) can be dealt with in one of two ways: by benefiting from direct labour savings; or by redeploying personnel to make the secondary screening process more efficient.

Estimated operational savings to C&I primary processing and toll collections would be $682 000 and $440 000 respectively for all three border crossings.

- More Effective Border Crossing Control

ITS would allow officials to achieve more effective border controls. By accessing real-time information provided by shippers prior to arrival at a border crossing, C&I inspectors would be informed of the identity of the driver and the contents of the vehicle. This process would significantly improve the ability of officials to separate low-risk commercial vehicles from higher-risk vehicles. Having accurate information that could be verified during primary screening would, more likely than not, permit the vehicle to bypass the secondary screening. This would allow Customs inspectors to concentrate on those vehicles that may require more rigorous inspections.

Similar operations could be introduced for private vehicle crossings. Already, programs such as the PACE program in British Columbia, which separates low-risk from higher-risk passenger vehicles, are being introduced in Canada. As a result, secondary screening should become much more effective.

Border control could also be improved if inspectors who were no longer needed for primary screening moved to secondary inspections. Whether this would be possible would depend on the location of the border crossing and the degree of automation of the electronically screened lanes.

Secondary screenings require care, thoroughness, and attention on the part of the inspectors, to achieve effective border control and to act as an effective deterrent. Canadian officials at the Ontario-Michigan crossings regularly experience pressure from bridge and toll operators to accelerate processing when traffic is congested. No empirical studies have been done to determine whether interdiction rates are lower when border crossings are congested than when they are not. However, this may well be the case.

The MMM 94 study measured benefits in terms of reduced staffing. This case study recommends changing the measurement to reflect greater productivity in terms of vehicle processing by individual inspectors and more effective border crossing control. These measurements would better reflect the potential of ITS to improve C&I operations.

Many of the EDI programs initiated by C&I are still too young for improvements in border crossing control to be measured. Empirical data is being collected by the department. However, an absence of observed violations does not necessarily mean no change in interdiction rates; it may indicate a more effective deterrent.

4.6.3 The Windsor-Detroit Conurbation Community (Third Order Benefits)

Estimating benefits and costs to the community at large when assessing the value of transportation investments is very difficult. Detailed estimates in monetary values are helpful, but one must question whether any investigation can provide accurate figures. Perhaps, as a supplemental exercise, an overview of the dynamic relationship between transportation, accessibility, mobility, and economic development can be just as valuable in a benefit-cost analysis.

Direct benefits to the Windsor-Detroit conurbation community would be derived from increased trade and economic activity. Investment in manufacturing, the primary source of economic output in the area, would increase. Of the $188 billion in annual Canadian-U.S. trade, 40 percent crosses the Ontario-Michigan border, and most of these trips are short haul, originating and terminating in Ontario and Michigan. Most shipments are manufactured goods, primarily auto-related. Impediments to mobility endanger the manufacturing process, putting at risk the thousands of jobs directly affected by the transportation infrastructure. In contrast, added mobility or accessibility to resources and markets offers greater economic promise to the region. Although direct linkages between transportation and manufacturing employment can be established, quantifying such relationships is difficult in the absence of empirical data.

Another factor to consider, when evaluating mobility, is the growing trend of private and public ventures, such as the Windsor Casino, to target both the Windsor and the Detroit communities as markets for new businesses. Except for the casino, there is little documentation on businesses that are being established or expanded to include the neighbouring market across the Detroit River.

The Windsor-Detroit area is a unique region straddling the border. Viewed from above, where the border is transparent, the urban form is a conurbation, a contiguous form separated only by a river, in much the same way as the St. Lawrence River separates the Island of Montreal from the South Shore of Montreal or the Island of Laval. As the impediments to crossing the Ontario-Michigan border are lessened, one can expect significant traffic surges.

A resident's perception of the urban environment is affected by his or her mobility and the range of accessible urban activities, whether for work, housing, shopping, culture, education, or other pursuits. While the choice of location for employment and housing will always be influenced by Canadian and American immigration laws, the choice of other activities would be increased to include the entire conurbation.

Already, according to the MMM 94 study, 79 percent of all Windsor-Detroit Tunnel crossings have an origin and destination in the Windsor-Detroit area. This contrasts with the 1.7 percent of trips where neither the origin nor the destination is in the Windsor-Detroit conurbation. Daily crossings, which account for 28 percent of passenger vehicles and 30 percent of commercial vehicular traffic, are a very good indication that residents on either side of the border are enjoying greater choices of urban activity. Considerably more research by urban geographers and planners will be needed to gauge the effects of a transparent border on traffic patterns.

One area for possible research is the development of a land-use model tied to a trip-generation model that would treat the conurbation as any typical urban area. Constraints on choices for employment and housing may be adjusted to meet existing and proposed immigration laws to forecast changes in traffic flows. This same model could then be used to assess the net cost to the economy of impeded traffic flow across the border, in terms of restricted choices of urban activities.

4.7 Private Investors

The role of private investors in this venture would be to initiate the implementation of ITS at border crossings. This initiative would be generated because the project is a fundamentally sound business proposal, as this case study has demonstrated. First and second order benefits measured in monetary terms are apparent for individual travellers and infrastructure managers. The magnitude of third order benefits, while difficult to measure, would be greatest for the Windsor-Detroit community.

Where the beneficiaries of ITS can be clearly identified and the measurement of benefits quantified, private suppliers armed with this market information can begin targetting the appropriate beneficiary to initiate ITS implementation.

4.8 Case Study 1 - Analysis

This test case reveals how the increased mobility permitted by ITS benefits a broad constituency that is not limited to individual travellers, but includes the transportation network and the community as a whole.

First order benefits to private motorists and truckers are apparent and easily measured. Although benefits to shippers cannot be quantified, research indicates that the monetary value of time savings for manufactured goods exceeds trucking cost savings.

Second order benefits to infrastructure managers can include deferred capital investment and increased revenues. For C&I, the benefits include reduced operational costs and more effective border control. For the federal government, benefits are manifested in increased trade and greater economic activity.

Third order benefits for the Windsor-Detroit community are linked to increased mobility for businesses and residents. This case study illustrates that, given a rather modest capital investment in AVI technology (in this instance $2.63 million per border crossing), a detailed quantification of third order benefits is not necessary, as long as a linkage is established between the regional economy and the maintained or increased mobility provided by an ITS application.

In contrast to earlier studies that considered only benefits and costs to individual travellers and to C&I, this case study has underlined the potential of exploring a wider partnership for the implementation of ITS.

5. CASE STUDY 2 - CONGESTION CHARGING

5.1 Background

Urban geographers and planners have long debated the impact of transportation on urban form and the impact of urban form on travel behaviour. This "chicken and the egg" debate over decentralized land use and increasing auto travel has engaged generations of transportation planners. Since World War II, we have designed our communities to adapt to the automobile, thus reinforcing the competitive advantage of that mode in providing accessibility.

In 1950, before the massive highway construction phase, vehicle-miles travelled (VMT) per person in the United States was 3 000 miles a year; by 1990, that figure grew to 8 700 miles (18). The highway, along with other economic and demographic forces, tripled motor vehicle use and urban activity patterns conformed to this use. One can visualize the forces of automobile-induced land use and access by automobile as two tires on a bicycle. The movement is fluid and in proper synchronization when both forces are accommodated. However, once a lack of resources, land and/or financial, threatens the continued use of the automobile to provide that accessibility, a disruption is caused and very real, short-term costs are imposed on society.

Congestion charging, which is the introduction of variable charging on toll roads to relieve congestion and to prolong the operational capacity of transportation infrastructure, has the potential to impede the movement of the bicycle. Whether the rider is thrown off and injured depends on the size of the obstruction that collides with the tire and the ability of the driver to withstand the impact. In short, how severe will the user charge be and how many motorists will be able to afford it?

Social scientists, including urban planners and urban economists, have varying opinions on the merit of congestion charging. Those promoting the fee argue that the imposition of a user charge will achieve congestion relief and redress the growing imbalance between the declining private cost of automobile use and the growing social cost that motorists impose on society. Those who oppose it argue that significant societal implications will result when restricted mobility reduces accessibility for the poorer segment of the population.

However, the same community is in strong agreement that the negative side effects of urban sprawl have become too severe to be allowed to continue or, in the case of the proposed automated highway, accelerated. In this case study, a clear distinction is drawn between the generic term, urban sprawl, which is associated with all forms of urban growth, and the negative side effects of urban sprawl. The tendency to consider all forms of urban growth facilitated by improved transportation systems as negative is a simplification that ignores some of the positive linkages between mobility, economic development, and urban development.

In general, social scientists also agree that congestion charging can alter travel behaviour patterns. The impediments to implementing congestion charging are not technical; they are related to social equity. As a result, the ultimate decision to implement congestion charging will rest with policy makers.

This case study reviews some of these issues and examines the current debate in London, England, on this topic. Much of the following is drawn from a Transportation Research Board (TRB) report on congestion charging (19).

5.2 Objective of Congestion Charging

The objective of congestion charging is to increase the capacity of the road network by introducing variable user tolls to effect changes in travel behaviour. The most common strategies are to stagger peak-hour volumes to non-peak-hour periods, to divert motorists to alternative transportation modes, and to increase car pooling.

5.2.1 Possible Effects of Congestion Charging on the Travelling Public

In the TRB report, Elizabeth Deakin outlines the following series of anticipated changes in travel behaviour:

- No change in travel behaviour or activities

  Pay charges;
  Continue previous pattern.

- Increase trip making, level of activities, or both

  Pay charges;
  Increase trip making to affected destinations because congestion charges make it easier to travel (possible without new infrastructure investments because of congestion relief; impact probably larger if revenues are invested in new infrastructure in affected corridors, as some have proposed).

- Reduce the overall costs of automobile use to offset the congestion charges without changing travel or activities

  Seek free parking or parking subsidy (if parking is currently priced);
  Use a more fuel-efficient vehicle;
  Keep vehicles longer, replace vehicle with a more modest vehicle, and so forth.

- Change travel behaviour without changing level of trip making or activities

  Avoid charges by deferring trips to uncongested periods;
  Avoid charges by using alternative routes with lower (or no) price;
  Share costs - ride share (if car pools travel free, as some proposals suggest, charges would be avoided);
  Switch to another mode with lower cost (e.g., public transit).

- Reduce trip making, level of activities, or both

  For example, work at home, shop less often and buy more per trip, shop by mail/phone/electronics, chain trips together.

- Change location of activities

  Avoid charges by changes in trip destination (e.g., shop at a location accessible without driving on a priced or high-priced facility; change jobs);
  Avoid charges by changing trip origin, change household location.

5.2.2 Possible Industry Response to Congestion Charging

Dr. Deakin also outlines industry's probable response to congestion charging:

- Those employing medium- to low-skilled labourers would suffer a reduction in the size of the labour force, unless transportation costs could somehow be reimbursed. The business could therefore become non-competitive.
- Industrial and retail commercial land use would be most affected. The long-range impact would be relocation from the city centre to the outskirts.
- For the highly skilled labour force or industry, congestion charging would be a boon. Reduced commuting times would attract new value-added businesses that currently ignore the core because of congestion, among other reasons.
- Trucking operations would be severely affected, and would likely seek an exemption.

Dr. Deakin's analysis does not consider how, after the introduction of variable charging, local and regional governments can determine the optimal timing for physical capacity upgrades. In the absence of congestion charging, optimal timing is when demand is greater than supply. Under the congestion charging scenario, is it when demand exceeds supply at 5 cents a kilometre, 10 cents a kilometre, or more? One can simply eliminate traffic by charging consistently higher rates as traffic volumes grow. Airlines, with fixed capacity aircraft, respond to increased demand by increasing yield. Will governments also respond in kind?

The difficulty is that as traffic is gradually eliminated, the impact of restricted mobility is increased. The effect is reduced accessibility to many urban activities, including housing, employment, shopping, education, and recreation. This unfulfilled range of activities also exacts costs in reduced economic input and output.

Traditionally traffic engineers observe, study, and analyse the volume of trips to present policy makers with transportation policy guidelines. Under the scenario of congestion charging, similar traffic engineering tools will not be able to assess reduced accessibility. How can a cancelled trip be measured? This particular problem of congestion charging is not addressed in the ITS literature.

5.3 Private Costs versus Social Costs

Urban economists describe two different cost components in transportation and the definitions are particularly applicable to motorists. Private costs are the direct operating costs of the vehicle, including fuel, interest, maintenance, and other costs, divided into the number of miles travelled. Social costs, or variable congestion costs, are based on the increment in the traffic flow that imposes costs on other users. As congestion increases, social costs increase more rapidly than private costs (20).

The concept of charging a toll related to social cost is not primarily intended to generate revenues but to effect a change in travel behaviour by forcing motorists to incorporate the social costs into the private costs of travelling by automobile. Without congestion charging, it is argued, motorists would continue to ignore the social costs that the decision to travel imposes on the transportation network in terms of congestion and harmful environmental side effects.

Urban economists have long argued that a variable charging mechanism is required to incorporate social costs. Transportation economists, such as Harry Richardson (20) in 1978 and Vickrey (21), as far back as 1963, have mused about the possibility of matching private costs to social costs through the application of information technology.

In fact, the term Automated Vehicle Identification dates back 30 years and can be traced to early suggestions for solving the problem of unallocated social costs.

5.4 Concerns of Fairness and Equity

In her paper *Equity and Fairness Considerations of Congestion Charging*, Dr. Giuliano examines the distribution of costs and benefits that would result from the implementation of congestion charging, which is aimed at correcting a market failure (19). In the case of road transport, the failure in the marketplace is that the cost of expanding capacity (supply) to meet rising demand has become too high.

Giuliano does not dispute the effectiveness of congestion charging in changing travel behaviour, but questions its social implications. Progressive taxation distributes the burden of taxation according to different income levels. It becomes regressive if the policy places an unfair burden on certain socio-economic groups, primarily the lower-income levels. Giuliano's chief concern is that congestion charging is a form of regressive taxation.

5.4.1 The Case Against Congestion Charging

Dr. Sussman of MIT has been quoted as saying that congestion charging has the ability to shift non-commuting traffic hours. He asserts that half of commuting traffic in the greater Boston area is composed of people who are not travelling to work (22). However, trip purpose and motorist user fees may not be directly correlated. As a result, low-paid commuters may give way to non-commuting motorists under congestion charging. Dr. Sussman also assumes that commuting traffic has a greater impact on regional economy than daytime non-commuting traffic. This may not be so.

The literature on the application of ITS traffic management tools suggests that transportation planners maintain a bias favouring commuting traffic and make the following assumptions that, if wrong, could result in important social costs:

Assumptions

- the majority of non-commuting traffic is not work related;
- as a result, restricting non-commuters’ mobility by increasing the commuting hours would have little negative economic impact;

- we therefore place a higher economic value on those people going to work than on those actually working in their cars;
- restricting consumer access to retail clusters has little negative economic impact.

What if

- the majority of non-commuting traffic is work related;
- as a result, restricting that mobility by increasing the commuting hours has significant negative economic impact;
- the aggregate economic value of non-commuting traffic or vehicle-dependent workers is equal to or higher than that of commuters;
- restricting consumer access to retail clusters has significant negative economic impact.

Consider a hypothetical worst-case scenario for Montreal. By the year 2010, the Trans-Canada Highway on the West Island, without capacity upgrades, will handle home-bound commuter traffic that will begin at 15:00 and last until 20:00. Although congestion charging has been successful in staggering work hours, traffic jams still occur and the Fairview Shopping Centre sees its catchment area and clientele reduced. Has the mall experienced a negative economic cost? Furthermore, have auto-dependent workers, such as sales people, experienced declining mobility and reduced productivity because they are restricted in the number of clients they can meet?

Possibly highway planners, by chance not design, have enabled the vehicle-dependent economy to grow substantially in the past three decades by giving it unprecedented mobility. The target market has been assumed to be the commuter market and, by default, the vehicle-dependent segment of the economy has experienced significant growth. There is little if any empirical evidence measuring the economic contribution of vehicle-dependent workers to our economy. Will congestion charging reduce their mobility? If so, at what cost?

Once distance becomes a greater impediment, reduced accessibility will result. Consequently, at least in theory, congestion charging will reduce the choices for housing, employment, education, shopping, and other urban activities. The collective impact of this causal effect could be substantial. If taken to extremes - with congestion progressively eliminated as demand rises and no substitute transportation mode introduced - it may result in greater class segregation in our cities.

Perhaps the greatest barrier to congestion charging is the concern that the public will view it as inherently undemocratic. Although many analysts have reviewed the experience of foreign countries where congestion charging has been aggressively applied, they have not weighed the cultural, historic, political, and economic distinctions present in North America. Here, the road network is a symbol of an egalitarian society where vehicles may vary in value but no individual is accorded any special privilege on our roads. It is blind to economic class, as access is universal for those able to drive; no other transportation mode can make this claim. Because it would alter this perception, many North American jurisdictions are wary of congestion charging.

5.4.2The Case For Congestion Charging

In *Edge City*, Joel Garreau discusses the unique relationship between expanding urban forms and the decision to expand the road network. The City of Irvine, for example, is an "edge city", a community conceived by private developers and designed by urban planners. According to Garreau, land developers designing edge cities adopt several informal transportation-land development corollaries, including the following:

- How many switches in travel mode a commuter will put up with

  Usually no more than one. Typically, zero. In other words, it is conceivable that a commuter will walk part way and take a bus part way, switching travel mode once. It is also possible that a commuter will take a car part way, and then switch to a train, switching mode once. But a car-bus-train two-mode-switch will rarely be used. Far more typically, once a person is in a car, he or she will never change to a different mode, no matter how bad the traffic is.

- The level of density at which automobile congestion starts becoming noticeable in an edge city

  When as much as twenty-five square feet of office is built on each hundred square feet of land. A Floor Area Ratio (FAR) of .25.

- The level of density at which it is necessary to construct parking garages instead of parking lots because the city has run out of land

  .4 FAR.

- The level of density at which traffic jams become a major political issue in an edge city

  1.0 FAR.

- The level of density beyond which few edge cities ever get

  1.5 FAR.

- The level of density at which light-rail transit starts making economic sense

  2.0 FAR.

- The density-gap corollary to the laws of density

  Edge cities always develop to the point where they become dense enough to make people crazy with the traffic, but rarely, if ever, do they get dense enough to support the rail alternative to automobile traffic (13).

These corollaries illustrate a direct cause and effect between the way in which we choose to build our communities and the transportation problems that emerge.

5.4.3 Cost of Automobile Ownership and Operation: A 20-Year Perspective

The perception among many is that we are paying more to operate an automobile today than we did twenty years ago. Surprisingly, the opposite has occurred. The Fixed to Variable Cost Ratio for automobile ownership and operation has increased from 1.82 (1975) to 3.29 (1993) in Canada and from 1.84 (1975) to 4.03 (1992) in the United States. In constant $1990, the combined cost has increased less than two cents a kilometre in Canada and has declined by almost two cents a mile in the United States (see Table 6).

Transportation planners often assume that people choose their travel mode rationally on the basis of costs incurred, and that those costs include depreciation, insurance, maintenance, and fuel. The Air Canada / CP Rail High Speed Train study exposed the error of these assumptions. When asked to approximate the cost of auto travel for any purpose, intercity motorists, without exception, calculated the cost as a function of fuel consumption only. Costs for maintenance, insurance, ownership interest, and depreciation were never considered (12).

The implication is that some form of correction is required for variable charging. Automobile engineers have correctly adjusted for expected fuel price increases by designing more fuel-efficient automobiles. While this has reduced fuel consumption per trip, it has not affected trip-making behaviour.

TABLE 6
Comparison of Automobile Fixed and Operating Costs 1975-1992/3 (in cents)

Type of Cost	United States Cost per Mile [23] (U.S. Currency) Constant 1990$		Canada Cost per Kilometre [24,25] (Canadian Currency) Constant 1990$	
	1975	**1992**	**1975**	**1993**
Variable Cost	15.66	8.47	11.12	7.71
Fixed Cost	28.80	34.14	20.26	25.38
Total Cost	44.46	42.61	31.38	33.09
Fixed to Variable Cost Ratio	**1.84**	**4.03**	**1.82**	**3.29**

5.5 The Politics of Congestion Charging

The Politics of Congestion Pricing, a paper by Mark Rom of Georgetown University, covers this subject in great detail (19).

From American history, Rom draws examples of citizens' acceptance of the notion of collective sacrifice to achieve concrete public benefits. To promote the merits of congestion charging, he urges government policy makers to outline a clear set of goals that can:

- convince the public of the need for congestion charging;
- demonstrate that congestion charging will translate into lower public expenditure on roads;
- return the generated revenue back into the transportation network;
- introduce the measure in concert with other transportation initiatives that provide viable substitutes to the automobile.

In a rebuttal to Dr. Guiliano, Rom acknowledges that congestion charging may generate inequities for some segments of the population, but he suggests that they can be significantly lessened if accessibility can be secured through other means.

5.5.1 City of London

The City of London is debating a proposal to charge all vehicles, whether commercial or private, a toll as they enter and exit the perimeter of the central city. Aside from buses, no exceptions have been proposed. Even taxis would be subject, although the only distinction between private taxis and buses is the number of passengers carried; bus companies in London are privately owned and operated. The major impediment to this plan is that policy makers are finding it difficult to convince the public that congestion charging will benefit those affected. Policies that redistribute revenues to property owners and promises of improvements to mass transit are proving rather difficult to sell.

In the case of reduced property taxes, the beneficiary may not be the person who paid these taxes prior to congestion charging. If the cost of doing business becomes too onerous for establishments that cater to price-sensitive markets, they will flee central London, to be replaced by less vulnerable businesses. The probable displacement of price sensitive occupants, whether commercial or industrial, is consistent with Dr. Deakin’s analysis of the effects of congestion charging.

The promise of reallocation of revenues to upgrade mass transit has been made more problematic following the decision in the 1980s to return the bus network to private hands; the underground is still a public utility. Questions of fairness abound as citizens consider the passage of taxi toll collections to subsidize private bus operations.

Especially worrisome is the admission by London planners that the source of congestion is not private vehicles (since 83 percent of peak time travellers commute by public transport), but taxis and commercial vehicles delivering parcels and goods (26). The composition of the traffic may not be well understood. Depending on the severity of the toll, what will be the effect on the urban form? Will businesses be forced to relocate outside Central London, to be followed later by their customers, residential as well as commercial occupants. If so, does it matter?

Planners appear to lack some of the essential tools for measuring the link between reduced mobility, a synonym for reduced accessibility, and economic development in Greater London. One may question the value of that research from a purely transportation engineering standpoint, but such knowledge would facilitate the design and the passage of congestion charging policies in the City of London.

5.6 Case Study 2 - Analysis

The variable costs of automobile operation have declined rapidly in the last 20 years. Some form of correction is needed to redress the imbalance between fixed and operating costs if travel behaviour is to be altered. While some would recommend that the cost of fuel be increased as an alternative to congestion charging, this is neither less regressive nor more effective in staggering demand into non-peak hours. Variable charging tied to the amount of road use at various times of the day is much more effective. In addition, the user charge can be adjusted to incorporate the social costs of quantified negative side effects, such as automobile emissions, directly into the private costs of the automobile.

Current information technology would allow changes in the implementation of congestion charging to mitigate its regressive nature. If movements can be accurately tracked and recorded by AVI systems, a variable toll rate could be applied for different socio-economic levels. Instead of a flat charge per bridge crossing or kilometre travelled, the charge could be tied to the value of the automobile. For example, a $36 000 automobile would be charged twice as much as one valued at $18 000. While this alternative has some merit, it may discourage the sale of more expensive cars. An alternative could be to tie the charge to the market value of a motorist's principal residence or business premises.

Congestion charging, although controversial, is an important tool for local and provincial governments to effect desired transportation policy changes.

6. CONCLUSION

ITS implementation generates wide-ranging benefits, not only for transportation users but also for transportation providers, private investors, suppliers, and the community at large. Changes effected through an ITS application will yield varying benefits among these groups. The ability to link these changes to benefits to specific groups will allow policy makers to determine whether ITS implementation is in the public interest and which beneficiaries should shoulder capital and operating costs.

The benefit-cost framework proposed in this report introduces a system that classifies benefits and costs individually, showing the linkages between ITS deployment and its beneficiaries, and providing an economic context for decisions on implementation and funding sources. In practice, a lack of resources and/or empirical data can impede the development of a comprehensive assessment. However, the contribution of this framework does not depend solely on its use in benefit-cost calculations, but also lies in its application to the interpretation of the benefit-cost results. If, for example, strong evidence indicates that automated border crossings can promote economic development for Canadian export industries, recognition of this outcome and its linkage to proposed ITS applications is more critical than quantification of the result.

ITS represents a significant opportunity for Transport Canada to better manage our nation's transportation infrastructure. Two bundles in particular hold promise: Commercial Vehicle Operations and Automated Border Crossings. They offer the possibility of significantly reducing the costs of transporting goods and industry resources, factors that weigh heavily on the ability of Canadian industry to compete in the global marketplace and within NAFTA.

Urban applications of ITS are also promising. In England and other European countries, national governments have focussed attention on urban areas, where ITS implementation is expected to generate the greatest source benefits. Given the mandate of these federal governments in local affairs, this is to be expected. In the United States, the Federal Highway Administration's role in the investment and management of the interstate freeway system gives it considerable presence in all areas of road transportation, including urban applications. In Canada, federal responsibility is limited to the national highway system. But since this system cuts through every major metropolitan region, urban congestion can restrict the free movement of goods between provinces and the United States, reducing Canada's industrial competitiveness. Thus, the federal government does have a limited and collaborative role to play in implementing ITS in sections of the national highway system that fall within urban areas.

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APPENDIX A

INTELLIGENT TRANSPORTATION SYSTEMS U.S. ARCHITECTURE SUBMISSIONS: A REVIEW

The U.S. Department of Transport (DOT) Federal Highway Administration (FHWA) is currently reviewing the ITS Architecture submissions from four consortia: Hughes, Rockwell, Loral, and Westinghouse. The task for the evaluators will be to select the architecture that best meets the performance specifications of the FHWA to achieve the national ITS goals with economy and effectiveness.

To demonstrate the competing systems' effectiveness, the performance of each architecture was measured against a simulated city called Urbansville, loosely modeled after Detroit. U.S. DOT instructed the architecture teams to simulate traffic conditions that would result from 10 percent and 60 percent market penetration of smart vehicles.

As a result, the emphasis for the submissions was on Advanced Traveller Information Systems (ATIS) and Advanced Traffic Management Systems (ATMS), with the exception of one team that also focussed on Advanced Public Transit Systems (APTS).

To justify the cost of ITS deployment, generated benefits concentrated on congestion relief, a short-term achievement, which incidentally is not one of the major ITS America goals. However, the goal of ITS is to significantly improve productivity and thus to defer the infrastructure investments needed to accommodate growing travel demand.

The absence of specific policy guidelines about the effected transportation change in Urbansville forced the applicants to make their own transportation policy statements/judgments. Some emphasized public transport, while others emphasized squeezing more cars onto the limited road network. As a result, ITS was presented as an end rather than a means to effect transportation policy.

This is not to suggest that the submissions are without value. They have increased the technical understanding of ITS deployment in terms of compatibility, performance, cost, and effectiveness. What is sorely lacking, however, is an appreciation of how the broad ITS initiatives can function in concert to achieve desired transportation policies. It is understandable, for example, that Advanced Rural Transportation Systems (ARTS) cannot be treated adequately in an Urbansville application.

ITS is composed of individual initiatives that have been banded together because their synergy was expected to produce wide-ranging benefits that would be greater than the sum of the advantages of each part. Unfortunately, an opportunity to demonstrate ITS synergy was lost. Unless the product of that synergy can be demonstrated, outsiders may question the wisdom of government-sponsored ITS initiatives, and the full benefits of ITS will never be realized.

Seen primarily as a productivity enhancement that limits or reduces environmental damage, ITS has as its basic goal to effectively maintain or improve mobility, whether by promoting public transit, improving traffic flows, improving safety, or reducing environmental damage. As a result of this interpretation, ITS need not be seen as promoting conflicting goals such as improving mobility and reducing environmental damage, but as providing an array of tools that allow transportation managers to achieve a delicate balance between mobility, environmental, and infrastructure cost requirements.

It may be more constructive for U.S. DOT to present Urbansville as a simulation again, but this time to outline policy scenarios. The challenge of the architecture teams would then be to achieve those desired policy objectives effectively and economically at five-year intervals.

Several scenarios come to mind, but the base case would always be as follows:

- Maintain current mobility level
- Maintain current level of occupancy vehicle ratios
- Maintain current modal shares
- Forecast travel demand by mode
- Set capacity requirements
- Estimate the cost of maintaining the current transportation service levels in terms of needed capital investment and environmental damage
- No ITS deployment of any kind

Sample Scenarios

Scenario 1

Achieve a higher Heavy occupancy vehicles/Single occupancy vehicles ratio with ATMS and ATIS.

Scenario 2

Achieve a higher public transit mode share with ATMS, ATIS, and APTS.

Scenario 3

Estimate property and passenger safety improvements with AVCS.

Scenario 4

Estimate improved trucking productivity and improved road infrastructure maintenance and operations using CVO.

APPENDIX B

Economic Trends and Multimodal Transportation Requirements

Taken from the work statement for Transportation Research Board - National Research Council NCHRP Project 2-20, FY 1995

Research Problem Statement

The U. S. economy is an evolving post-industrial economy. The service sector, which currently accounts for 80 percent of economic activity, is one of the fastest growing sectors and relies more on the movement of people than goods. During this transition, the manufacturing sector has also been restructuring its operations. Manufacturing in general has shifted from heavy industry to lighter manufacturing that requires more frequent and smaller shipments of higher value goods and reliable, timely deliveries. Growth in the manufacturing sector has been centred in high technology, the refinement of processes, and a recommitment to quality. In supporting economic expansion goals, it is important to consider how multimodal transportation investments can sustain development in the future. This is particularly true in light of the opportunities for increasing the market reach of U.S. economic production and the competitiveness of American business in the changing global economy.

Research is needed to provide valuable information to AASHTO, FHWA, and other U.S. DOT administrations, state DOTs, and MPOs regarding the type of multimodal transportation investments that can best increase the competitiveness of American business. It will provide a reference document for all levels of government that will be useful in the preparation of project plans, metropolitan plans, statewide plans, management systems, and in the development of national transportation legislation. The results of the research will provide information that can be used as a basis for a shift in investment priorities at the national, state, and local levels.

Objective

The objective of this research is to develop guidance for use by planning practitioners and other transportation decision makers based on the relationship between current and future regional, national, and economic trends and the freight and passenger transportation requirements of American business. To accomplish this objective, a three-phased effort is envisioned:

Phase I - Identification and Discussion of Economic Trends Affecting Multimodal Transportation.

Task 1 - Review existing literature on economic trends affecting multimodal transportation and any related surveys of American business. Determine the necessity for an additional survey to be conducted in Phase II ...

Task 2 - Identify current and probable future economic trends affecting multimodal transportation at the regional, national, and global levels.

Task 3 - From a multimodal transportation perspective, discuss the significance of recent economic trends that affect transportation including, but not limited to, corporate downsizing, outsourcing, integrated logistics, decentralized manufacturing, growth of the service-oriented economy, as well as the growth rate of various other economic sectors. Additional consideration should be given to the impacts of fuel costs, multinational trade agreements, improved employee and customer access, quality initiatives, regulatory and legislative changes, and other important issues identified by the contractor.

Task 4 - Provide an interim report on the results of Phase 1 for review and approval by NCHRP.

Phase II - Identification and Assessment of Multimodal Transportation Needs and Requirements of American Business.

Task 5 - Based on the findings of Phase I, identify and assess the multimodal transportation needs and requirements of American business sectors and ways in which transportation can facilitate their competitiveness. For example:

a) How does emphasis on reduced inventory levels and just-in-time delivery affect the transportation system?
b) How can economic expansion be facilitated through transportation improvements that reduce congestion and increase reliability of delivery time (e.g., incident management, congestion management, Intelligent Vehicle Highway System programs)?
c) How does decentralized manufacturing affect domestic and international transportation needs?

d) What are the transportation-investment requirements resulting from the North American Free Trade Agreement (e.g., new corridors) and increased global trade (e.g., better integration of domestic and international links and improved access to ports and airports)?
e) How can transportation reliability and speed increase the competitiveness of American business?
f) How might the National Highway System (NHS) and the National Transportation System (NTS) impact economic development and competitiveness?

Task 6 - Meet with the NCHRP panel to present the findings of Phases I and II and discuss the Phase III research approach. At least one month prior to meeting, the contractor will provide the panel with an interim report on Task 5 and a revised work plan for Phase III.

Phase III - Development of Strategies for Addressing Multimodal Transportation Needs and Requirements of American Business.

Task 7 - Identify potential strategies for addressing multimodal transportation needs based on the findings of Phases I and II.

Task 8 - Assess the feasibility and cost effectiveness of implementing each of these strategies and identify procedures for implementation.

Task 9 - Develop a means by which planning practitioners and other transportation decision makers can use the research findings. This may take the form of a toolbox, a management-system component, or another mechanism that can be tailored to the needs of planning practitioners. This stand-alone product shall be submitted to the NCHRP for review.

Task 10 - Prepare and submit a final report that fully documents the research effort and presents all findings, conclusions, and recommendations, and prepare an executive summary in lay terms that can be used as a stand-alone guidance document for decision makers.