Transport Canada

The Impact of Transit Improvements on GHG Emissions: A National Perspective

Final Report

March 2005

CANSULT
Engineers and Project Managers

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Prepared for:

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Disclaimer

Although data and information that form the basis of the analysis and findings of this study have been obtained from specific municipal organizations and transit operators, the findings, conclusions, and recommendations are the sole responsibility of the consultants and are not necessarily endorsed by the participating municipal organizations.

Notwithstanding that Transport Canada commissioned this study, the views expressed in The Impact of Transit Improvements on GHG Emissions: A National Perspective are those of the consultants who prepared the report. They do not represent federal government policy and are not necessarily endorsed by Transport Canada or any other federal government department.

Background and Purpose of the Study

Much of the current emphasis on transportation and land use planning in urban areas stresses improvements in transit, as well as transportation demand measures (TDM) as key means of achieving new 'visions' of urban transportation characterized by general reductions in all travel, reduced automobile dependence, higher transit ridership, and relative increases in non-motorized travel such as walking and cycling.

A Transportation Association of Canada (TAC) vision statement, for example, based on a fundamental premise that *current trends are leading to urban transportation systems which do not meet needs and which are not sustainable,* has already been endorsed by many municipal governments in Canada.[1]

Particular interest in greenhouse gas (GHG) emission reductions derive from the Kyoto Protocol, negotiated by Canada in 1997 under the United Nations Framework Convention on Climate Change. The Kyoto Protocol came into effect February 16, 2005. Canada ratified to reduce its GHG emissions by 6 percent relative to 1990 levels during the period 2008 to 2012.

Motivated by the Kyoto Protocol, the federal, provincial, and territorial ministers of transportation established the Transportation Climate Change Table as a means of contributing to a national strategy intended to respond to the Kyoto Protocol. The federal government also sponsored a number of studies and programs related to policies, strategies and the feasibility of achieving national targets for GHG reductions. The Table identified transportation as the largest single source of GHG emissions (about 25 percent of emissions from all sources in Canada)[2] and recommended a target reduction of about 8 Mt by 2010.

Reducing GHG emissions from *urban* transportation can be achieved through:

- Shorter trips of all types,
- A higher proportion of trips by transit (modal shift from auto to transit),

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[1] Transportation Association of Canada, *A New Vision for Urban Transportation*, Ottawa: reprinted November 1998.

[2] *Transportation and Climate Change: Options for Action*, Ottawa: Government of Canada, November 1999.

- A relative increase in trips made by non-motorized means (modal shift from auto and transit to walk/bike), and
- Greater efficiency (less fuel intensity, higher vehicle occupancy) for all motorized trips, including transit.

As a first attempt to measure potential reductions, the Transportation Table estimated that 2010 GHG emissions could be reduced by 3.7 to 10.1 Mt., depending upon a range of specific methods and policies that might be adopted.

Recognizing some degree of inter-relationship between transit use and GHG reductions, Transport Canada subsequently sponsored a follow up study that defined *targets* for change in such indicators as transit ridership, transit mode split, and revenue-operating cost ratios according to municipal population, as shown in Table 1.[3]

Table 1 Potential National Urban Transit Targets in 2020*

Quantitative Indicator	Urban Population		
	<0.2M	0.2 -0.9M	>0.9M
Percent increase in annual transit ridership (%) relative to year 2000	20-40	30-60	40-80
Annual transit rides per capita (annual rides/capita)	20-50	30-100	100-250
24 hour weekday transit mode split (%)	2-10	5-15	10-25
Peak hour mode split to the central area (%)	10-30	30-50	50-80
Transit Revenue/Operating Costs (%)	40-60	50-70	60-80

* *National Vision for Urban Transit in 2020*, p.67

This study focuses on how emission reductions can be achieved through a variety of urban transportation policy initiatives. The main objectives are to:

1. Obtain cost estimates of the most realistic, cost-effective paths to meet the transit ridership and modal share target ranges (where practical) presented in Transport Canada's Vision study,

[3] IBI Group and Richard M. Soberman, *National Vision for Urban Transit to 2020*, Ottawa: Transport Canada, 30 October 2001.

2. Estimate the GHG emissions reductions achievable by implementing projects identified in objective (1)
    - through transit investment alone, and
    - through transportation demand management (TDM) measures combined with transit investment;
3. Confirm or update the Transportation Table estimated GHG emission reductions for all Census Metropolitan Areas (CMAs) included in the previously noted Climate Change Plan for Canada, and
4. Estimate co-benefits (as referenced in the Vision study and other cost-benefit studies) where available.

With regard to these objectives, costs for specific municipalities are excluded from the background technical analysis so as to eliminate any inferences with respect to relative efficiencies that may be taken out of context. Moreover, almost all co-benefits can be directly related to ridership changes, particularly those concerning air pollution and various non-quantifiable benefits. Thus, co-benefits are not treated explicitly in the report.

It should be also be noted that although data and information which form the basis of the analysis and findings of this study have been obtained from specific municipal organizations and transit operators, the findings, conclusions, and recommendations are the sole responsibility of the consultants and are not necessarily endorsed by the participating municipal organizations.

Study Approach

The approach for determining the efficacy of transit investment and other forms of transit improvements from the standpoint of reducing GHG emissions is to compare estimates and predictions of emissions for the 'do nothing' or 'business as usual' (BAU) case with alternative transportation plans that involve varying combinations of transit investment (both infrastructure and vehicles) and TDM policies.

Such comparisons can be made using transportation models, data and information available from specific case studies, and data and information obtained from recent literature.

In the case of modelling, key inputs to estimating GHG emissions derive from estimates and predictions of such travel measures as vehicle-km of travel (VKT) by mode, type of facility, and the characteristics of flow on individual facilities. As illustrated in Figure 1, models can thus be applied to alternative transportation and land use scenarios, however characterized, including the BAU alternative. In this manner, the costs and impacts of the range of alternatives can be compared. The underlying assumption is that the travel behaviour of individuals in the future will, more or less, be similar to behaviour observed when the surveys were conducted and the models calibrated.

With respect to this general approach,

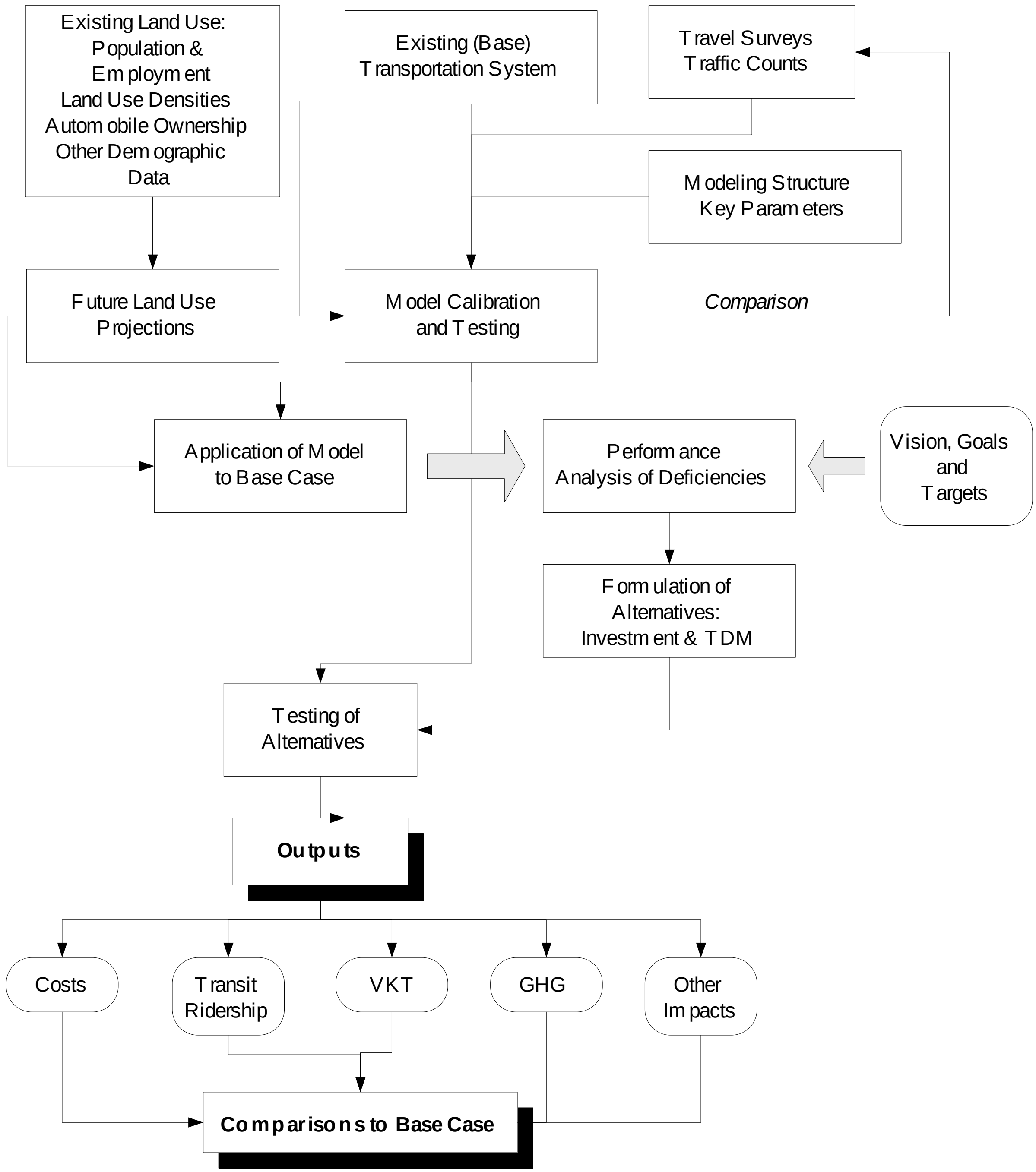
- land use changes that alter population and employment distributions by increasing employment in close proximity to transit, mixed land uses that reduce the need for some vehicular trips, and transit oriented development, all affect origin-destinations relative to the base case.
- investment in new transit facilities and services alter the performance characteristics of the transportation network in ways that change travel times and costs, the choice of destination, the relative competitiveness of auto and transit travel, as well as the utilization of transit services.
- the application of TDM measures such as high occupancy vehicle (HOV) or reserved transit lanes affects travel times relative to the base case whereas pricing, fuel taxes, and parking regulations affect relative costs, thereby influencing outputs.

Since models of any sort have their weaknesses, estimating GHG emissions on the basis of results obtained from transportation models shares these same weaknesses. Moreover, the process by which transportation modelling outputs are translated into GHG estimates (also, usually involving some form of modelling) suffers from the same weaknesses associated with transportation modelling.

In addition, the introduction of TDM measures is problematic from the standpoint of modelling simply because there is little empirical evidence available from Canadian sources as to the effectiveness of such measures as HOV or reserved transit lanes.

For these reasons, 'benchmarking' is another important means of supplementing available forecasts, as well as validating modelling results. Benchmarking involves examining what actually happened following investments in some form of rapid transit, ranging from conventional subway or heavy rail (HRT) and Commuter Rail to light rail transit (LRT) or bus rapid transit (BRT), as well as the application of TDM measures both within and outside of Canada.

Figure 1 The Role of Models in Estimating Impacts


Existing Land Use:
Population &
Employment
Land Use Densities
Automobile Ownership
Other Demographic
Data
Existing (Base)
Transportation System
Travel Surveys
Traffic Counts
Modeling Structure
Key Parameters
Future Land Use
Projections
Model Calibration
and Testing
Comparison
Application of Model
to Base Case
Performance
Analysis of Deficiencies
Vision, Goals
and
Targets
Formulation of
Alternatives:
Investment & TDM
Testing of
Alternatives
Outputs
Costs
Transit
Ridership
VKT
GHG
Other
Impacts
Comparisons to Base Case

Thus, the study approach involved two main activities, namely:

- the application of models to transportation plans already developed in a number of Canadian municipalities (referred to as the modelling approach) or the analysis of forecasts developed by municipal staff, in cities where models were not available to the study team (referred to as the research approach), and
- the development of supplementary information from benchmarking, a review of the relevant literature, and more detailed analysis of specific case study material.

Although the modelling/research component of the study is based on specific individual municipal plans, aggregate, nation-wide estimates were also developed on the basis of extrapolation of results from these municipalities and other documented national and international experience. The main elements of the approach, shown in Figure 2, were:

1. selection of municipalities for detailed assessment that, collectively, account for an adequate proportion of national GHG emissions (about 80 percent) which can then be expanded to provide total Canadian estimates.
2. determination of the most appropriate analytical approach for modelling or researching the impacts for each of the selected municipalities.
3. application of the relevant modelling/research approach for the selected municipalities.
4. acquisition of cost estimates for the selected municipalities.
5. review of the relevant literature to provide supplementary information on:
    - benchmarking for TDM impacts not reflected in the available database for the selected municipalities,
    - post-project implementation results for other cities in North America and elsewhere, and
    - comparative costs of transit technology and, where possible, TDM measures.
6. translation of modelling/research results into implied reductions in GHG emissions for the selected municipalities and expansion to represent nation-wide impacts.
7. comparison of various transit investments and TDM measures in terms of relative cost effectiveness.

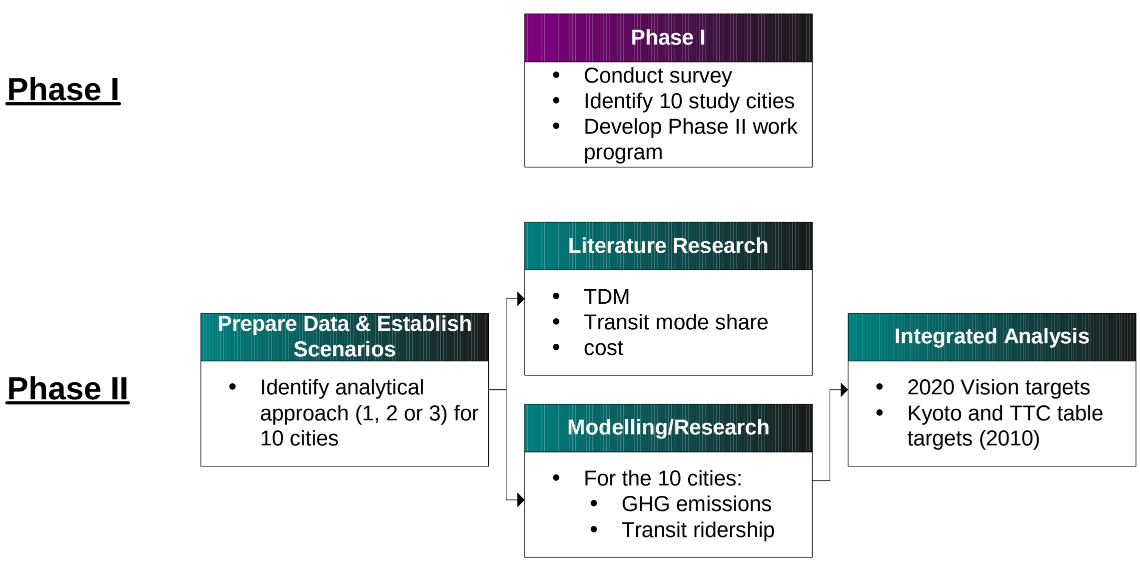
8. comparison of study national estimates with other sources such as the findings of the Transportation Climate Change Table.

The selection of municipalities for detailed analysis was based largely on a preliminary survey of modelling activity, availability of data and transportation plans, and the willingness of agencies to participate in the conduct of the study. The ten municipalities selected were:

- Greater Victoria – Capital Regional District (CRD)
- Greater Vancouver – Greater Vancouver Regional District (GVRD)
- City of Winnipeg
- City of Calgary
- City of Edmonton
- Greater Toronto Area (GTA) – York Region
- GTA – City of Toronto
- Ottawa – Gatineau
- Montreal (AMT)
- Halifax Regional Municipality

When York Region and the City of Toronto are combined within the GTA, the nine entire urbanized areas (EUAs) account for 12.9 million inhabitants, or about 76 percent of the urban CMA population of Canada.

Figure 2 Study Approach



The procedures used to generate forecasts for different combinations of transit investment and TDM scenarios involved the eight scenarios shown in Table 2. These scenarios were developed in consultation with municipal staff based on the most appropriate transportation plans. In most cases, the low and high transit scenarios are distinguished by different levels of transit investment. Low TDM is defined as incentive measures whereas high TDM is defined as disincentive measures.

Table 2 Modelling Approach for Each Municipality

Scenario	Year
Base Year	1999 – 2001
Do-Minimum	Future
Low Transit	Future
Low Transit + Low TDM	Future
Low Transit + High TDM	Future
High Transit	Future
High Transit + Low TDM	Future
High Transit + High TDM	Future

TDM

TDM (examples of which are shown in Table 3 refers to any policy or regulation that facilitates or encourages multi-occupant vehicle use and/or reduces total vehicle trip making, particularly, but not exclusively, during congested periods.

Table 3 Objectives and Examples of TDM Policies/Measures

Trip Reduction Measures	**Disincentive Policies and Measures – "Sticks"**
• E-Commerce and delivery systems • Flexible work schedules • Home and satellite telecommuting	• Parking management - Limited supply of long term parking - Higher and more extensive parking charges • Road pricing (i.e. tolls) • Institutional measures - Trip reduction by-laws - Bicycle parking by-laws • Distance-based vehicle insurance • Taxes and fees on vehicle ownership • Fuel taxes
Incentive Policies and Measures – "Carrots"	**Transit-Supportive and Other Supply Side Alternative Mode Measures**
• Employer-based TDM programs • Ridematching	• Premium transit services • Private shuttle services

• Guaranteed ride home • Carpooling and vanpooling • Discount transit fares • Public education and targeted marketing • Location efficient mortgages • Walking school buses	• Bus rapid transit (BRT) • Intelligent transportation systems (ITS) • Transit priority measures • Park-and-ride lots • HOV/Transit and High Occupancy Toll (HOT) lanes • Traffic calming • Improved pedestrian facilities • Bicycle racks on buses and cycling facilities

TDM policies generally seek to achieve one or more of the following:

1. Trip reduction – outright elimination of the need, opportunity or incentive to travel
2. Mode change – encouragement of higher occupancies in private vehicles or greater use of public transit or other modes;
3. Temporal change – encouraging vehicle drivers to travel in less congested periods; and
4. Route change – encouraging vehicle drivers to travel on less congested routes.

The relevance of TDM measures for this study relates to the use of models for evaluating infrastructure investment decisions and land use/transport policy. Some TDM policies have a direct effect on model inputs and are therefore explicitly considered in the modelling process. Such policies include parking policies (price and supply), transit priority lanes and park-and-ride. However, policies intended to change behavioural patterns, such as the establishment of employer-based promotion of transit use are rarely included in the model development stage. Summary of findings of the literature review is shown in Table 4.

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Table 4 Summary of Findings from Case Studies

COMPREHENSIVE PROGRAMS

TDM Strategy	Case Study	Effect of Policy/Measure
"Soft factor" interventions: • Workplace travel plans • School travel plans • Personalized travel planning • Public transport information and marketing • Travel awareness campaigns • Car sharing • Carpooling • Teleworking • Teleconferencing • Home shopping	*Smarter Choices* research project for the UK Department for Transport. Study compares the impact on travel demand over the next ten years in the UK for two different policy scenarios: (1) 'low intensity' scenario, which is defined as a projection of present (2003-4) levels of local and national activity on soft measures and (2) 'high intensity', which is defined as a significant expansion of current soft factor practices. Estimates are based on a review of international and UK literature and 24 individual case studies taken from 12 local authorities.	Low intensity scenario would have the potential to • Reduce peak period urban traffic by about 5% • Reduce nationwide traffic by 2-3%. High intensity scenario would have the potential to • Reduce peak period urban traffic by about 21% (off-peak by 13%) • Reduce peak period non-urban traffic by about 14% (off-peak by 7%) • Reduce nationwide traffic by about 11% *if* sufficient supportive policies are implemented to prevent induced traffic from reducing the benefits of the TDM measures.
Five official Transportation Emission Reduction Measures (TERM): • Telework resource centres • Guaranteed ride home • Integrated rideshare • Employer outreach • Employer outreach for bicycling Also: • Commuter Operations Centre (providing commute information and a ridematching database)	Metropolitan Washington (D.C.) Council of Governments *Commuter Connections* program	In a metropolitan area with 4.2 million people, the combined impacts for five official TERMs was 94,363 fewer daily vehicle trips and 1,708,613 fewer daily VMT. The 'Commuter Operations Centre' had an additional impact of reducing daily vehicle trips by 1,970 and daily VMT by 66,056.
Three program areas to change employee and employer behaviour: • Media campaigning • Employer and individual outreach services • Regional supporting programs and services, which support commuting alternatives such as carpooling, vanpooling, transit, biking, walking, teleworking and compressed work week schedules	Metropolitan Atlanta's *Atlanta TDM Framework* collaboration between 8 transportation management associations, the Clean Air Campaign, Commute Connections and the State Employee Commuters Assistance Program	In a metropolitan area with 4.1 million people, there were 53,400 alternative mode commuters associated with Framework related TDM programs, who collectively eliminated 37,500 daily vehicle trips and 780,000 daily VMT.

TRIP REDUCTION MEASURES

TDM Strategy	Case Study/Source	Effect of Policy/Measure
• E-commerce and home delivery	Literature review, including of study in Netherlands	Net effect of Internet shopping was to increase road vehicle movement by 15% over the next five years.
• E-commerce and home delivery	Literature review and case studies of UK chain stores	Home shopping and delivery have greatest impact in the grocery sector. Vehicle mileage savings of 70% per shopping load, which suggests an overall 1-4% reduction in vehicle mileage for shopping purposes over ten years. (Good market potential for grocery home deliveries in the UK, accounting for 5-15% of grocery sales by value within ten years.)
• Compressed Workweek (4/40)	Los Angeles County Department of Public Works	Building closure on Fridays, affected 1,600 employers at one worksite. Resulted in an [illegible]

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		2,300 mi, 81 lb of pollutants and 2,185 lb of carbon dioxide.
• Telecommuting	Telecommuters in southern California and Puget Sound area of Washington	Telecommuters experienced a drop of over 70% in average distance driven per day and a drop of about 50% in number of trips per day.
• Telecommuting	Telecommuters in metropolitan Washington, D.C.	Growth in telecommuting – nearly 100,000 commuters have begun telecommuting since 1996. In a region of 4.2 million people, nearly 15% of workers telecommuted at least occasionally. In the 36-month evaluation period from 1999-2002, metropolitan Washington gained 97,999 new telecommuters, reduced daily vehicle trips by 47,432 and reduced daily VMT by 1,553,856. 30% of the new telecommuters and 27% of the vehicle trips reduced could be credited to the Telework Resource Center, one of the five TDM strategies adopted by the metropolitan Commuter Connections program. Trip reduction factor of 0.49 daily trips reduced per telecommuter, based on a telecommute frequency of 1.49 days per week.

INCENTIVE POLICIES AND MEASURES

TDM Strategy	**Case Study/Source**	**Effect of Policy/Measure**
• HOV lanes • Toll roads • Public transportation • Park-and-ride facilities • Free/discount transit pass • Area-wide carpool/vanpool • Priority reserved parking and parking discount • Flexible work hours • Compressed workweek • Telecommuting	Survey of 72 metropolitan planning organizations in the United States	Respondents consistently rated employer-based measures (i.e. flexible work schedules and telecommuting) as more effective TDM measures than traditionally considered supply side measures such as HOV lanes and toll roads.
• Employer-based programs (car/vanpooling, transit support, etc.) in jurisdictions with mandated TDM policies	Medium-sized employers in Washington and California	Companies located in both urban and suburban areas had employee SOV mode splits that were about 20% below the local area average.
• Voluntary employee trip reduction programs	Corporations, institutions and public sector organizations in Chicago	Average employer reduced solo driving rates by 5.5%.
• Employer-based TDM programs	Large companies in California	Able to achieve relatively high employee participation rates, from 20-30%. Enabled one company to increase transit ridership by 10% and carpools by 57%.
• Employer-based TDM plans	21 workplace travel plans in the UK	21 employers experienced an average reduction of 18% (median reduction of 15%) in car driver mode share and the number of cars driven to work was reduced by 14 for every 100 staff. For the 13 plans which addressed parking (e.g. restricting the number of employees with parking spaces, introduction of parking charges, incentives to give up parking space), the average reduction in vehicle driver mode share was 24% (median of 17%), while the 8 employer travel plans that did not address parking had a lower average reduction of 10% (median of 9%).
• Employer-based TDM plans	Workplace travel plans at 26 employer organisations (covering 33,000 employees), located in 7 different local authorities having TDM programs	The TDM programs for these 26 employers led to an average decrease of 9.8 cars per 100 staff. The weighted average reduction in traffic was 17.8%, with area-wide reductions in the 7 local areas ranging from 7.5 to 27.3%. Good market potential, especially in urban areas – city authorities engaged employers whose staff comprised 30% of the workforce in the area, while county authorities engaged employers with staff representing 8-12% of the workforce (overall, 16% of the workforce in the case study areas were working for organisations with travel plans in the summer of 2003). Larger companies more likely to implement TDM programs, and local authorities in the case studies were able to secure the participation of 20-40% of companies with more than 300 employees.
• Employer-based TDM plans	Employer outreach programs run by *Atlanta TDM Framework* partners to encourage large, private sector employers to voluntarily adopt TDM strategies at the workplace	Employers open to considering the idea of TDM – 1,561 meetings held with employer or property managers in FY2002. Based on the 433 employers in the database having higher level TDM programs and using the US EPA's COMMUTER Model (because of the absence of post-program survey results), it was estimated that Employer Outreach reduced daily vehicle trips by 71,267 and daily VMT by 1,107,698 (between 7/99 and 6/02).

• Ridematching systems	*Integrated Rideshare*, an integrated ride matching service in metropolitan Washington, D.C., which used software upgrades and information kiosks to improve the quality of the regional ridematching service by additionally integrating and providing information on transit, HOV lanes, park-and-ride lots and telecommuting	*Integrated Rideshare* is credited with reducing daily vehicle trips by 3,418 and daily VMT by 117,940 in a region with 4.2 million people. The number of vehicle trips was determined by multiplying the number of commuters who had applied to Commuter Connections by placement rates determined from surveys of commuters who had used the information provided (0.8% for continued placement, 0.1% for temporary placements and 5.7% for one-time placements), then applying the VTR factors which were also determined from surveys (VTR factor of 0.60 for continued, 0.60 temporary and 0.80 for one-time placements). Temporary (8.3 weeks) and one-time (2 days) placements were additionally discounted by factors of 0.16 and 0.008 (percentage of the year) to reflect their shorter duration.
• Ridematching systems	Regional rideshare database in the *Commute Connections* program run by the Atlanta Regional Commission in collaboration with Atlanta TDM Framework partners	Success in getting interest – 28,123 commuters registered in the database at end of the 2002 fiscal year, a 26% increase from the previous year. Not every registrant becomes a carpooler or vanpooler. Placement rates of 11.2% for new carpoolers and 7.5% for retained carpoolers in the population of people who contacted Commute Connections for rideshare matching or GRH services. Likewise, the regional rideshare placement survey indicated a 3.4% new vanpool placement rate and a 1.4% retained vanpool placement rate. A survey of database registrants showed that only 58% of rideshare applicants received a matchlist, and only 28% of the people who received a matchlist actually tried to contact someone on the list. Atlanta TDM Framework programs resulted in 10,580 carpoolers and 2,306 vanpoolers, accounting respectively for reductions of 5,515 and 2,663 daily vehicle trips. Daily VMT reductions were 127,034 miles for carpooling and 91,341 for vanpooling.
• Guaranteed Ride Home (GRH) programs	GRH service in metropolitan Washington, D.C.	Surveys of GRH-registered commuters indicate that GRH is a useful service which has some influence on the mode choice made by commuters. The impacts allocated to GRH (between 7/99 and 6/02) were a reduction of 6,803 daily trips and 202,058 daily VMT. However, GRH is not the only factor considered by commuters. While 73% of survey respondents who began using an alternative mode stated that GRH was important to their decision to change modes, 63% also said they were "very likely" to have made the change without GRH.
• Guaranteed Ride Home (GRH) programs	GRH service in the *Commute Connections* program run by the Atlanta Regional Commission	Success in getting interest – 471 worksites registered for the GRH program at the end of the 2002 fiscal year, an increase of 49% from the previous year.
• Vanpooling	Employer and individual outreach services to promote vanpooling under the Atlanta TDM Framework	Atlanta TDM Framework programs resulted in 2,306 vanpoolers, who accounted for a reduction of 2,663 daily vehicle trips and 91,341 daily VMT. There were three primary regional vanpool service providers in metropolitan Atlanta at the close of the 2002 fiscal year, who collectively had about 190 vans and a total ridership of about 1,846 riders. Survey of 11,500 commuters who worked for employers who implemented TDM programs associated with the Atlanta TDM Framework found that these employees had the following weekly commute mode splits: 1.9% vanpool as compared to 9.6% carpool and 74.8% SOV.
• Vanpooling	Vanpooling in Washington State counties where the Commute Trip Reduction (CTR) Law affects employers with more than 100 full-time employees	Potential for vanpooling high – a survey found unrealized market potential for 11,000 new vanpools in the four Puget Sound counties (equivalent to 7% of total commuters in the region). In 2001, the 1,340 vanpools in the Puget Sound region removed about 9,380 vehicles from the roads each morning. 93% of the vanpools in the Puget Sound region go to CTR-affected worksites. Despite the apparent demand for vanpools, the vanpool mode share for the 523,000 CTR-affected employees in Washington State was only 1%. Kitsap County had the highest rate for vanpooling – 2.9% of commute trips to CTR-affected worksites in the county were by vanpools.
• Car-sharing program	*City CarShare* program in San-Francisco Bay area	City CarShare has 1,800 members (about 0.25% of San Francisco's population) and an average of 2,350 reservations per month. Program resulted in trip suppression by members, in large part because 30% of members sold one or more of their cars and two-thirds opted not to buy a car. Average daily VMT on weekdays for members, which was 13.10 miles in March 2003, declined by 0.9 miles during the two-year evaluation period. By contrast, average daily (weekday) VMT for a control group of non-members increased by 6.37 miles to 28.3 miles. Because of smaller cars and carpooling by members, the mode- and engine-size adjusted VMT (an index of travel consumption which accounts for occupancy level and engine size of vehicle) declined by an average of 81% for members during the two-year evaluation period, while it increased by an average of 154% for non-members. During the same time period, the average daily (weekday) transportation-related carbon dioxide emissions for members fell by an estimated 0.76 lbs in comparison to a daily increase of 0.25 lbs for non-members.
• U-Pass	Compulsory, low-cost transit pass for university students in Vancouver and Burnaby, BC	Bus trips to the two universities increased by 40-50%. SOV trips fell by about 20%. Following the introduction of the U-Pass in September 2003, transit mode share increased significantly from 26.2% in Fall 2002 to 38.5% in Fall 2003.

• U-Pass	U-Passes at the University of Victoria (Victoria, BC); the University of Western Ontario Bus Pass and Fanshawe College (London, ON); and Saint Mary's University (Halifax, NS)	Following the launch of University of Victoria's U-Pass in 1999 (18,000 U-Passes), post-secondary transit ridership rose from 13% of Victoria's transit ridership in 1997-1998 to 24% in 1999-2000. For student travel to the university, transit mode share increased steadily from 31% in 1988 to 44% in 2000, 47% in 2001 and 51% in 2003. At the same time, mode share for car drivers dropped from 20% to 19%, car passengers dropped from 22% to 13%, and pedestrians dropped from 20% to 13%. Mode shares for overall travel to campus by staff and students changed between 1996 and 2000: (1) car driver share dropped from 57.6% to 54.4%; (2) car passenger share dropped from15.7% to 11.0%, and (3) transit share increased from 11.1% to 17.8%. Additionally, the number of parking permits sold by the university in the fall of 2000 dropped by 12% from the previous year. Following the launch of the University of Western Ontario Bus Pass in 1998 and the Fanshawe College Bus Pass in 1999 (over 35,000 U-Passes), campus transit ridership increased by 50% in the first year and provided the impetus for London Transit to increase its service hours by 5,600 in the first year. Bus Pass contributed to an overall 40% increase in London Transit's system-wide ridership between 1997 and 2003. Number of parking permits issued by Western continue to sell out every year, but an increase in undergraduate students (from 18,000 in 1998 to 24,000 in 2003) has led to a drop in the number of students per parking space. Following the launch of Saint Mary's University U-Pass in 2003 (6,000 U-passes), the average number of transit trips taken per month by a Saint Mary's student increased from 7-8 a month to 14, representing an increase of 50,000 monthly transit trips by Saint Mary's student population.
• Discounted employee transit fares	*Metrochek*, a farecard voucher provided as a tax-free employee benefit in the Washington, D.C. area; a federal executive order requires all federal agencies make the full ($100 tax-free maximum) Metrochek benefit available to all federal employees in the region	The 138 large (100 or more employees) private companies in the Washington, D.C. area offering Metrochek benefits to their employees accounted for a reduction of 27,221 daily vehicle trips and 421,926 daily VMT (between 7/99 and 6/02).
• Discounted employee transit fares	*Wageworks* and *Commuter Check*, two US companies that assist other firms in providing commuter (and other benefits) programs to employees through vouchers, transit passes or debit-style cards	Wageworks reported a 15% increase in ridership by a major bank employer. Commuter Check reported an average ridership increase of 16.4%. Also, a survey on the impact of TransitChek, a similar commuter benefit program in metropolitan New York, found that 14% of respondents did not use mass transit prior to receiving TransitCheks.
• Voluntary travel behaviour change programs	Adelaide, South Perth and Brisbane, Australia	Participating households experienced a reduction in VKT by 10-20% and an increase in public transit trips by 20-30%. Results of these targeted marketing programs, when translated to the community as a whole, could mean a total VKT reduction of about 11%.
• Location Efficient Mortgages (LEM)	Fannie Mae and Institute for Location Efficiency (ILE) sponsored LEM pilot programs in Seattle, Chicago, the San Francisco Bay area and Los Angeles County	In a survey of 21 out of 27 participants in Chicago's LEM program that was carried out in 2001, one year after the start of the program, survey respondents indicated that their driving had decreased and transit use was increasing. However, the desirability for lenders to participate in LEM programs is uncertain. Studies carried out in 2001 and 2002 indicated that there was no reduction in mortgage defaults in more accessible locations and LEM savings were not significant enough to affect the propensity to default.
• Walking school bus	Various locations and Hertfordshire, UK	Good uptake potential for walking school bus programs – such programs found in many international locations, from being part of a safety program in Chicago to the *TravelSmart* program in Australia. A 2001 UK survey, found that walking school buses were the most common initiative in school-based TDM programs – 50 of 120 school-based TDM programs had implemented one or more walking buses and 31 were planning to do so. Rapid increase in walking buses in Hertfordshire County, from the first walking school bus in the UK in 1998 to 68 such buses in 41 schools by 2002; however, there was a rapid decline to 26 walking school buses in 22 schools in 2003. Program succeeded in reducing congestion around schools – an estimated 62% of 107 participating children used to travel to school by car (school surveys showed a range from 31-100% of participants previously were auto passengers). However, maintenance of walking school bus programs was hampered by lack of volunteers and program coordinators.

DISINCENTIVE POLICIES AND MEASURES		
TDM Strategy	**Case Study/Source**	**Effect of Policy/Measure**
• Parking component of employer-based TDM programs	Medium-sized employers in Washington and California	Parking scarcity and parking charges identified as an important factor in low SOV rate for company employees in almost 60% of the cases.
• Institutional measures for parking management	City of Vancouver, BC	Zoning bylaws influence parking supply. City of Vancouver has propriety and commercial interest in a parking corporation that influences city parking, i.e. by setting time limits on metered parking to discourage commuter parking.
• Area congestion pricing	Singapore	Reduced peak hour traffic by 15%.
• Area congestion pricing	Trondheim, Norway	Reduced peak hour traffic by 10%.
• Area congestion pricing	London, England	Reduced congestion by 30%, journey times by 14% and vehicles entering into the charging zone during the toll operating hours by 16%.
• Mandated versus voluntary employee trip reduction programs	Medium-sized employers in Washington and California and employers in Chicago area	As noted above under incentive measures, both mandated-initiates and voluntary TDM programs can lower SOV mode splits.

SUPPLY SIDE, TRANSIT-SUPPORTIVE POLICIES AND MEASURES		
TDM Strategy	**Case Study/Source**	**Effect of Policy/Measure**
• Personalized Demand Responsive Transit (PDRT)	San Francisco Bay area, CA	Focus group and telephone surveys revealed that more than 10% of respondents were "very likely" to use PDRT in low density, suburban areas.
• Private shuttle service	Shuttle service for underserved areas/times and worksites, operated by Transportation Management Associations (TMA) and individual employers in Atlanta, GA	One TMA shuttle service has an average monthly ridership of 5,550 people, while two other TMAs operate holiday and mid-day shuttles that respectively had 959 and 5,475 boardings in December 2001. In 2002, 15 employer-sponsored shuttles were reported – 12 were operating as feeder shuttles to transport individuals from transit stations to the worksite and 3 were shuttles that transported individuals from the worksite to local shopping malls during the midday lunch hour (no travel impacts reported).
• Bus rapid transit (BRT)	26 case studies of BRT located in the United States, Canada, Australia, Europe and South America	TRB case studies showed that BRT can attract and retain new riders. Daily ridership on Ottawa's Transitway system exceeds 150,000 per day and carries more people in the peak-hour peak direction than most LRT segments in North America. Other reported ridership increases include: - Houston (Express HOV/Busway) – 18-30% of riders were new riders, up to 72% were diverted from automobiles - Los Angeles (Metro Bus on Wilshire-Whittier and Ventura Blvds.) – 26-33% gain in riders, 1/3 of which were new riders, 1/3 were diverted from other corridors and 1/3 were riders who made the trip more often - Adelaide (Guided Busway System) – 76% gain in ridership at a time when overall system ridership declined by 28% - Brisbane (South East Busway) – 42% gain in riders during the first six months of service and a reduction of 375,000 automobile trips annually - Leeds (Superbus Guided Bus System) – 50% gain in ridership during first 2.5 years - Pittsburgh (East Busway) – 38% gain in ridership, from 21,000 in 1983 to 29,000 in recent years Additional BRT benefits are travel time savings: Busways on dedicated rights-of-way generally save 2-3 minutes per mile compared with pre-BRT conditions, including time for stops. Bus lanes on arterial streets typically save 1-2 minutes per mile. Greatest time savings are on previously congested routes, e.g. Pittsburgh reported travel time savings of up to 5 minutes per mile during peak hours. Travel time savings from BRT operations in the North American, Australian and European case studies ranged from a 20-44% reduction. The report noted that travel time savings of 23% (1.5 min/mile) and

		because the buses operate in mixed traffic.
• Bus rapid transit (BRT)	#98 B-Line bus route between Richmond city centre, the airport and downtown Vancouver	The #98 B-Line bus route between Richmond city centre, the airport and downtown Vancouver includes the first segregated median busway in Canada along a portion of the route (2.5 km of segregated median bus lane along a total route of 15.8 km). Using ITS technology and a dedicated fleet of 28 low floor articulated buses, the 98 B-Line provide frequent service throughout the day, seven days a week. The benefits of the dedicated busway and ITS technology include: - Travel time savings – Scheduled travel decreased by 20%, dropping from 100 to 84 minutes, due to infrastructure improvements (i.e. fewer stops, bus lanes, queue jump lanes); without the ITS technology and bus priority measures, the 98 B-Line fleet would require five additional vehicles to provide the same level of service. - Travel reliability - Variability in travel times has decreased significantly due to the Transit Signal Priority (TSP) and Automated Vehicle Location (AVL) systems; TSP allows for more efficient scheduling and results in a reduction in fleet requirement of about one vehicle. - Induced a 23% mode shift from auto to transit on the corridor, resulting in a net increase of 1.2 million passengers per year; the net increase of about 4,000 passengers per day represents a 29% growth on the corridor from 2001 to 2002.
• Hybrid buses	Diesel-electric hybrid buses which reduce GHG emissions (though not strictly a TDM measure) in Seattle and New York City	First of 235 hybrid buses were delivered in Seattle in May 2004; new buses will comprise 15% of King Country Metro Transit's 1,300-vehicle fleet. The Seattle hybrid buses in Seattle use General Motor's Allison Electric Drive system, which GM asserts reduces particulate emissions (hydrocarbon and carbon monoxide emissions) by 90% and nitrogen oxides by up to 60%. The technology can also increase the fuel economy of the buses by up to 60%. New York City Transit (NYCT) began pilot project with 10 diesel-electric buses in 1998, with all 10 buses entering into revenue service by mid-2000. A 1999-2001 evaluation that compared performance data from hybrid buses and conventional diesel transit buses operating in the Commercial Business District, found that hybrid buses emissions were lower by 97% for carbon monoxide, 36% for nitrogen oxides, 43% for hydrocarbons, 50% for particulate matter and 19% for carbon dioxide. Additionally, the in-service fuel economy for hybrid buses was 10% higher than for conventional diesel buses. In 2002-2003, NYTC placed orders for an additional 325 diesel-electric hybrid buses to add to its fleet of 4,489 buses.
• Schedule-dependent transit priority system	Portland, OR	Reduced transit travel time by 8-11% during PM peak hour. Improved performance and reliability by reducing travel time variability during AM and PM peak hours by up to 19%.
• Bus-actuated traffic signals	York, England	Reduced bus journey time by 13% during rush hour.
• ITS – traffic signal coordination	North Carolina and other parts of the United States	Typically travel time reductions of 8-18% and stopped delay reductions of 20-45% were achieved. Fuel consumption savings of 5.5-13% and reduced emissions in the range of 10-15% have been achieved.
• ITS – transit signal priority measures	England and France Toronto	European experience shows transit travel time reductions of 6-42% with only increases of 0.3-2.5% in auto time. In Toronto, transit delay reductions of 15-49% have been realised at signals with transit priority.
• ITS – ramp meters	United States	In most applications, travel time reductions have been demonstrated for both through traffic and entering traffic. Travel time reductions range from 7-45%.
• ITS – automatic vehicle location (AVL)	Canada United States	In some systems, AVL can be used to provide transit system passengers with real-time travel information. Benefits of AVL also include a 4-23% improvement in schedule adherence and a 2-5% reduction in the base bus fleet.
• ITS – electronic toll collection	United States	Electronic toll collection allows toll operators to "collect" toll payment automatically from moving vehicles. The benefits include more than doubling the capacity of each toll booth, thus reducing the number of booths required, and up to a 85% reduction in toll plaza delay. The reduced delay provides for significant savings in fuel consumption and reductions in emissions at toll plazas by 45-83%.
• ITS – electronic fare collection	Canada United States	Electronic fare collection has been credited with reduced fare evasion, operator savings, increased ridership and increased revenue. Precise quantification of these various benefits is not documented in the studies reviewed.
• ITS – real time traveller information	North Carolina and other parts of the United States	Real time information on transportation network conditions has led to up to 36% of travellers changing their route or time of travel and 3-4% changing their mode of travel, including a 1% increase in transit ridership.

• System of managed lanes—HOV/HOT lanes supported by park-and-ride/park-and-pool, transit centres and express bus services	Houston, TX	Encouraged change in mode of travel. Surveys of HOV lane users show that 36-45% of carpoolers and 38-46% of bus riders used to be solo drivers.
• HOT lanes with charge for HOV-2	Katy and Northwest Freeways, Houston, TX	Low level of registration and usage.
• HOT lanes with differential rates for SOV, HOV-2 and HOV-3+	91 Express Lanes, Orange County, CA	No evidence to show that road pricing on the express lanes either encouraged or discouraged carpooling.
• Traffic calming	Analysis of 10 case studies of traffic calming in UK	Of 10 case studies, two town centres experienced an increase in vehicle traffic, one experienced no change and the others experienced a proportional decrease ranging from 4-50%, with an average decrease of 0.3% and median decrease of 12.2%.
• Road restrictions	Car free residential areas (CFRA) in the London borough of Camden and the Vauban residential area in Freiburg, Germany	Study noted that "results are difficult to measure," though, significantly, car use in Friedburg centre decreased from 43% to 34%, from 1976 to 2000, in spite of a 46% increase in car ownership.
• Bicycle facilities	*Cycling Network Program* (CNP), a 50/50 cost shared program between the BC provincial government and local governments that operated between 1995 and 2001/02 and funded the building of cycling infrastructure for commuting (not recreational) purposes	Program funding resulted in a 93% increase of cycling trips on the 121 funded projects for which before and after bicycle count data are available (though the before figures may not be consistently based on actual counts). Individually on the CNP-funded facilities, there was an average increase in bicycle trips of over 200% during the commute time period. However, the actual number of bicycle trips is relatively small. For these 121 funded bicycle commuting infrastructure projects, the average number of bike trips was 127 before the infrastructure improvement and 245 afterwards, while the median number of trips was 50 trips before and 115 afterwards.
• Bicycle facilities	European Commission's *Urban Transport Benchmarking Initiative, Cycling Working Group* examination of cycling in the cities of Bescia, Copenhagen, Lyon and Oxford	Copenhagen had a 25% bicycle mode share for daily one-way journeys – the highest of the four European cities examined by the benchmarking team. Bicycle mode share for all trips under 5 km (excluding by walking) in Copenhagen was about 30%, just slightly higher than in Oxford. Correspondingly, Copenhagen had the highest spending on bicycle infrastructure and the greatest proportion of cycling space in proportion to the total road network length – 45% in Copenhagen as opposed about 5% in the other three cities.

Among the key observations, it should be noted that:

- Parking price and supply appear to be the most important determinants of effective TDM programs,
- Both mandated and voluntary employer-based programs demonstrate high potential,
- Area and congestion pricing has high impact,
- Transit priority affects travel times in ways that increase the relative competitiveness of transit, and
- Significant impacts of HOV lanes on mode choice have yet to be demonstrated.

Literature Review of Post Implementation Impacts

The literature review was based primarily on:

- reports on modelling and behavioural research,
- studies of service elasticities,
- comparisons of pre-project and post-project estimates and results,
- articles reporting on the benchmarking of earlier transit investments in terms of ridership, costs, revenues, etc.,
- contextual materials that either support further investment in rail transit or BRT and those that are opposed to such investments (some of which are essentially polemics), as well as general works that address urban planning and transportation issues, and
- detailed case studies of general trends, as well as specific corridor impacts related to rapid transit expansion in Toronto and Montreal.

In general terms, the literature review and the specific case studies enforce, and frequently supplement well understood relationships, many of which are already incorporated in most transportation modelling attempts.

Some of the more important findings are summarized below.

1. The range of factors that influence mode choice includes auto ownership/access, various socio-demographic and locational factors and, of course, the competitiveness of the transit service relative to travel by automobile for trips to various destinations, considering travel time, reliability, convenience, comfort, and costs.
2. Auto ownership and access to an auto is undoubtedly the single most important factor that explains variations in transit use.
3. Transit service (measured in terms of frequency, hours of service and door-to-door travel times) is a major factor in determining the competitive position of transit vis-à-vis the auto. Travel times typically involve walking to a transit stop, waiting for the bus or train, in-vehicle time, transfer time (if more than one vehicle is used) and walking time to the destination.
4. Thus mode choice decisions are very sensitive to:
    - transit access and land use/locational factors,

- total door-to-door travel time including walking and waiting times,
- a variety of "cost" factors, and
- network effects (integration and access to multiple destinations).

5. Although it is typically assumed that changes in transit service, such as new rapid transit lines, will result in behavioural changes, some of the literature suggests that once various locational and socio-demographic factors such as auto ownership are accounted for, variations in transit service levels do not appear to explain a substantial portion of the observed variations in transit mode splits for travel to areas outside the downtown. In other words, longer term locational and car ownership decisions that are influenced by the availability of rapid transit service have more influence on future transit market shares than do short-term modal shift decisions.

6. Observations from the literature regarding elasticities (which measure the sensitivity of travelers to changes in various transit service and cost factors) suggest:

   - bus frequency elasticities from +0.3 to +1 with a typical value being +0.5,
   - the elasticity of 'transit captives' persons is lower than for choice riders,
   - peak trips, which are generally non-discretionary, are less sensitive to changes in service than more discretionary off-peak trips,
   - the highest bus frequency elasticities (ranging from +0.8 to +1.14) were associated with carefully planned suburban bus expansion programs that included increased service hours,
   - the highest commuter rail service elasticities apply to conditions where the original headways are greater than 50 minutes, and
   - there is strong support for the view that that *service elasticity is "almost always greater" than fare elasticity* for changes of similar values when service levels are low and especially for new service areas and express services.

7. Although there are numerous examples in the literature related to modal shifts,

   - in many cases, actual ridership for new heavy and light rail lines was substantially lower than forecasted, and

- the level of ridership and ridership growth reported for LRT by 1995, at least, was unlikely to have made a measurable contribution GHG reductions.

8. In general, the literature review and contacts with transit agencies provided relatively little data that directly addresses the modal shift issue or estimates of the numbers of cars taken off the road for a given increase in transit ridership. Notable exceptions include excellent survey data collected as part of the monitoring of recent Commuter Rail and arterial BRT projects in Vancouver and BRT projects in Los Angeles.
9. More recent experience with arterial BRT and LRT projects suggests that 15-20 percent of total BRT and LRT project riders are former auto drivers whereas between 40 and 50 percent of BRT riders are new, as opposed to diversions from other transit services. These figures also suggest that 30 to 60 percent of net new riders attracted to new BRT and LRT lines in the first 1 to 3 years of operation are former auto drivers and/or passengers.
10. Express buses operating on freeways, particularly in reserved or HOV lanes, serving downtown destinations, would offer travel time savings and ridership increases comparable to those associated with commuter rail (up to 70 percent new riders based on data for the West Coast Express) and could be expected to achieve auto driver mode shifts of up to 80 percent.
11. The literature and the analysis of data for the West Coast Express in Vancouver and GO Transit in the Greater Toronto Area, suggest that commuter rail attracts the highest numbers of new transit riders and the highest proportion of former auto users.
12. In general terms, urban forms that result in highly concentrated travel patterns can obviously be served by transit more cost effectively than urban forms that encourage much more dispersed patterns of travel.
13. There is strong evidence that forecasts tend to understate investment costs and overstate transit ridership and diversions from single occupancy automobiles.
14. The literature indicates that parking price and supply are major determinants of mode choice and that achieving transit targets is easiest for travel to CBDs. In this regard, general trends involving decentralization of residents and jobs are major barriers to achieving higher transit mode splits and reduced use of single occupancy vehicles. In other words, trends in land use and urban growth

management are essentially contrary to the goal of reduced VKT and GHG emissions.

15. Because investment costs are highly site specific, information and data related to transit costs obtained from a review of a variety of documents, in the end, is unlikely to be particularly useful in assessing cost effectiveness of transit investment and TDM on reducing GHG emissions.

16. The emphasis on operating cost recovery provides a false picture of the real public cost of transit and relative cost effectiveness of alternative technologies. For Canadian cities, full cost accounting suggests average subsidies of up to $3.50 per trip as typical of the ten cities being considered in this study. By and large, proposed transit improvements and 'new starts' typically exceed such averages by a significant amount and, in some cases, by an order of magnitude.

17. Much of the literature on the relative costs of alternative transit technologies sets out to prove *à priori* views and lack objectivity. It certainly appears that except for high capacity travel to the CBD, the cost effectiveness of rail transit in achieving modal shifts from auto to transit appears to be lower than for bus-based transit solutions such as BRT. The effectiveness of LRT and BRT in supporting transit oriented development objectives and longer term modal shifts is not well understood and requires further research.

In summary, the literature review suggests that:

- Of the wide range of factors that influence mode choice, auto ownership is the single most important,
- Of the various factors considered, Level of Service (LOS) accounts for 6 to 23 percent of the variation in observed mode choice,
- Access and wait times (both of which are more onerous than in-vehicle times) are critical components of LOS,
- A *network* of transit services offering convenience and competitive door-to-door travel times to a wide variety of destinations are essential elements of improved transit competitiveness,
- Cities with high LOS tend to have lower auto ownership, and
- Based on limited evidence, the proportion of new riders diverted from autos for new surface bus services appears lower than for rapid transit.

Integrated Analysis of Findings

The modelling and research-based analysis for the study cities featured different time horizons (ranging from 2010 to 2026) as defined by the municipal or regional plans. The Kyoto targets established for Canada include a 6 percent reduction in GHG emissions relative to 1990 levels by 2008 to 2012, whereas the National Vision for Urban Transit established targets for transit ridership for the 2020 time horizon. In order to compare results with one another and with the Kyoto and Vision 2020 targets, therefore, results were extrapolated or interpolated to 2010 and 2020.

Since the background technical analysis provides more detail for individual municipalities than can be effectively presented in the final report, only two examples are illustrated.

Figure 3 shows the potential range of 2020 annual transit rides per capita for each municipality along with the 2001 TAC Urban Transportation Indicator (UTI) values. The range represents the difference between the BAU and High Transit and High TDM scenarios. The Vision 2020 targets for medium (0.2-0.9M residents: 30-100 rides/capita) and large (>0.9M residents: 100-250 rides/capita) cities are also highlighted. (Note that results for York and Toronto have been combined and expanded to cover the entire GTA.) In most cases, the 2020 BAU scenario would result in a drop or no change in the annual transit rides per capita compared to 2001 levels. In general, the medium-sized cities (Halifax, Victoria, Winnipeg and Edmonton) fall within the Vision 2020 target range, while larger cities are either below or at the lower end of the target range.

Figure 3 2020 Annual Transit Rides per Capita

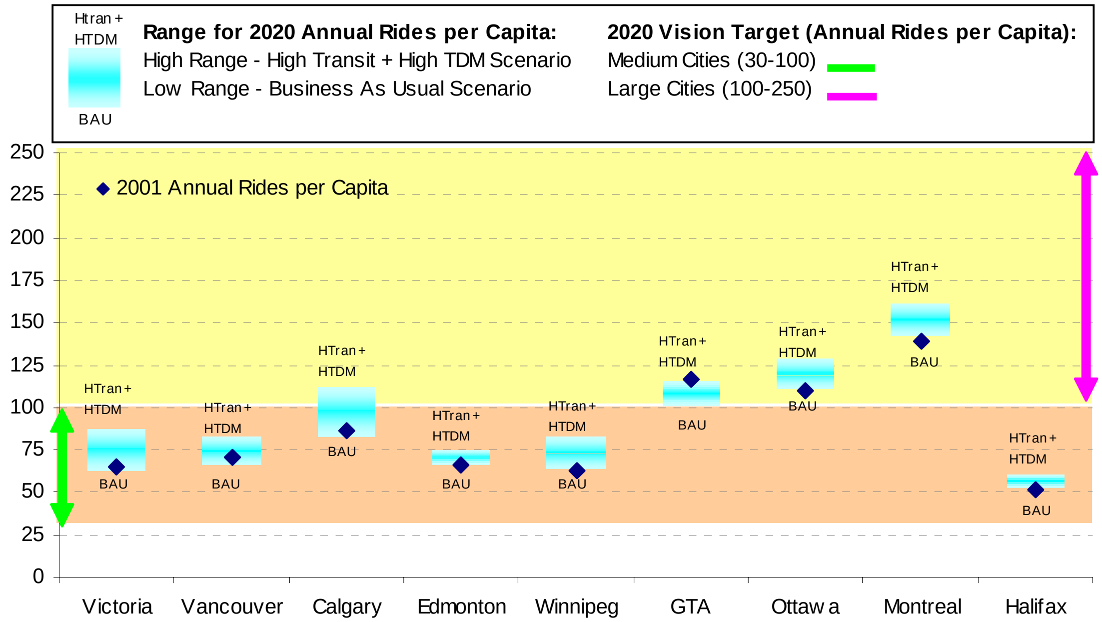


Figure 4 shows the 2020 annual GHG emissions per capita and the 2001 TAC UTI values. Note that these figures represent direct GHG emissions from automobiles and light trucks and are based on gasoline fuel sales. In general, BAU would result in higher GHG emissions per capita than 2001 levels. Heavy investment in transit and TDM could result in notably lower emission levels on a per capita basis.

To put the GHG results in the context of the Kyoto target, the total annual 2010 GHG estimates for each city are compared to 1990 levels as shown in Table 5. The 1990 GHG estimates by city have been calculated based on information from the TAC UTI report. By 2010, BAU GHG emissions for the study cities are estimated to be 30 percent higher than 1990 levels. Implementation of high transit investment and high TDM could reduce the 2010 GHG emissions to 24 percent above 1990 levels. Note that the effectiveness of high transit and high TDM varies significantly as some cities have identified more aggressive transit and TDM strategies than others. While investment in transit and TDM could have a significant impact on GHG emissions, *none of the cities approach the Kyoto target of a 6 percent reduction relative to 1990 levels*.

Figure 4 2020 Annual GHG Emissions per Capita (Tonnes)

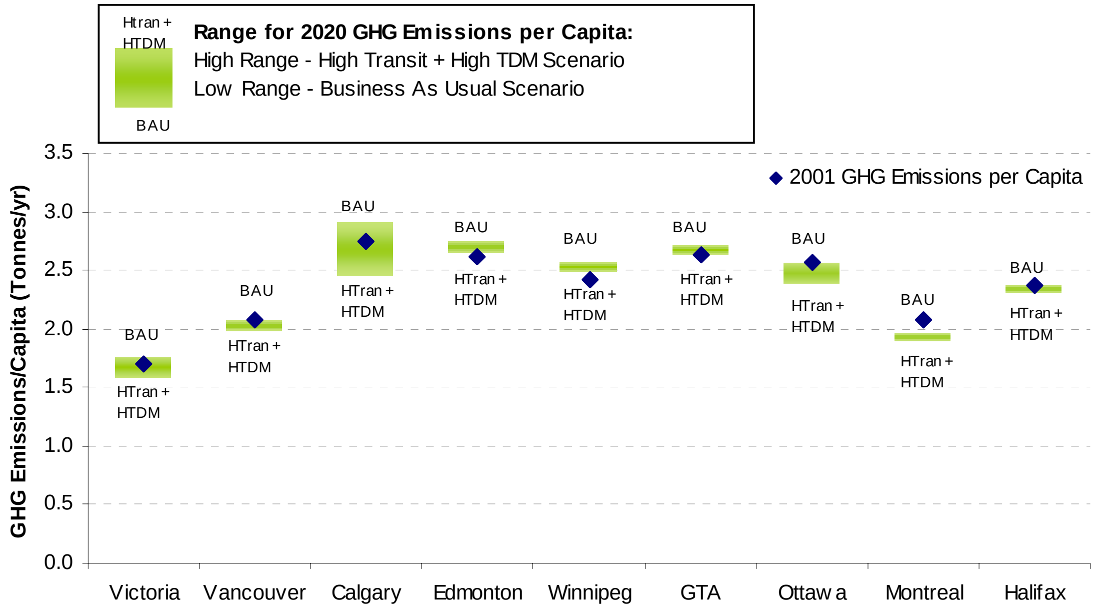


Table 5 Annual GHG Emissions by Municipality (2010 vs 1990)

Cities	Annual GHG Emissions (kt)				% Chg from 1990	
	Year 2001	Year 2010		1990 Estimate		
		BAU	High Transit + High TDM		BAU	High Transit + High TDM
Victoria	500	568	507	438	30%	16%
Vancouver	3,765	4,282	4,053	3,294	30%	23%
Calgary	2,417	2,896	2,443	2,115	37%	16%
Edmonton	1,739	1,986	1,921	1,521	31%	26%
Winnipeg	1,475	1,673	1,620	1,290	30%	26%
GTA	11,435	13,733	13,336	10,004	37%	33%
Ottawa	2,375	2,848	2,663	2,078	37%	28%
Montreal	6,579	6,569	6,375	5,756	14%	11%
Halifax	648	720	698	567	27%	23%
Total	30,930	35,280	33,620	27,060	30.4%	24%

The 9 municipalities (combining York Region and Toronto within the GTA) have a total entire urbanized area (EUA) population of 12.9 million, about 76 percent of urban CMA population in Canada. The TAC UTI report provides a basis for extrapolation to include other large centres on the basis of annual transit ridership and GHG estimates for 22 cities across Canada. The EUA population for these cities represents 82 percent of the urban CMA population in Canada. Table 6 provides a summary of the 2001 population, annual transit ridership and annual GHG emissions for the 22 cities.

Using statistical techniques such as regression to account for differences in population growth rates and other factors, emission estimates for all 22 cities were combined to determine the total annual GHG emissions by scenario as shown in Figure 5. For the High Transit and High TDM scenario, it is estimated that a GHG reduction of 2 Mt could be achieved.

Table 6 2001 EUA Population, Transit Riders and GHG Emissions

Cities	Year 2001				
	EUA Population	Annual Transit Ridership (000's)	GHG Emission (kt)	Annual Transit Rides/Capita	Annual GHG/Capita (t)
Victoria	294,000	19,000	500	65	1.70
Vancouver	1,806,000	129,000	3,765	71	2.08
Calgary	879,000	76,000	2,417	87	2.75
Edmonton	666,000	44,000	1,739	66	2.61
Winnipeg	610,000	39,000	1,475	63	2.42
GTA[1]	4,346,000	507,000	11,435	117	2.63
Ottawa	927,000	102,000	2,375	110	2.56
Montreal	3,163,000	439,000	6,579	139	2.08
Halifax	273,000	14,000	648	52	2.37
Quebec	636,000	40,000	1,428	62	2.25
London	335,000	16,000	908	49	2.71
Kitchener	387,000	11,000	961	28	2.48
Windsor	226,000	5,000	616	24	2.73
Oshawa	226,000	10,000	666	45	2.94
Saskatoon	193,000	8,000	483	41	2.50
Regina	172,000	6,000	436	36	2.54
St. John's	122,000	3,000	313	22	2.56
Sudbury	82,000	4,000	283	49	3.44
Sherbrooke	139,000	6,000	332	45	2.38
Trois-Rivieres	122,000	3,000	291	22	2.38
Saint John	89,000	2,000	293	27	3.31
Thunder Bay	109,000	3,000	304	27	2.79
Study Cities	12,964,000	1,369,000	30,900	106	2.39
Other Cities	2,838,000	117,000	7,300	41	2.58
Total	15,802,000	1,486,000	38,200	94	2.42

1. Results for York and Toronto have been combined and expanded to cover the entire GTA.

Figure 5 also includes a hypothetical scenario “High Transit + Aggressive High TDM”. This scenario is based on extrapolating the results from Victoria and Calgary to all other cities. Both of these cities included significant auto pricing in their High TDM packages. Note that this estimate is intended for illustrative purposes only. However, it does demonstrate that under an aggressive auto-pricing regime, 2010 GHG emissions could be lowered to around 2001 levels (still approximately 13 percent above 1990 levels).

Finally, Figure 6 illustrates the percentage of GHG emissions relative to1990 levels. The projected 2010 GHG estimates for the BAU scenario would be approximately 30 percent higher than in 1990. The effect of low transit investments on GHG emissions would be negligible. With high transit investments, the projected GHG emissions would likely be 28 percent higher than 1990 levels, depending on the level of transit investments. Under High Transit and High TDM scenario, the 2010 GHG emissions would be 24 percent higher than 1990. The scenario with aggressive auto pricing and high transit investments appear to be the most promising combination which could reduce GHG emissions to 2001 levels.

Figure 5 2010 GHG Emissions (85 percent of urban CMA population)

	2001 Base	2010 BAU	Low Transit	Low Transit + Low TDM	Low Transit + High TDM	High Transit	High Transit + Low TDM	High Transit + High TDM	High Transit + Aggressive High TDM
	38.2	43.1	42.9	42.6	41.7	42.3	42.0	41.1	37.3
% chg from 2001		13%	12%	11%	9%	11%	10%	7%	-2%
Reduction from BAU (Mt)			-0.1	-0.5	-1.4	-0.7	-1.1	-2.0	-5.7

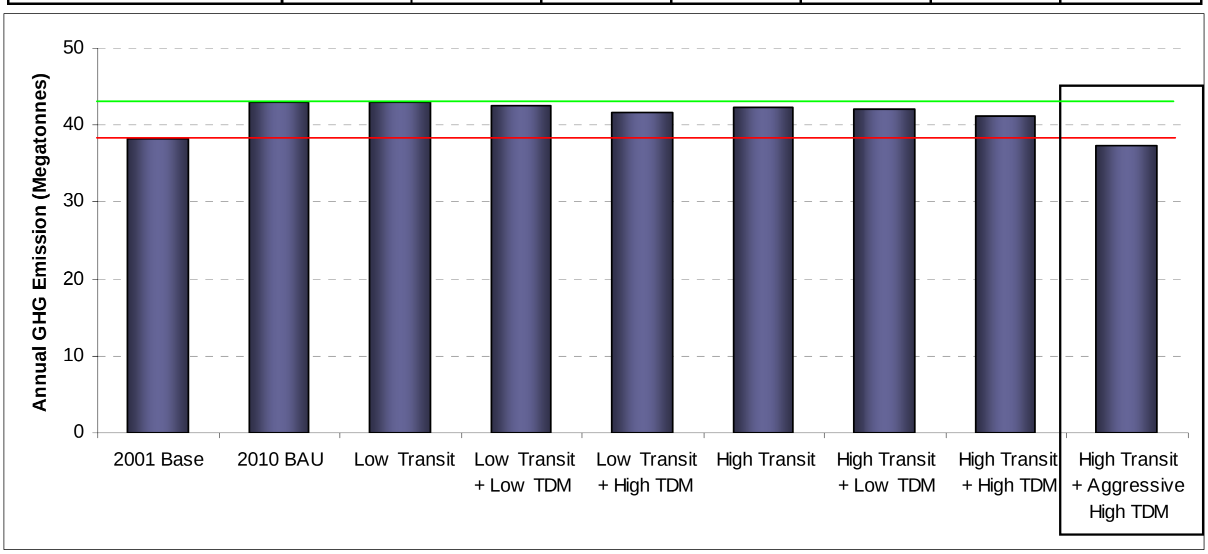
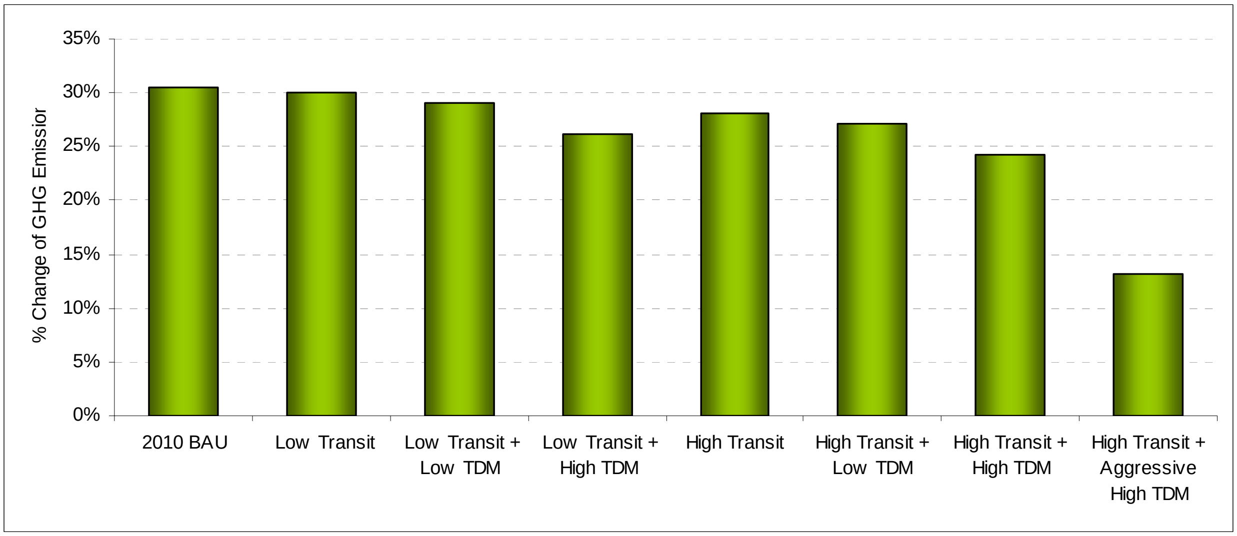


Figure 6 Percent Change of 2010 GHG Emissions (Relative to 1990)


35%
30%
25%
20%
15%
10%
5%
0%
% Change of GHG Emission
2010 BAU
Low Transit
Low Transit + Low TDM
Low Transit + High TDM
High Transit
High Transit + Low TDM
High Transit + High TDM
High Transit + Aggressive High TDM

Conclusions

Although, given the fairly broad scope of the study and analyses, there are a number of important lessons learned regarding the efficacy of various approaches to transportation planning intended to reduce automobile dependence and associated greenhouse gas emissions, there are probably two main conclusions related to the principal study objectives.

First, recognizing that the TCC Table estimates of potential GHG reductions from urban transportation represent a first attempt based on information, data, and literature available at the time they were made, the analysis of this study suggests those estimates may be optimistic. Depending upon the range of policy instruments applied, the TCC Table estimated reductions by 2010 ranged from 3.7 to 10.1 MT of GHG (compared to the 'business as usual' or BAU case). This analysis suggests that, based on plans and information provided by the study municipalities, the likely range of GHG reductions relative to the BAU case falls between 0.1 and 2.0 MT for Canadian CMAs.

Second, this study suggests that capital investment in expanded transit systems appears to have relatively little impact on GHG reductions on its own unless accompanied by highly integrated and effective TDM measures. 'Effective' TDM is characterized by area or region-wide measures that do not disadvantage specific areas identified for intensification and redevelopment. Effective TDM may also require the gradual introduction of road pricing,

- First, as a means of improving the efficiency with which existing and planned transportation systems (including roads) are used, and
- Second, as a means of eliminating distortions in modal choices resulting from existing pricing mechanisms

In other words, achieving transit ridership goals and associated emission reductions requires appropriate TDM policies (probably eventually including road pricing) and real land use initiatives. At the same time, if appropriate TDM policies are implemented, considerable capital investment in expanded transit services will be required to accommodate the anticipated modal shifts.

The following points summarize some of the other more important conclusions of the study.

1. Except in a few cases, proposals for new investment in transit are rarely supported by analyses or comparisons of the incremental costs and benefits relative to the base or business as usual case. The typical emphasis on proposed projects and plans is placed on the virtues of the proposal in absolute terms or relative to alternatives that may be prematurely dismissed or not analyzed in the same level of detail.
2. There is considerable variation in the level of sophistication in transport modelling, as well as in data collection efforts across the ten study cities
3. Plans and proposals based on a particular choice of technology sometimes understate the performance capabilities of alternative technologies by assuming different design and operating characteristics.
4. With some exceptions, there is little noticeable evidence of actual policies adopted to ensure aggressive TDM, even though most plans assume that such measures as both the supply and pricing of parking and even road pricing are to be pursued.
5. The literature review and benchmarking material suggest that achieving transit ridership goals is most successful where transportation and land use polices are actually well integrated and embedded in zoning by-laws.
6. The literature review also shows that in other cases,
   - Many proposed transit projects have not achieved forecasted ridership levels, and
   - Estimated costs have been exceeded by substantial amounts.
7. High investment in transit expansion appears to show little increase in transit ridership, *unless accompanied by aggressive TDM measures*. However, it also appears that in the absence of high transit investment, low transit investment scenarios would not be practical in combination with high TDM measures simply because the diversions of trips to transit could not be effectively accommodated by minimal improvements in transit service.
8. Aggressive TDM measures are essentially intended to achieve more efficient use of the available transportation system and to eliminate effects modal choice and general travel behaviour that may be attributable to distortions in the pricing of road use and parking.

9. Based on extrapolation of the 10 city results, the GHG reduction over the BAU is likely to be between 0.1 and 2.0 Mt for Canadian CMAs.
10. The main modelling results presented in this study suggest that both reductions in GHG emissions and the increases in transit ridership are less than indicated in the findings of the *Transportation Table on Climate Change* and the *Vision Study*, respectively

It should be emphasized that the main findings of this study are based on the methods of forecasting used in the study municipalities with little or no attempt to either modify or comment either on the validity of individual modelling procedures or their input assumptions.

Drawing on results presented in the previous section, Table 7 summarizes the comparison of the estimated 2020 transit ridership to the targets cited in the Vision Report. The modelling results also show that, on a regional basis, the effects of low transit investment on annual GHG emissions relative to the BAU case are negligible. High transit investment could reduce annual GHG emissions by approximately 2 percent relative to the BAU case. In terms of TDM measures, low TDM measures could further reduce annual GHG emissions by approximately 1 percent while an annual GHG emission reduction of approximately 3 percent could be achieved with high TDM measures. Therefore, a total of approximately 5 percent of annual GHG emissions could be achieved with the implementation of both high transit investment and high TDM measures.

Table 8 shows the summary of ridership and GHG study results for 2010. The combined effect of high transit investment and high TDM measures is to reduce annual GHG Emissions in 2010 for the study cities from 35.3 to 33.6 Mt when compared to the BAU case. As compared to 1990, these figures represent an increase of 24 percent for the High transit and High TDM scenario, well above the 6 percent targeted reduction.

For the estimates prepared in this study, the 2010 reduction is 1.7 Mt for the study cities, increasing to 2 Mt for 82 percent of urban CMA population, both assuming high transit investment and high TDM. A hypothetical scenario (High Transit, Aggressive High TDM) shows that approximately 5.7 Mt reduction could be achieved relative to BAU, which is 13 percent above the 1990 levels.

Table 7 Summary of Ridership and GHG Study Results (2020)

	2020 Population (1000s)	2020 Rides per capita			2020 Annual Riders % Change from 2001			2020 Transit Split to/from EUA			2020 kTonnes	
		BAU	High Transit + High TDM	*Vision*	BAU	High Transit + High TDM	*Vision*	BAU	High Transit + High TDM	*Vision*	BAU	High Transit + High TDM
Study Cities												
Victoria	360	62	88	30 -100	18%	66%	30-60%	8%	11%	5-15%	645	576
Vancouver	2,330	66	83	100 - 250	19%	51%	40-80%	11%	14%	10-25%	4,857	4,598
Calgary	1,190	83	112	100 - 250	29%	75%	40-80%	6%	8%	10-25%	3,456	2,915
Edmonton	830	66	75	30 100	24%	41%	30-60%	8%	9%	5-15%	2,273	2,198
Winnipeg	740	64	83	30 100	23%	60%	30-60%	7%	9%	5-15%	1,903	1,842
GTA	6,040	101	115	100 - 250	20%	37%	40-80%	13%	15%	10-25%	16,354	15,882
Ottawa	1,320	111	129	100 - 250	43%	67%	40-80%	14%	16%	10-25%	3,374	3,154
Montreal	3,350	143	161	100 - 250	9%	23%	40-80%	15%	17%	10-25%	6,546	6,353
Halifax	340	53	61	30 -100	25%	44%	30-60%	8%	9%	5-15%	800	776
Sub Totals	16,500										40,210	38,290
Other Cities	3,100	na	na	na							8,220	7,900
											GHG Reduction	-2,240

Table 8 Summary of Ridership and GHG Study Results (2010)

	2010 Population (1000s)	2010 Rides per capita			2010 kTonnes	
		BAU	High Transit + High TDM	*Vision*	BAU	High Transit + High TDM
Study Cities						
Victoria	330	64	90	30 -100	568	507
Vancouver	2,050	69	87	100 - 250	4,282	4,053
Calgary	1,020	85	115	100 - 250	2,896	2,443
Edmonton	740	66	75	30 100	1,986	1,921
Winnipeg	670	64	83	30 100	1,673	1,620
GTA	5,150	109	125	100 - 250	13,733	13,336
Ottawa	1,110	111	129	100 - 250	2,848	2,663
Montreal	3,250	141	159	100 - 250	6,569	6,375
Halifax	300	52	60	30 -100	720	698
Sub Totals	14,620				35,280	33,620
Other Cities	2,990	na	na	na	7,790	7,480
					GHG Reduction	-2,000

Without significant changes in modal use, of course, GHG reductions can be achieved through changes in the fleet of private automobiles and light trucks that result in higher average fuel efficiency. Given the replacement cycle for typical private vehicles, impacts by 2010 are likely to be relatively low, but could become significant over the longer term. Incentives to encourage the acquisition of such vehicles can thus also be considered within the context of both TDM measures and road pricing.

Recommendations

The conclusions and findings of this study derive primarily from information and data provided by the study municipalities, the application of transportation modelling to plans and proposals already formulated by these municipalities, and an extensive review of the literature supplemented by specific case studies.

Based on this material, the following five general recommendations are made.

Recommendation 1

Programs for the implementation of appropriate TDM measures and policies should form an integral component of most proposals for capital investment in new transit services. Appropriate measures refer to policies that:

- Do not disadvantage areas, in relative terms, within a specific region, designated for intensification and redevelopment,
- Do not encourage the emergence of unsustainable forms of land development such as sprawl, as well as policies that
- Are equitable with respect to different socio-economic and geographic constituencies.

Recommendation 2

Recognizing considerable political and community concern that is likely to be generated by the concept of road pricing, as well as various ramifications with respect to equity, it would prudent to explore now the full range of strengths and weaknesses associated with various road pricing alternatives. A comprehensive evaluation of road pricing should include:

- Detailed review of existing information technology hardware and software to determine the most promising methods of implementing vehicle use based pricing, including information collection, data management, billing, and payment processes,
- Research, authorized by the Minister of Finance, to determine the proportion of private vehicular ownership and use now subsidized through car allowances, free parking, and tax deductions,
- An analysis of potential net tax revenues that could be generated through:
  - Enforcement of current income tax regulations governing allowable deductions for the ownership and operation of private vehicles, and
  - A range of modifications or amendments to existing tax regulations,
- Examination of alternative provincial and federal, revenue neutral, sales and energy tax regimes that provide:
  - Incentives for the purchase of energy efficient automobiles and light trucks (with special emphasis on hybrid or alternative fuel vehicles), and
  - Disincentives for the purchase of fuel intensive vehicles.

Recommendation 3

In assessing alternative technologies, the complete range of realistic alternatives for meeting the transportation objectives of a new project should be included in the analysis. In this regard,

- All forecasts should estimate differential impacts among alternatives, including the base case,
- Key inputs (and assumptions) that influence impact estimation should be clearly stated,
- Monetary values should be expressed in constant dollars for the year in which the evaluation is carried out,
- Where 'point' estimates are made for target years, intermediate values should be interpolated to provide the complete stream of impacts, and
- All impacts should be discounted to the same year for purposes of comparison.

Recommendation 4

The federal government should take a leadership role in establishing a continuing research program to assist municipalities in assessing the impacts of alternative transportation investments, TDM policies, and land use instruments with respect to achieving more sustainable urban transportation and contributing to national commitments consistent with ratification of the Kyoto Protocol. The main elements of such a research program could include:

- Model development and application in the particular areas of GHG estimation,
- The assessment of TDM measures, and
- The impact of technology on modal choice with a view to better estimation of how bus-based and rail-based transit influences ridership and land development decisions.

Recommendation 5

Transport Canada should develop and maintain a web site that provides up-to-date data and information particularly relevant to project and transportation plan evaluation, including:

- TDM applications,
- Unit costs for various components of transit infrastructure based on actual implementation,
- A catalogue of transit vehicles, dimensions, and performance characteristics currently in use or recently acquired, as well as unit costs for transit vehicle acquisitions and bid prices
- Comparisons of proposed and actual costs of transit projects, and
- Comparisons of predicted and actual ridership