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Costs of Road Congestion in the Greater Toronto and Hamilton Area: Impact and Cost Benefit Analysis of the Metrolinx Draft Regional Transportation Plan

Final Report

December 1, 2008

HDR Corporation
Decision Economics

Risk Analysis · Investment and Finance
Economics and Policy

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EXECUTIVE SUMMARY

OVERVIEW

The quality of life in the Greater Toronto and Hamilton Area (GTHA), the competitiveness of the region's industrial base and the ability to attract and sustain business and tourism, all hinge on the provision of safe, fast, reliable and convenient roads, bridges and public transit. To be sure, economic growth brings with it some congestion during busy times. Up to a point, crowds and queues signal mobility, prosperity and economic health. Indeed, it would not be economically sensible to expand transportation infrastructure to operate with zero congestion at all times of the day and the year -- the economic benefits would not justify the economic costs. But beyond a certain level of congestion, its attendant costs -- costs that arise in the form of delay, diminished productivity, wasted energy, environmental degradation, a diminished standard of living -- surpass the benefits and threaten the region's viability as a decent place to live, visit and conduct business. In 2006 alone, the economic burden of congestion amounted to \$3.3 billion for commuters and \$2.7 billion in lost opportunities for economic expansion. These economic, social and environmental costs will more than double over the next quarter century if the congestion from which they arise remains unattended.

Metrolinx has developed a Draft Regional Transportation Plan in response to the challenges posed by mounting congestion. Comprising a 25-year program of investments in roadways, bridges and public transit, the Plan posts estimated capital costs of \$48 billion (in constant 2006 dollars) plus another \$12 billion to operate the new infrastructure and keep the facilities and equipment in a state of good repair. When converted to their present-day equivalent value (to allow for the time-value of resources), these costs total fully \$31.2 billion: However, valued at \$46.7 billion, the Plan's economic, safety, community, social, and environmental benefits are greater still -- \$15.5 billion greater, fully justifying the investment with an average annual rate of return of almost 20 percent.

The construction program under the Plan would generate just under 430,000 jobs in Ontario over the multi-year course of its completion. The first full year of construction would create an estimated 17,000 jobs. The Ontario-based production of goods and services in support of the Plan would represent fully \$18 billion. Unless the construction program is executed during a period when Ontario labour and productive capacity are already fully employed, these macroeconomic effects represent net new economic activity and growth for the Province. Coming now, at a point of decline in macroeconomic activity in Ontario, and to the extent that projects can be started up quickly, the Plan offers the Province a win-win proposition -- an economically worthwhile investment for the long-term and the prospect of significant near-term redress in the region's and Province's diminished economic fortunes.

CONGESTION IN THE GTHA: THE COST OF DOING NOTHING

The impact of traffic congestion is palpable to anyone witnessing delay on the region's roadways. Currently, more than two million automobile trips are made during the peak travel period each morning in the GTHA, with the number to approach three million by 2031. Traffic congestion is now excessive and portends to become even more severe, with the hustle and bustle of an economically healthy region resulting in an excessive amount of time stuck in traffic. Traffic congestion in the GTHA increases the costs of the region's transportation activities, negatively impacts the region's economy, and impairs the quality of life by costing travelers' time and money, degrading the environment and causing accidents.

The principal economic and social costs of congestion are as follows:

1. The costs of reduced economic output and accompanying job loss;
2. The costs of travel delays for auto and transit users and the unreliability of trip times;
3. The increased vehicle operating costs associated with higher traffic volumes; and
4. The additional environmental costs of vehicle emissions and the higher frequency of accidents.

As shown in Summary Table 1, existing traffic conditions result in a significant economic, social and environmental cost to the GTHA region; in 2006 the annual cost to commuters was \$3.3 billion and the annual cost to the economy was \$2.7 billion. This cost can be expected to increase significantly, with population growth bringing about an increase in daily traffic demand and thus exacerbating the level of congestion – indeed, the cost of congestion experienced by GTHA inhabitants is forecast to increase considerably by 2031, resulting in an increase from \$3.3 billion per year to \$7.8 billion. Similarly, the cost to the economy would experience a similar increase, with a reduction in GDP due to excess congestion rising from \$2.7 billion in 2006 to \$7.2 billion in 2031. These values are in line with those of other large metropolitan regions; studies report the 2006 cost of congestion in the New York City region to be \$7 billion for commuters and \$4 billion for the regional economy.¹ The cost of congestion in Chicago was an estimated \$7.3 billion in 2006².

¹ Partnership for New York City, “The Economic Costs of Congestion in the New York City Region” (study conducted by HDR|Decision Economics)

² Metropolitan Planning Council “Moving at the Speed of Congestion: The True Costs of Traffic in the Chicago Metropolitan Area” (study conducted by HDR|Decision Economics)

Summary Table 1: Summary of Components of Congestion Cost in 2006, GTHA Average

COST COMPONENT	ANNUAL EXCESS COST OF CONGESTION (\$MILLIONS)
Time cost - auto users	\$2,245
Time cost - transit riders	\$337
Vehicle operating costs	\$479
Accidents	\$256
Vehicle emissions	\$29
COST OF CONGESTION	\$3,347
REDUCTION IN REGIONAL GDP	\$2,733

COSTS OF THE METROLINX DRAFT REGIONAL TRANSPORTATION PLAN

The DRTP requires a considerable level of investment. Over the 25-year horizon of the DRTP (from 2006-2031), capital expenditures account for an estimated \$48 billion, while operating and maintenance costs account for an additional \$12 billion, amounting to a total life-cycle cost of nearly \$60 billion (in constant 2006 dollars)³. Discounting these costs over the study period at an annual rate of 5 percent, the result is a present value of \$31.2 billion. In order for the DRTP to be an economically worthwhile undertaking, the present value of its expected benefits must thus exceed \$31.2 billion.

BENEFITS OF THE METROLINX DRAFT REGIONAL TRANSPORTATION PLAN

Benefits of the DRTP arise, inter alia, in the form of time savings to auto and transit users, savings in vehicle operating costs, reduced emissions and accident frequency, enhanced mobility for low-income travelers and related cross-sector benefits, commercial and economic development, and increased economic output.

As shown in Summary Table 2, the estimated benefits likely to arise under the DRTP over the 25-year study period are approximately \$46.7 billion for the GTHA, of which congestion management benefits account for \$28 billion, mobility benefits for \$3.6 billion, community development for \$5.1 billion and increased economic output for \$10 billion.

³ At the time of the analysis maintenance and storage facilities and refurbishment costs were not included. Also, the operations and maintenance cost estimate did not include Program and Policy Operating Costs.

Summary Table 2: Benefits of the Draft Regional Transportation Plan by Source (2010-2031)

BENEFITS CATEGORY	GTHA
Congestion Management	\$27,959
Mobility Benefits	\$3,604
Community Development	\$5,060
Economic Output	\$10,051
ALL BENEFITS	\$46,674

Note: values are in millions of dollars (\$2006), in present value terms

Over the 25-year study period, the present value of the benefits of the DRTP ranges from \$4,201 per person in the city of Hamilton to \$8,844 per person in York region (with the GTHA average being \$6,359 per person⁴).

NET BENEFITS AND RETURN ON INVESTMENT OF THE METROLINX DRAFT REGIONAL TRANSPORTATION PLAN

As shown in Summary Table 3, the estimated benefits of the Draft Regional Transportation Plan significantly exceed the expected costs of its implementation. The mean net present value (NPV) is \$15.5 billion (with a 90 percent confidence interval of \$12.6 billion to \$21.2 billion). This is equivalent to a 19 percent internal rate of return (IRR).

Summary Table 3: Cost Benefit Analysis of the 25-Year DRTP

INDICATOR – VALUE FOR MONEY	MEAN
Total Costs (Present Value)	\$31,156
Total Benefits (Present Value)	\$46,674
Net Present Value (at 5%)	\$15,519
Internal Rate of Return	19.0%

Note: values are in millions of dollars (\$2006), in present value terms

MACROECONOMIC EFFECTS OF THE DRTP CONSTRUCTION PROGRAM

The economic impacts of the DRTP construction program are estimated as direct, indirect, and induced impacts of the investment expenditures. All impacts are estimated in terms of business revenue, jobs, employment income, GDP, and tax revenues within the province of Ontario. More specifically, output is defined as the sum of gross business revenue across all affected business establishments. Employment is the number of jobs (both full-time and part-time). Employment income is the value of wages and salaries, supplementary labour income, and propriety income. GDP, or the Gross Regional Product, is the sum of a value added at every stage of production of final goods and services

⁴ Note that the ‘per capita’ calculations are based on the average population of the region over the period from 2006 to the forecasted population level in 2031

As economic impact in an area of interest is driven by the amount of expenditures made in that area, it is necessary to estimate the amount of DRTP expenditures that would take place in Ontario to Ontario manufacturers and service suppliers. The estimated DRTP expenditures to be made within Ontario amount to nearly \$34 billion, or 71 percent of the estimated total capital expenditure of \$48 billion.

The total output impact of the DRTP investment projects amount to over \$69.6 billion, including \$33.9 billion of the original expenditures that would take place in Ontario, \$20.9 billion in indirect or spin-off effects, and \$14.7 billion of induced impacts. The plan will create an estimated 429,528 jobs, including 153,795 direct jobs, 116,126 indirect jobs, and 159,607 induced jobs. These jobs would generate an employment income effect of over \$20.9 billion, including \$9.4 billion of direct employment income, \$5.9 billion of indirect income and \$5.6 billion induced income. The DRTP projects will result in an increase in Ontario's GDP of over \$31 billion. This estimate includes over \$12.4 billion of direct GDP, \$9.3 billion of indirect GDP, and \$9.4 billion of induced GDP.

The total tax revenue impact of the DRTP is estimated to exceed \$14.8 billion. This includes \$1.9 billion in local and municipal tax revenues, \$6.8 billion of provincial tax revenues, and \$6 billion of federal tax revenues. These tax revenues include all sources of taxation, in particular personal income taxes, corporate income taxes, property taxes, and consumption taxes.

Summary Table 4 gives the present value of the economic impacts over the investment period of the DRTP.

Summary Table 4: Economic Impact Analysis Evaluation Metrics of the 25-Year DRTP

ECONOMIC IMPACT	PRESENT VALUE
Output	\$39,266
Employment Income	\$11,825
GDP	\$17,630

Note: values are in millions of dollars (\$2006), in present value terms

All results discussed above represent the cumulative impact over the period when expenditures for the DRTP would be made. The annual impact of the DRTP would be equal to the proportion of expenditures made in a particular year. For example, if all expenditures were equally distributed over a period of 25 years, the annual impact of the DRTP in each year (during this 25-year period) could be calculated by dividing all impacts by a factor of 25.

CONCLUSION

Congestion in the Greater Toronto and Hamilton Area (GTHA) is significant and increasing. In 2006 alone, it cost the region's economy \$2.7 billion. Motorists and transit riders endured \$3.3 billion in travel delays, unreliable travel times, increased vehicle operating costs, and higher costs associated with vehicle emissions and accidents.

The Metrolinx Draft Regional Transportation Plan seeks to address the congestion problem through investment in public transportation services and infrastructure, roadway improvements,

and traffic demand management and related initiatives. While necessitating a large-scale commitment of capital funding, the DRTP would yield net benefits of an estimated \$15 billion, a rate of return of just under 20 percent. The construction program would yield almost 430,000 jobs.

CHAPTER 1: INTRODUCTION

Commuters in the GTHA experience the effects of traffic congestion on a daily basis. Many of these costs directly affect the driver's sense of well-being – be it the time wasted sitting in a traffic queue, missed appointments, a higher fuel bill, and so on – but many of the costs are less perceptible. What is the effect on the environment of excess congestion? What about the impact of forcing changes in behaviour due to the unreliability of travel times in the presence of congestion? Or what is the effect on the regional economy, in terms of lost economic output and employment?

The purpose of this report is three-fold. First, the current level of congestion in the GTHA is determined, and assessed relative to the economically efficient level of congestion. That is because a certain level of congestion is a good thing – it represents business activity occurring, people taking part in activities that they enjoy, and so forth. But when congestion encroaches beyond the “tipping point”, and the costs of congestion exceed the underlying benefits of the transportation occurring, then society is worse off and the issue should be addressed. The first step is thus to estimate the extent of congestion, and to then calculate the *excess* congestion. It is then possible to estimate the cost of this excess congestion, which is manifested in time delays to commuters, higher vehicle operating costs, more frequent accidents, higher levels of vehicle emissions, and lost economic output.

The second step is to then analyze the impact that the Draft Regional Transportation Plan (DRTP) would have on congestion in the region. A systematic cost-benefit analysis must be undertaken in order to produce an assessment of the total benefits of the DRTP relative to its costs, in order to determine whether the DRTP is economically justified. The costs of the DRTP are capital costs and operating and maintenance costs, while the benefits are in the form of improved congestion management, enhanced mobility, community development and increased economic output.

The third step is to estimate the economic impact of the DRTP investment on the economy. Unless the construction program is executed during a period when Ontario labour and productive capacity are already fully employed, these macroeconomic effects represent net new economic activity and growth for the Province.

Chapter 2 discusses the current cost of congestion in the GTHA. Chapter 3 outlines the DRTP and provides the results of the cost-benefit analysis. Chapter 4 then provides a discussion of the macroeconomic impacts of the DRTP, and subsequent appendices contain technical concerning the theory and application of the cost of congestion model, the cost-benefit analysis framework, and the macroeconomic impact analysis model (Appendices 1-5), as well as a detailed summary of input values and assumptions used in the modeling process (Appendix 6). The report also compares, to the extent possible, this cost of congestion study with those done by HDR|Decision Economics for New York and Chicago (Appendix 7).

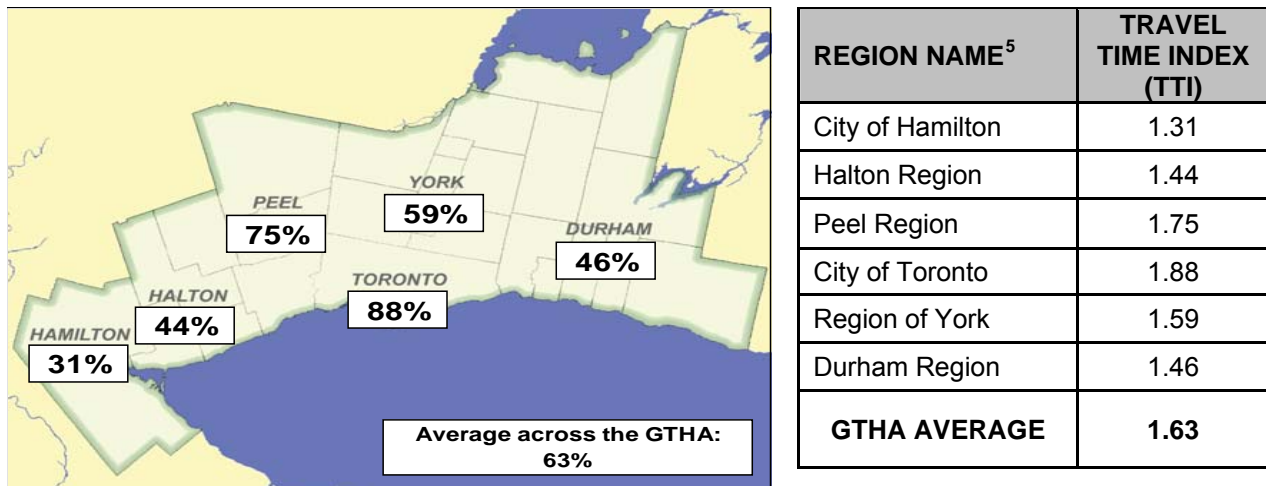
CHAPTER 2: CURRENT COSTS OF CONGESTION IN THE GTHA

The Draft Regional Transportation Plan (DRTP) proposes a number of interrelated projects across the transportation network of the Greater Toronto and Hamilton Area (GTHA), which is composed of 6 cities and regional municipalities, with a total population of over 6 million:

REGION	POPULATION (2006)
City of Hamilton	504,559
Halton Region	439,526
Peel Region	1,159,405
City of Toronto	2,503,281
Region of York	892,712
Durham Region	561,258
GREATER TORONTO AND HAMILTON AREA (GTHA)	6,060,741

The impact of traffic congestion is most acute during the weekday morning and evening commuting period. In 2006, peak morning traffic resulted in a substantial reduction in travel speeds – and commensurately longer travel times. Figure 1 illustrates the Travel Time Index (TTI) for each region in the GTHA. The TTI is the ratio of peak period travel time to free-flow travel time, expressing the average amount of extra time it takes to travel during congested time periods. As an example, in Toronto the TTI is 1.88, which indicates that a trip that would take 20 minutes in free-flow conditions will take 38 minutes during the peak travel time periods, an 18-minute (or 88 percent) travel time penalty. Appendix 1 contains additional data regarding the current level of congestion in these regions.

Figure 1: Increase in Travel Time Due to Congestion⁶ (in 2006)



⁵ It should be noted that all references to the 6 regions of the GTHA are based on the region in which the trip originated; thus the regional distributions are not equivalent to the trips made by the residents of the region or the degree to which the trip occurs in each region (in the case of inter-regional trips).

⁶ Relative to free-flow speed.

However, free-flow travel conditions are not the *optimal* conditions from a societal point of view, as it is not desirable to eliminate traffic congestion completely. Transportation is considered a derived demand; that is, people choose to make a trip because they value the activity that they are able to undertake at the destination, whether it is a shopping trip, visiting friends and family, or commuting to and from work. From society's perspective then, a trip is worthwhile if the benefits derived from making the trip exceed the costs of the trip.

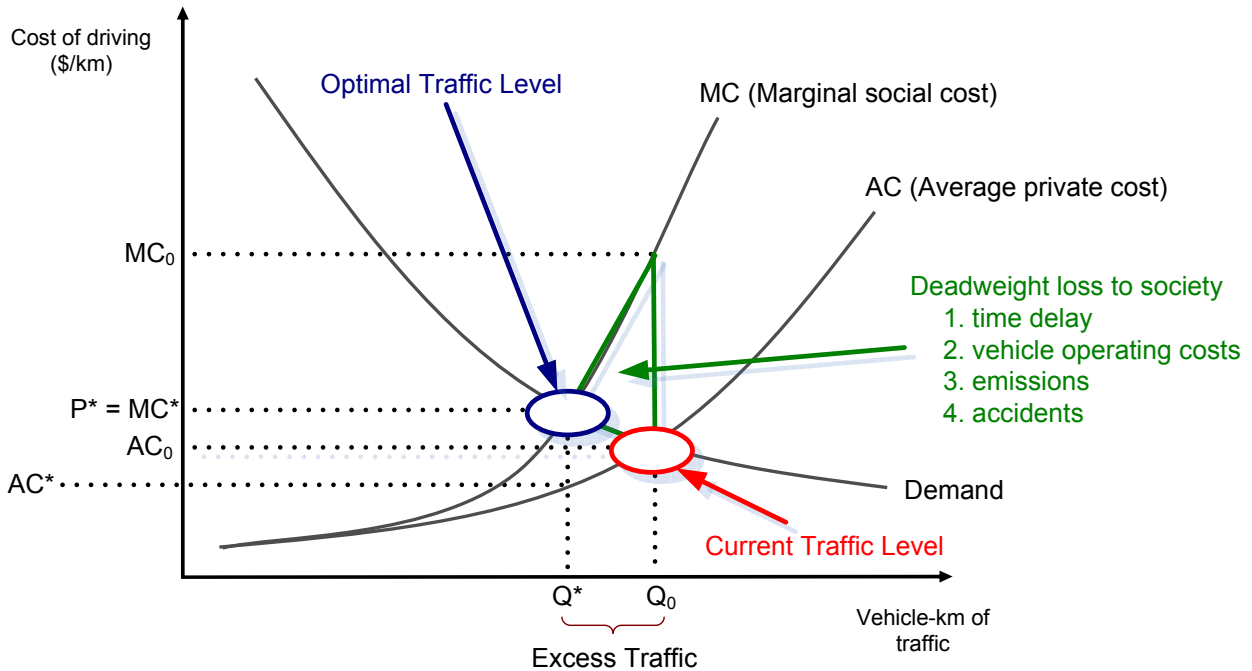
The costs of congestion observed by commuters each day are the result of a market failure in the determination of the number of trips taken. For most goods, prices send the correct signals (via "the invisible hand") to coordinate supply and demand and facilitate the decision-making of firms and individuals in order to coordinate an efficient allocation of resources. However, this is not so for the transportation market.

The cause of this market failure is the inefficiency in how the decisions of individuals interact to affect the well-being of society. When an individual considers whether or not to make a trip, they consider the benefit that they will obtain in taking the trip and the costs that they will incur (out-of-pocket expenses such as fuel, as well as implicit "opportunity costs" such as the value placed on time spent traveling). However, in making their travel decisions, individuals ignore the delay that their presence on the road causes other motorists. The level of congestion that would occur if road users took proper account of this effect is the *economically efficient* level. Congestion above this level is wasteful (and denoted as excess traffic) because the benefits from accommodating the additional traffic are outweighed by the costs that reduced travel speeds impose on other motorists.

Reduced speed means additional travel time, and this creates various costs. Some of these costs occur during working hours, such as the labour hours of truck drivers, and the paid - but relatively unproductive - time spent traveling on the road to business meetings. Also important, however, are the costs that travelers attach to their own unpaid time on the road; the time needed for commuting, for example, leaves less time for working and personal pursuits.

Figure 2 illustrates this point. The socially efficient, and *optimal*, level of traffic would occur only if the full social cost of each trip is taken into consideration (at a volume of traffic Q^*). However, currently only the private cost is taken into account, and a volume of traffic Q_0 exists. The difference between these two volumes is considered 'excess traffic', since for trips beyond Q_0 (which can be considered the 'tipping point') the social costs of these trips outweigh their benefits. Appendix 2 provides a detailed discussion of the theoretical framework used to measure the excess costs of congestion and how the model can be applied in practice.

Figure 2: Optimal (Economically Efficient) vs. Current Traffic Levels



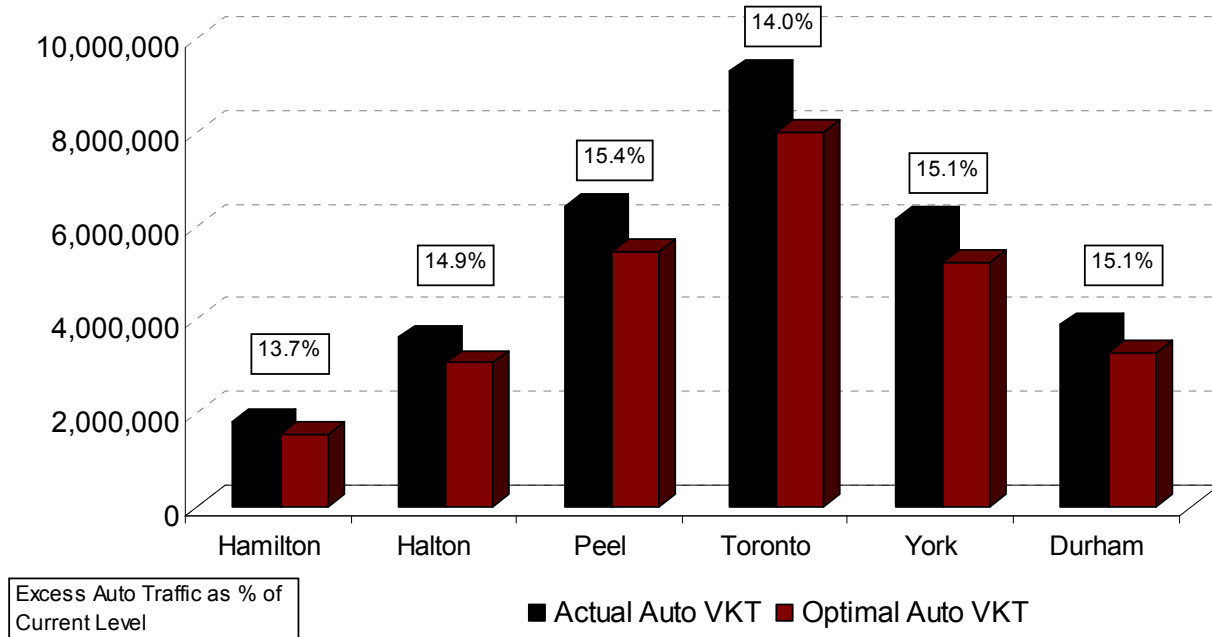
- Average private cost = vehicle operating costs + personal value of time
- Marginal social cost = vehicle operating costs + personal value of time + external value of time + emissions + accidents

It is this excess congestion, not the total congestion, which should concern policy makers and transportation planners. If congestion is above the tipping point, the transportation system is not running as efficiently as it could and resources (money, time, the environment, etc.) are being wasted. If excess congestion beyond the tipping point is reduced, society will be better off.

“Deadweight loss” is the term used by economists to describe the net loss in economic resources, or economic welfare, which arises under congestion. Conceptually, the deadweight loss encompasses all losses in economic value due to delays caused by congestion (see Figure 2).

The current and optimal traffic volumes were estimated for the GTHA (and each of the 6 sub-regions), based on 2006 data. Figure 3 illustrates the degree to which traffic is currently exceeding the ‘tipping point’: for each sub-region, auto traffic in the AM peak period exceeds the optimal value from 14-15 percent.

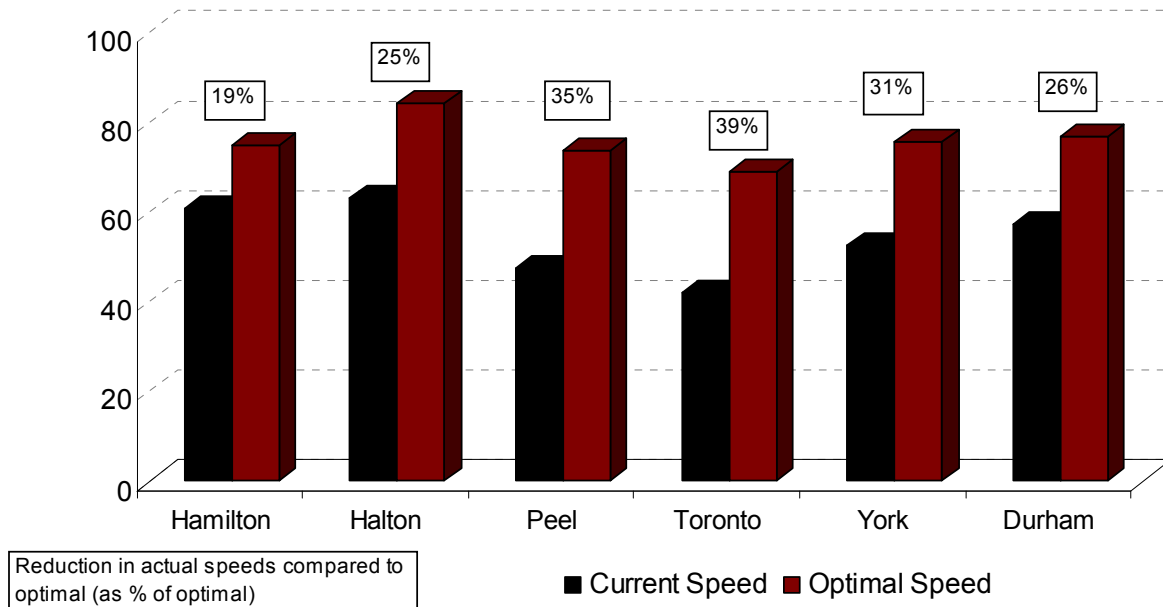
Figure 3: Excess Auto Traffic⁷ in the GTHA, 2006 (daily auto VKT in AM Peak Period)



This inefficiently high volume of traffic leads directly to suboptimal reductions in travel speeds. As Figure 4 shows, for each region the actual travel speeds are between 19-39 percent lower than the speeds that would occur if the optimal volume of traffic existed.

⁷ Relative to the “optimal” – or economically efficient – volume of traffic

Figure 4: Congested Travel Speeds⁸ in the GTHA, 2006 (km/hr in AM Peak Period)



Note: Optimal speed refers to the implied speed at the economically efficient level of congestion. See footnote for more on its interpretation.

These lower travel speeds translate into longer, and more unpredictable, travel times. In 2006, this translated to an average excess delay of 11.5 minutes per day per commuter in the GTHA – which is equivalent to 50 hours per year.

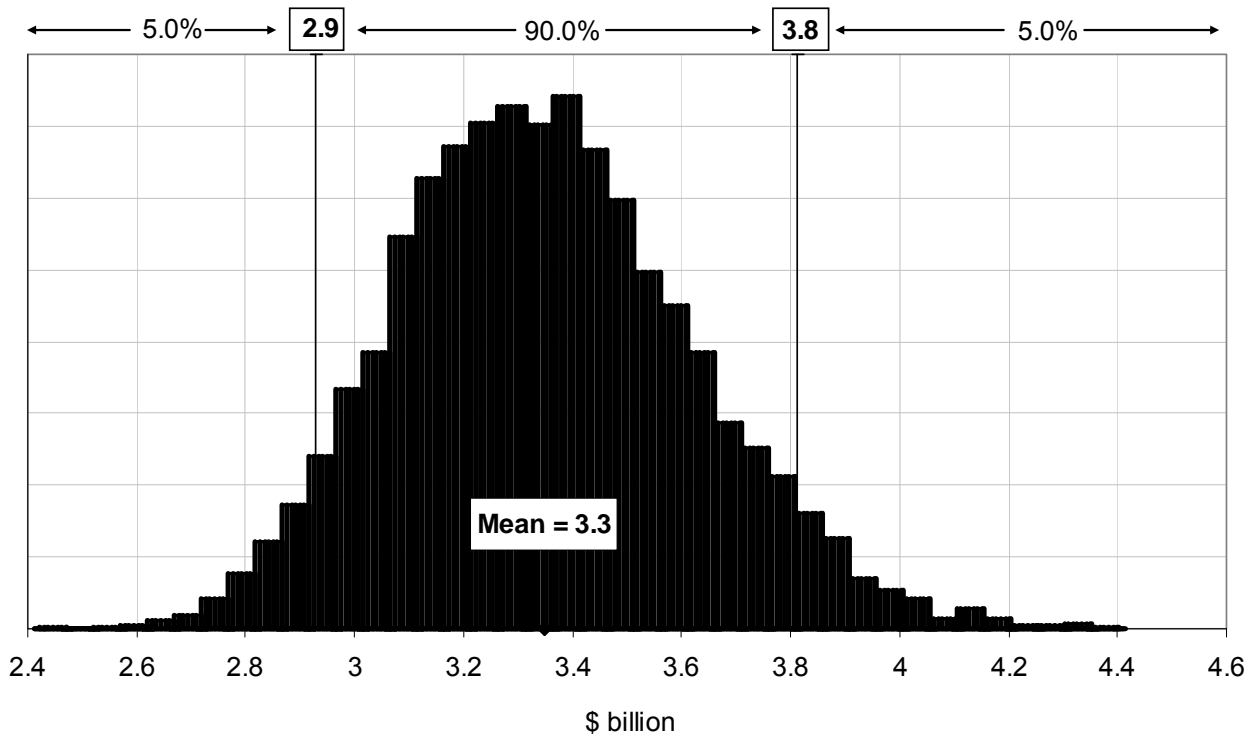
Table 1: The Extent of Excess Travel Delay in the GTHA, 2006

REGION NAME	HOURS PER DAY	HOURS PER YEAR	MINUTES PER DAY, PER COMMUTER	HOURS PER YEAR, PER COMMUTER
City of Hamilton	9,002	2,340,523	4.8	21
Halton Region	24,314	6,321,584	7.8	34
Peel Region	88,844	23,099,566	11.1	48
City of Toronto	163,319	42,463,052	15.6	67
Region of York	64,596	16,794,912	12.9	56
Durham Region	30,419	7,909,060	8.8	38
GREATER TORONTO AND HAMILTON AREA (GTHA)	357,759	93,017,276	11.5	50

⁸ Optimal speed here refers to the speed at the economically efficient level of congestion. This speed may not be optimal for all and this is not the sense in which optimal is used here. For example, the speed at the economically efficient level of congestion will not be optimal for pedestrians and cyclists for whom a slower speed would usually be better.

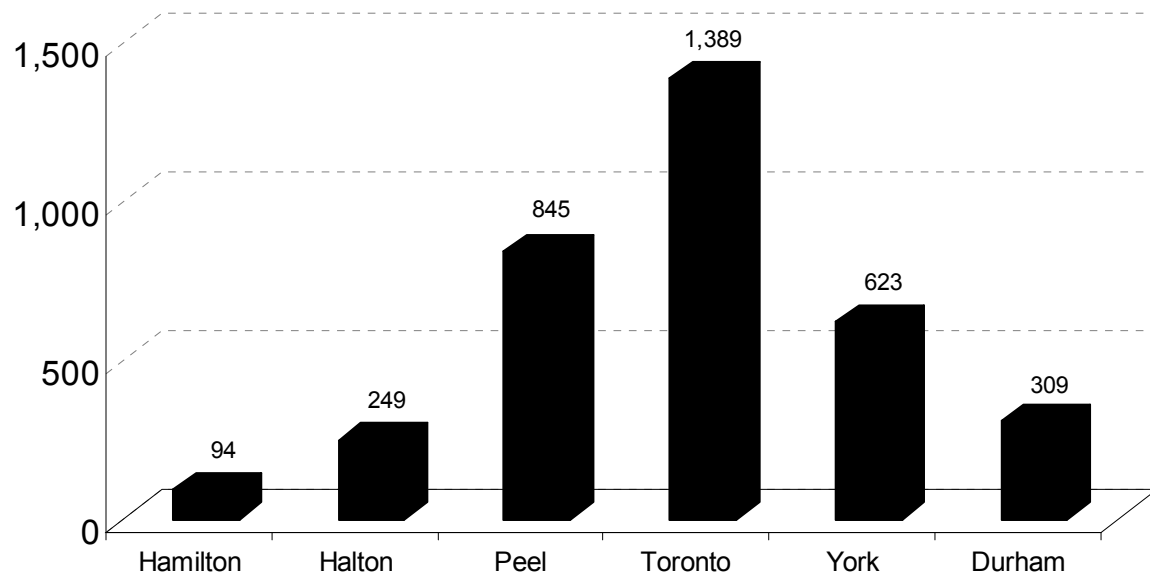
These time delays entail a significant cost on motorists and transit riders. In 2006, the total cost of excess congestion experienced by commuters in the morning and evening peak periods – including time delays, travel time unreliability, increased vehicle operating costs, and the higher levels of emissions and accidents – is estimated at \$3.3 billion per year⁹. Accounting for the uncertainty in the valuation of the inputs into the calculation, the 90 percent confidence interval ranges from \$2.9 billion to \$3.8 billion per year (see Figure 5). Figure 6 depicts the regional distribution of this annual cost. Appendix 3 provides additional results pertaining to the current cost of excess congestion in the GTHA.

Figure 5: Estimated Cost of Congestion to GTHA Commuters, 2006 (AM + PM Peak Periods)



⁹ Note that all dollar values referred to in this report are expressed in 2006 dollars.

Figure 6: Regional Distribution of the Total Annual Cost of Excess Congestion Experienced by Commuters, 2006 (\$ million)



The ‘Triple Bottom Line’ – Economic, Environmental, and Social Value

The above figures highlight the immense cost of excess congestion in the GTHA. The issue of *sustainability* has been receiving increased attention in recent years in light of growing concern with the environment and climate change. Sustainability is linked to the so-called ‘triple bottom line’ framework, which focuses on a project or activity’s economic, environmental and social value. The following section outlines the degree to which current excess congestion affects these costs. As can be seen, the costs are significant, and portend to increase if the issue of congestion is not addressed.

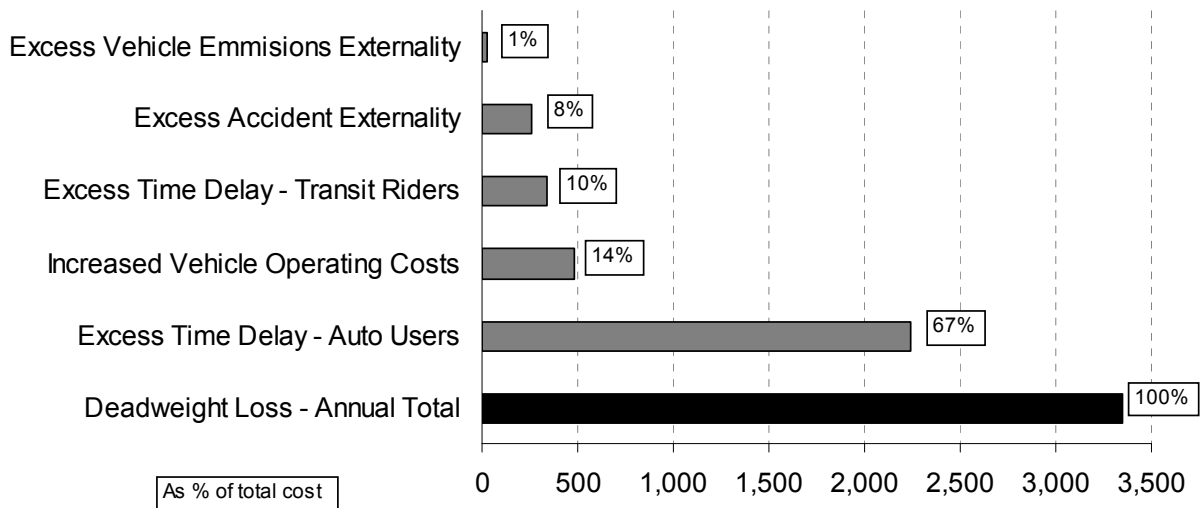
The deadweight loss – illustrated in Figure 2 - is comprised of the following five components:

- *Excess time delay – auto users:*
 - Longer travel times result in a cost to motorists in the form of the value placed on this excess time spent traveling. This is referred to as an ‘opportunity cost’ which is equivalent to the value of activities foregone. The added unpredictability of travel times is included in this cost.
- *Excess time delay – transit riders:*
 - For transit operations occurring on shared roadways, these transit users experience a cost of excess travel delay of the same form as auto users.
- *Increased vehicle operating costs:*
 - Vehicle operating costs increase in congested traffic conditions due to the stop-and-go nature of travel; additionally, the higher traffic volumes represent operating costs in excess of the socially optimal level.

- *Excess accident externality costs:*
 - Congested traffic conditions result in a higher accident rate, which translates into additional cost to auto users.
- *Excess vehicle emissions externality costs:*
 - As with operating costs, vehicle emissions increase with congestion due to the stop-and-go driving conditions, and the total amount of emissions is inefficiently high due to the excess traffic volume.

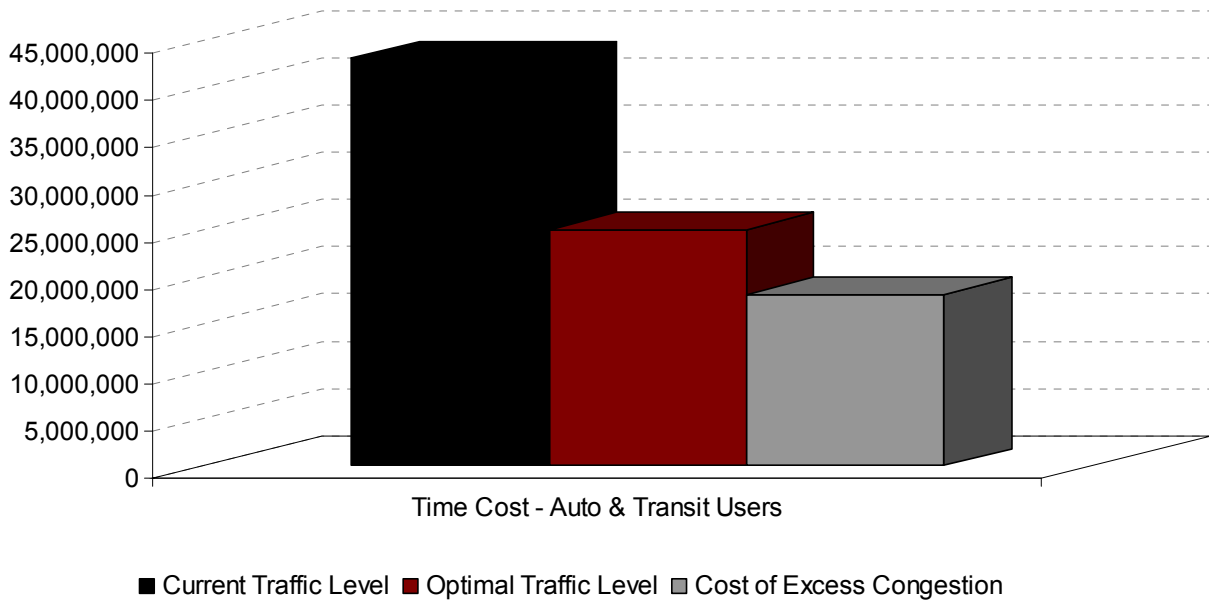
Figure 7 shows how the total annual cost to commuters of \$3.3 billion per year in 2006 is distributed among these five components; as can be seen, the time delay to auto users accounts for two-thirds of the total cost experienced by commuters.

Figure 7: Breakdown of Annual Cost of Congestion for GTHA Commuters, 2006 (\$ million)



The following four figures illustrate the extent to which these social costs could be reduced by eliminating the excess congestion. The reduction in vehicle-kilometres traveled each day would reduce the cost of vehicle emissions, accidents and vehicle operating costs by 15 percent each, while the daily cost of time for auto and transit users would be reduced by 42 percent. This would have a significant effect towards furthering the path towards sustainable transportation in the GTHA.

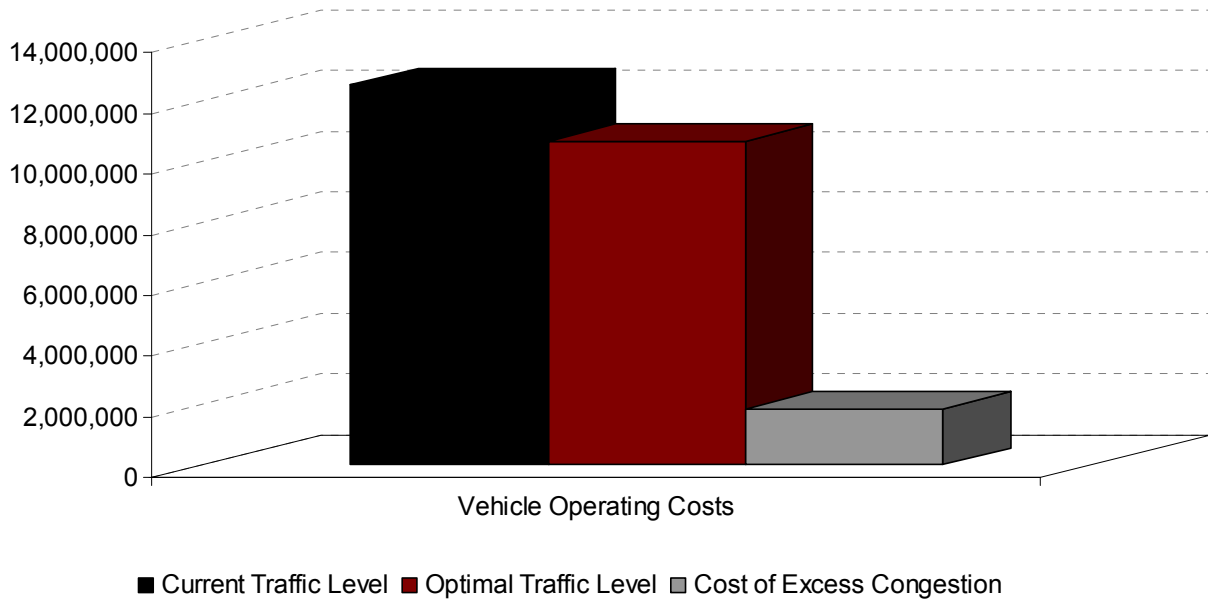
Figure 8: The Daily Cost of Travel Time in the GTHA, 2006 (\$/day, AM + PM Peak Periods)



TIME COST - AUTO & TRANSIT USERS - \$/DAY, 2006	
Daily cost in 2006 at the current traffic level	43,143,840
Daily cost in 2006 at the optimal traffic level	25,040,823
Daily excess cost in 2006	18,103,016
PERCENTAGE THAT THIS COST WOULD BE REDUCED BY ELIMINATING EXCESS CONGESTION	42%

As Figure 8 shows, the current excess cost of congestion amounts to nearly \$20 million each day. This cost could be reduced by 42 percent by removing the excess congestion that currently exists.

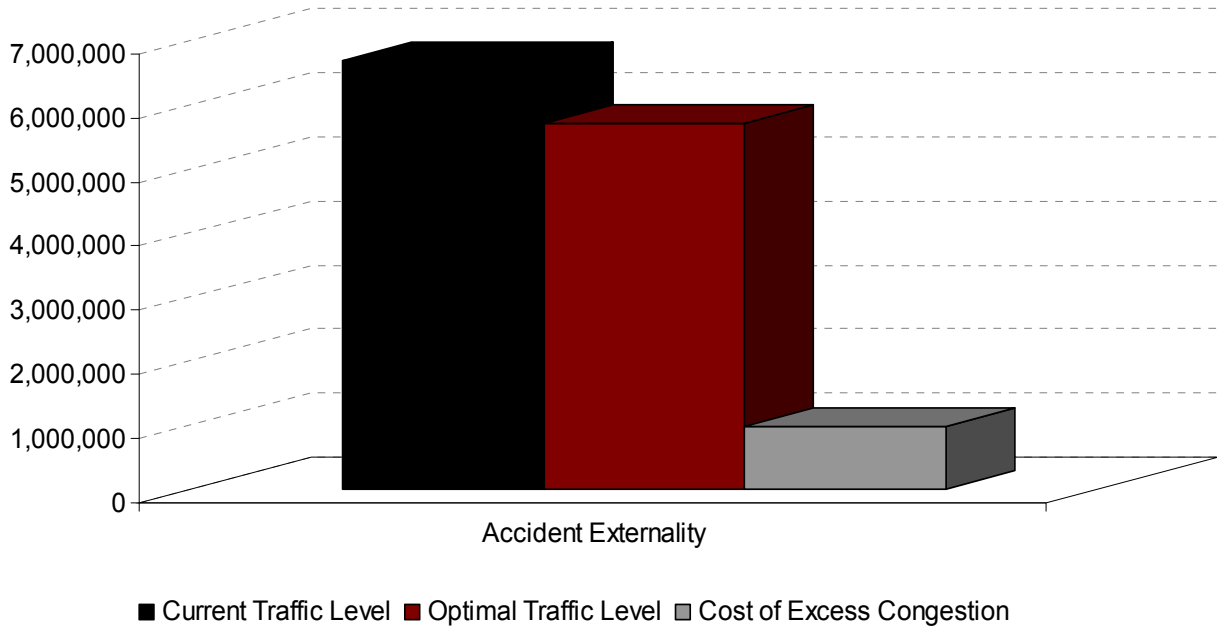
Figure 9: Daily Vehicle Operating Costs in the GTHA, 2006 (\$/day, AM + PM Peak Periods)



VEHICLE OPERATING COSTS - \$/DAY, 2006	
Daily cost in 2006 at the current traffic level	12,512,146
Daily cost in 2006 at the optimal traffic level	10,668,873
Daily excess cost in 2006	1,843,273
PERCENTAGE THAT THIS COST WOULD BE REDUCED BY ELIMINATING EXCESS CONGESTION	15%

In Figure 9 it is shown that the excess cost of vehicle operating costs associated with the inefficiently high level of traffic is nearly \$2 million per day. This cost would be reduced by 15 percent by eliminating the excess congestion.

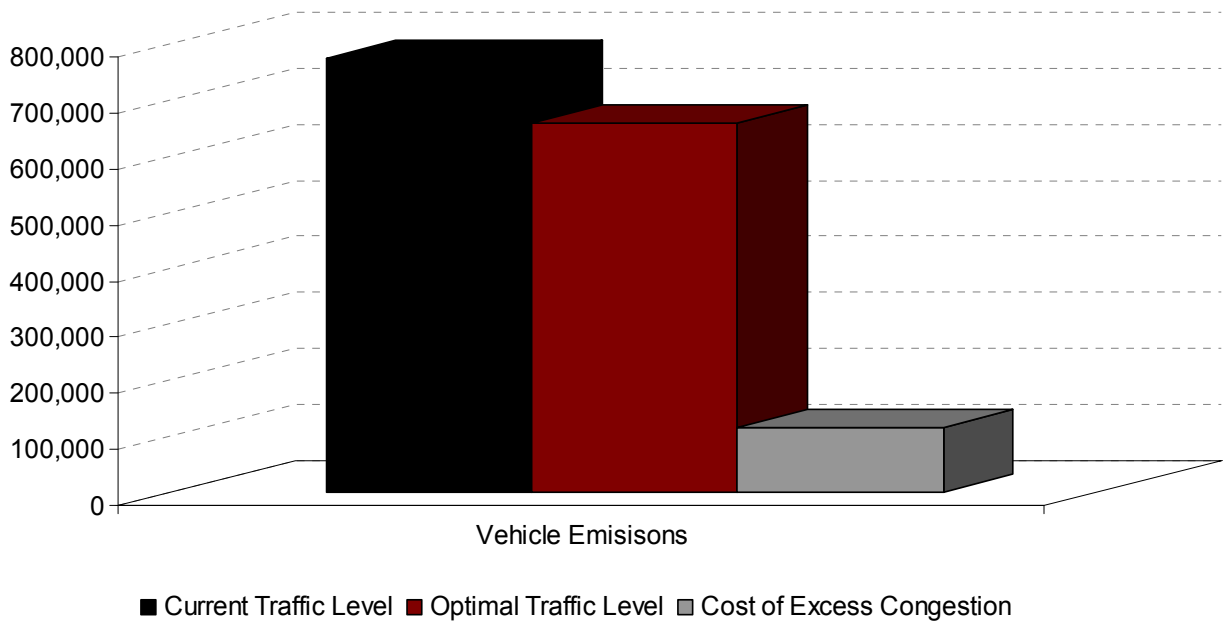
Figure 10: Daily Cost of Accidents in the GTHA, 2006 (\$/day, AM + PM Peak Periods)



ACCIDENT EXTERNALITY - \$/DAY, 2006	
Daily cost in 2006 at the current traffic level	6,690,549
Daily cost in 2006 at the optimal traffic level	5,704,906
Daily excess cost in 2006	985,643
PERCENTAGE THAT THIS COST WOULD BE REDUCED BY ELIMINATING EXCESS CONGESTION	15%

The current excess congestion leads to an excess cost of accidents of nearly \$1 million each day (see Figure 10); this value could be reduced by 15 percent by addressing the excess congestion.

Figure 11: Daily Cost of Vehicle Emissions in the GTHA, 2006 (\$/day, AM + PM Peak Periods)



VEHICLE EMISSIONS - \$/DAY, 2006	
Daily cost in 2006 at the current traffic level	773,828
Daily cost in 2006 at the optimal traffic level	659,829
Daily excess cost in 2006	113,999
PERCENTAGE THAT THIS COST WOULD BE REDUCED BY ELIMINATING EXCESS CONGESTION	15%

The cost of vehicle emissions in the GTHA amounts to over \$200 million each year, with the excess cost being over \$100,000 each day. This cost could also be reduced by 15 percent by eliminating excess congestion.

Table 2 provides the daily and annual cost for each region, as well as the annual cost of congestion per capita, for each of these above social and environmental costs. It can be seen that the total annual excess cost of congestion varies from \$186-\$729 per person, depending on the sub-region.

Table 2: Summary of Components of Congestion Cost in 2006 by GTHA Sub-Region

COST COMPONENT	DAILY EXCESS COST OF CONGESTION (\$)	ANNUAL EXCESS COST OF CONGESTION (\$)	ANNUAL EXCESS COST OF CONGESTION, PER CAPITA (\$/PERSON)
Hamilton			
Time cost - auto users	105,528	27,437,310	54
Time cost - transit riders	98,173	25,524,998	51
Vehicle operating costs	98,863	25,704,423	51
Accidents	52,865	13,744,780	27
Vehicle emissions	6,114	1,589,720	3
TOTAL	361,543	94,001,230	186
Halton			
Time cost - auto users	545,046	141,711,831	322
Time cost - transit riders	67,723	17,608,077	40
Vehicle operating costs	216,585	56,312,139	128
Accidents	115,813	30,111,470	69
Vehicle emissions	13,395	3,482,690	8
TOTAL	958,562	249,226,207	567
Peel			
Time cost - auto users	2,450,511	637,132,911	550
Time cost - transit riders	165,420	43,009,150	37
Vehicle operating costs	397,260	103,287,721	89
Accidents	212,425	55,230,455	48
Vehicle emissions	24,569	6,387,949	6
TOTAL	3,250,185	845,048,187	729
Toronto			
Time cost - auto users	3,803,236	988,841,429	395
Time cost - transit riders	703,966	183,031,209	73
Vehicle operating costs	523,637	136,145,696	54
Accidents	280,002	72,800,413	29
Vehicle emissions	32,385	8,420,089	3
TOTAL	5,343,226	1,389,238,835	555
York			
Time cost - auto users	1,633,571	424,728,379	476
Time cost - transit riders	167,546	43,561,987	49
Vehicle operating costs	372,052	96,733,638	108
Accidents	198,945	51,725,827	58
Vehicle emissions	23,010	5,982,604	7
TOTAL	2,395,125	622,732,435	698
Durham			
Time cost - auto users	754,233	196,100,471	349
Time cost - transit riders	58,975	15,333,546	27
Vehicle operating costs	234,875	61,067,431	109
Accidents	125,593	32,654,240	58
Vehicle emissions	14,526	3,776,786	7
TOTAL	1,188,202	308,932,474	550

Table 3: Summary of Components of Congestion Cost in 2006, GTHA Average

COST COMPONENT	DAILY EXCESS COST OF CONGESTION (\$)	ANNUAL EXCESS COST OF CONGESTION (\$)	ANNUAL EXCESS COST OF CONGESTION, PER CAPITA (\$/PERSON)
Greater Toronto and Hamilton Area (GTHA)			
Time cost - auto users	8,635,110	2,245,128,711	370
Time cost - transit riders	1,296,555	337,104,226	56
Vehicle operating costs	1,843,273	479,251,048	79
Accidents	985,643	256,267,185	42
Vehicle emissions	113,999	29,639,838	5
TOTAL	12,874,581	3,347,391,008	552

Table 3 shows the allocation of congestion costs across the GTHA: on average, the cost of time delays, vehicle operating costs, accidents and vehicle emissions associated with excess congestion amount to \$552 per person each year. Each day, excess congestion costs the GTHA nearly \$13 million.

In addition to the above costs that affect motorists directly, excess congestion also entails an indirect cost on the economy as a whole. The above costs of congestion result in a higher cost of business activity, due to (1) the direct increase in transportation costs and (2) the adverse impact on the labour market, as higher commuting costs are manifested in higher wages and decreased demand for labour, which thus leads to a suboptimal allocation of labour resources. The end result is that regional economic output (measured via regional gross domestic product or GDP) is below the level that would exist in the absence of excess congestion.

This cost is substantial; as Figure 12 illustrates, the cost to the GTHA economy in the form of decreased GDP due to congestion is estimated to be \$2.7 billion per year in 2006 (with a 90 percent confidence interval ranging from \$2.1 billion to \$3.6 billion per year).

Related to this reduction in regional economic output, business revenues are estimated to be reduced by \$4.7 billion per year in 2006 due to excess congestion depressing business activity, and the excess commuting costs lower the number of jobs in the region by 25,962.

Further, excess congestion results in higher transportation and logistics costs for various industries, due to the higher direct costs of transportation (fuel expenses, labour costs, maintenance, etc.) and several indirect costs, such as the need to maintain higher levels of inventory as a buffer against delivery time reliability, a higher frequency of missed deliveries, and so forth. These effects serve to both increase costs and decrease revenues, with a concomitant reduction in employment. The estimated impact on selected industries is contained in Table 4.

Figure 12: Estimated Cost of Congestion to the GTHA Economy, 2006 (AM + PM Peak Periods)

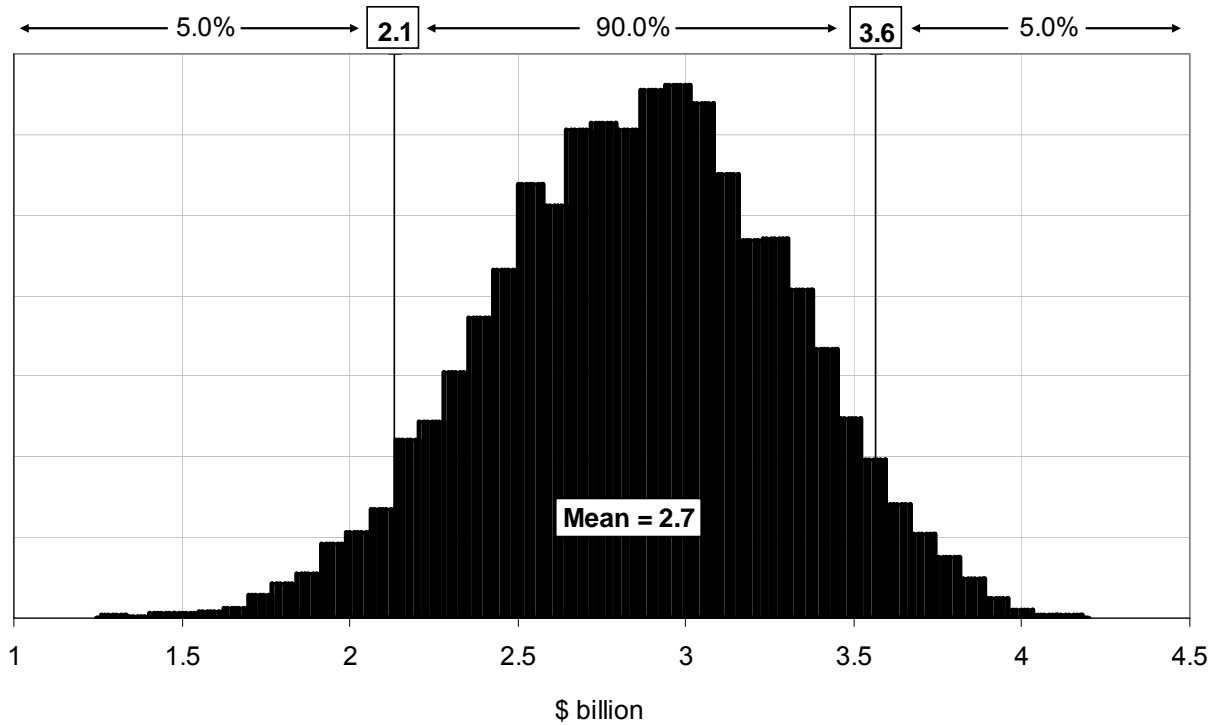
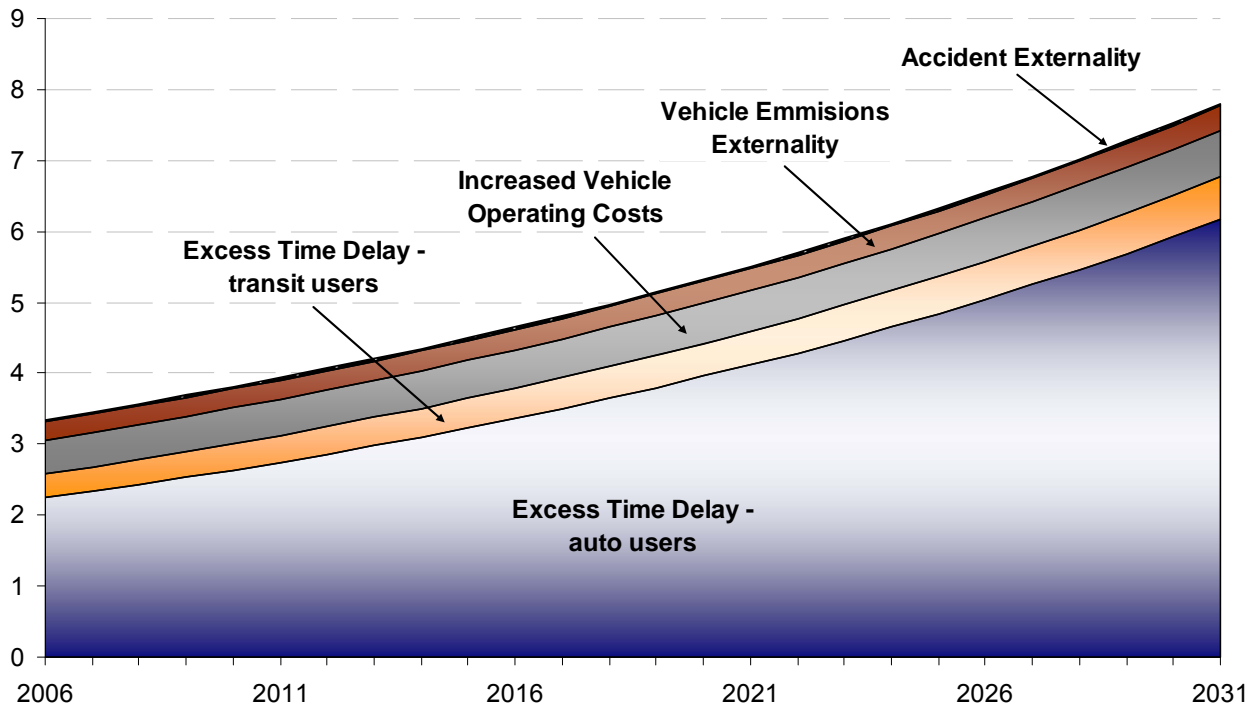


Table 4: Impact of Congestion on Selected Industries, 2006

INDUSTRY	INCREASE IN INDUSTRY COSTS (\$ MILLIONS)	REDUCTION IN INDUSTRY REVENUES (\$ MILLIONS)	REDUCTION IN INDUSTRY EMPLOYMENT (FTE JOBS)
Retail Trade	22.1	27.5	467
Construction	63.1	-	-
Manufacturing	97.6	804.0	1,959
Wholesale Trade	56.3	-	-
Agriculture	4.1	52.5	429
Accommodation and Food services	-	40.4	849
Arts and Entertainment	-	6.2	94
Transportation	16.7	6.0	43
SUBTOTAL	259.9	936.6	3,841

It is clear that existing traffic conditions result in a significant cost to the GTHA region, with the annual cost to commuters in 2006 being \$3.3 billion and the annual cost to the economy being \$2.7 billion. This cost can be expected to increase significantly, with population growth bringing about an increase in daily traffic demand and thus exacerbating the level of congestion. Figure 13 illustrates the degree to which the cost of congestion can be expected to increase from 2006 to 2031 in the absence of any significant investment in transportation infrastructure. As can be seen, the excess delay experienced by auto users is forecast to increase considerably, resulting in an increase from \$3.3 billion per year to \$7.8 billion – an increase of 136 percent.

Figure 13: Forecast Growth in the Cost of Congestion to Commuters, 2006 to 2031 (\$ billion per year, 2006 dollars)

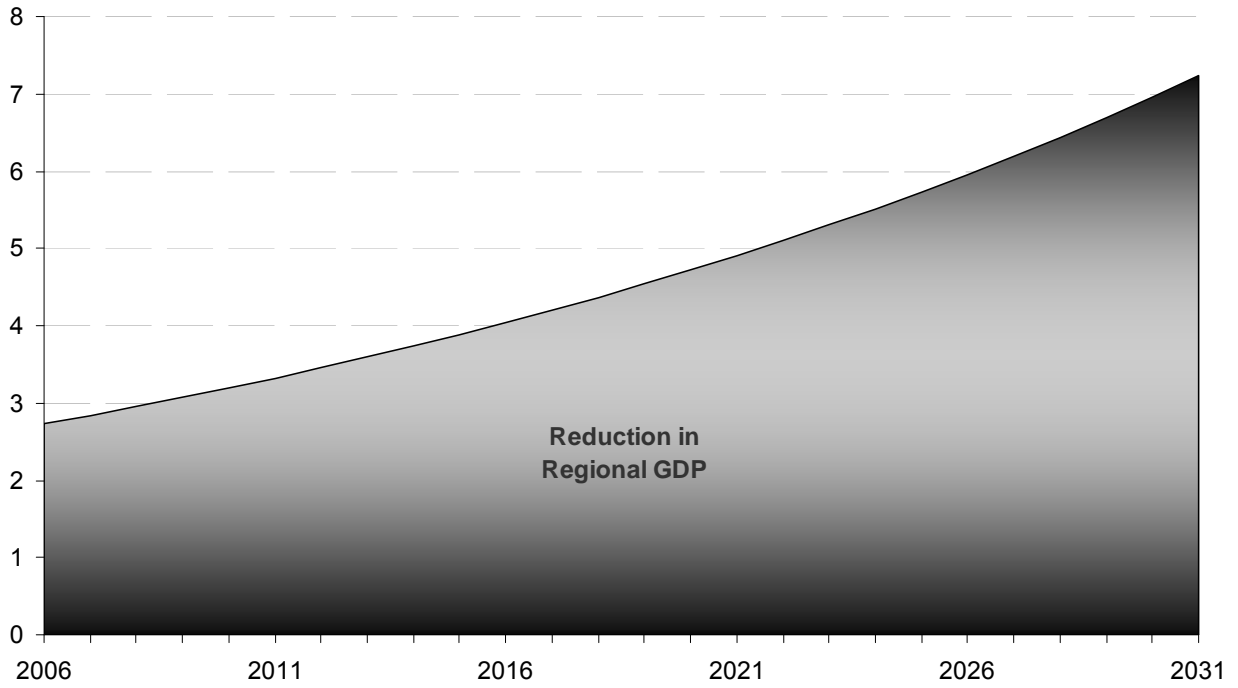


Similarly, the cost to the economy would exhibit a similar increase. As Figure 14 shows, the reduction in GDP due to excess congestion would increase from \$2.7 billion in 2006 to \$7.2 billion in 2031 – an increase of 167 percent.

The costs of congestion in the GTHA are significant. It is of interest to compare the cost of excess congestion in the GTHA with that experienced by other large urban regions. Similar studies of the New York and Chicago regions have found results in line with those of the GTHA. On a per capita basis, the annual excess cost of congestion in the GTHA is \$1,000 per person – for New York the cost is \$917 and for Chicago it is \$912 (see Appendix 7 for details).

These figures underscore the seriousness of the issue of traffic congestion in the GTHA, and the degree to which the costs are forecast to increase should provide the impetus for a reasoned and thorough response towards improving the regional transportation system.

Figure 14: Forecast Growth in the Cost of Congestion to the GTHA Economy, 2006 to 2031
(\$ billion per year, 2006 dollars)



CHAPTER 3: AN EVALUATION OF THE DRAFT REGIONAL TRANSPORTATION PLAN

Metrolinx's Draft Regional Transportation Plan (DRTP) is intended to address the traffic congestion in the GTHA and provide a more sustainable regional transportation network in the future. The DRTP combines large-scale investment in transit service and roadway infrastructure, along with traffic demand management initiatives and sustainable transportation improvements. The DRTP extends to 2031, and as a result this study employs a baseline of the year 2006 and also goes to 2031.

In evaluating any investment or project, it is necessary to define a baseline in order to provide context for the comparison. In this case the baseline scenario is the "business as usual" (BAU) case, whereby the current situation is forecast out over the study horizon. The BAU case represents a projection of the future scenario if the DRTP is not implemented; it thus assumes no significant investment over this horizon. An illustration of the cost of congestion under the BAU scenario is provided in Figures 13 and 14.

The implementation of the DRTP is thus evaluated relative to the BAU scenario. It should be noted that the entire impact of the DRTP is taken into consideration, and individual projects are not assessed separately. This is necessary when evaluating a transportation network due to the inter-related nature of the initiatives to be undertaken and the manner in which traffic moves through the system.

The DRTP outline provides three implementation horizons (10, 15, and 25 years), encompassing a large number of projects. The total capital cost is estimated to be roughly \$48 billion over the 25 years (with an additional \$12 billion required for additional operating and maintenance activities); allocated evenly over the study period, the present value of the costs of implementing the DRTP is \$31 billion, which includes both capital expenditures and operations and maintenance costs.

As the projects contained in the DRTP are implemented, a significant impact on regional travel behaviour is anticipated, including a sizable increase in public transportation ridership. Several benefits will be associated with the implementation of the DRTP, including congestion management, enhanced mobility, community development and economic output.

The DRTP requires a considerable level of investment. Table 5 outlines the initial capital spending plan. As can be seen, when the capital and operating maintenance costs are converted into present value terms by discounting the flow of costs at an annual discount rate of 5 percent, the result is a present value of \$31.2 billion. In order for the DRTP to be a worthwhile undertaking, the present value of its expected benefits must thus exceed \$31.2 billion.

Table 5: Draft Regional Transportation Plan - 25-Year Capital Spending Plan

CATEGORY	CAPITAL SPENDING BY PLAN (\$ million)			
	10 YEAR	15 YEAR	25 YEAR	ALL YEARS
UNDISCOUNTED COSTS				
Capital Expenditures	\$17,510	\$11,150	\$19,190	\$47,850
Operating and Maintenance Costs	\$1,497	\$2,621	\$7,824	\$11,943
ALL COSTS	\$19,007	\$13,771	\$27,014	\$59,793
DISCOUNTED COSTS*				
Capital Expenditures	\$12,831	\$5,927	\$7,128	\$25,886
Operating and Maintenance Costs	\$1,017	\$1,381	\$2,871	\$5,270
ALL COSTS	\$13,848	\$7,308	\$9,999	\$31,156

* discounting uses an annual discount rate of 5 percent.

Table 6 produces the estimated benefits of the DRTP, disaggregated into the various components and shown at both the sub-regional level and for the GTHA as a whole. The present value of the stream of benefits ranges from \$2.4 billion for the city of Hamilton to \$14.5 billion for the city of Toronto. Overall, the estimated benefits brought about by the DRTP are approximately \$46.7 billion for the GTHA, of which congestion management benefits account for \$28 billion, mobility benefits for \$3.6 billion, community development for \$5.1 billion and economic output for \$10 billion.

Table 7 provides a similar overview of the benefits of the DRTP. However, here these values are expressed on a per capita basis. Over the study horizon, the present value of the benefits of the DRTP range from \$4,201 per person in the city of Hamilton to \$8,844 per person in York region (with the GTHA average being \$6,359 per person).

Table 6: Estimated Benefits of the Draft Regional Transportation Plan, by Source and by Sub-Region (2010-2031)

CATEGORY	GTHA	CITY OF HAMILTON	HALTON REGION	PEEL REGION	CITY OF TORONTO	YORK REGION	DURHAM REGION
BENEFITS							
CONGESTION MANAGEMENT							
Time Savings - Auto Users	\$21,656	\$1,245	\$2,360	\$4,589	\$4,315	\$5,619	\$3,527
Savings in Vehicle Operating Costs	\$4,812	\$288	\$323	\$988	\$1,543	\$1,115	\$554
Emission Savings	\$823	\$96	\$112	\$196	\$2	\$256	\$161
Accident Cost Savings	\$669	\$58	\$56	\$132	\$164	\$148	\$111
<i>Total Congestion Management</i>	\$27,959	\$1,688	\$2,850	\$5,905	\$6,024	\$7,138	\$4,354
MOBILITY							
Time Savings - Transit Users	\$3,249	\$3	\$59	\$599	\$2,109	\$551	-\$74
Value to Low-Income Travelers	\$307	\$27	\$40	\$55	\$73	\$69	\$43
Cross Sector Benefits	\$49	\$2	\$4	\$8	\$22	\$5	\$6
<i>Total Mobility Benefits</i>	\$3,604	\$33	\$103	\$663	\$2,205	\$626	-\$25
COMMUNITY DEVELOPMENT							
Commercial Development	\$1,887	\$52	\$31	\$224	\$1,483	\$66	\$30
Residential Development	\$3,173	\$67	\$53	\$216	\$2,612	\$184	\$41
<i>Total Community Development</i>	\$5,060	\$119	\$84	\$440	\$4,095	\$251	\$71
ECONOMIC OUTPUT							
<i>Economic Output</i>	\$10,051	\$607	\$1,025	\$2,123	\$2,166	\$2,566	\$1,565
ALL BENEFITS	\$46,674	\$2,446	\$4,062	\$9,131	\$14,489	\$10,581	\$5,966

Note: values are in millions of dollars (\$2006), in present value terms

It should again be noted that the sub-regional distributions are based on the distribution of trip *origins*, and thus do not correspond to the residents of each region. Also note that the benefits are calculated over the period of 2010-2031. The assumption is that the benefits of the DRTP will start to be experienced in 2010, and will be ramped-up as the projects are finalized throughout the course of the DRTP.

Table 7: Estimated Benefits per Capita of the Draft Regional Transportation Plan, by Source and by Sub-Region (2010-2031)

CATEGORY	GTHA	CITY OF HAMILTON	HALTON REGION	PEEL REGION	CITY OF TORONTO	YORK REGION	DURHAM REGION
BENEFITS							
CONGESTION MANAGEMENT							
Time Savings - Auto Users	\$2,950	\$2,139	\$3,870	\$3,279	\$1,546	\$4,697	\$4,637
Savings in Vehicle Operating Costs	\$656	\$495	\$529	\$706	\$553	\$932	\$729
Emission Savings	\$112	\$165	\$184	\$140	\$1	\$214	\$212
Accident Cost Savings	\$91	\$100	\$92	\$94	\$59	\$124	\$146
<i>Total Congestion Management</i>	\$3,809	\$2,898	\$4,674	\$4,219	\$2,158	\$5,967	\$5,725
MOBILITY							
Time Savings - Transit Users	\$443	\$5	\$97	\$428	\$756	\$461	-\$97
Value to Low-Income Travelers	\$42	\$47	\$65	\$39	\$26	\$58	\$56
Cross Sector Benefits	\$7	\$4	\$7	\$6	\$8	\$5	\$8
<i>Total Mobility Benefits</i>	\$491	\$56	\$169	\$473	\$790	\$523	-\$33
COMMUNITY DEVELOPMENT							
Commercial Development	\$257	\$90	\$52	\$160	\$531	\$56	\$39
Residential Development	\$432	\$115	\$87	\$154	\$936	\$154	\$54
<i>Total Community Development</i>	\$689	\$205	\$138	\$314	\$1,467	\$210	\$94
ECONOMIC OUTPUT							
<i>Economic Output</i>	\$1,369	\$458	\$1,948	\$1,354	\$4,702	\$1,204	\$5,152
ALL BENEFITS	\$6,359	\$4,201	\$6,662	\$6,523	\$5,190	\$8,844	\$7,843

Note: values are in dollars (\$2006), in present value terms, and divided by the average population between 2006 and 2031 in each region

As before, the above sub-regional distribution is based on the distribution of trip *origins*, and thus does not correspond to the residents of each region.

Figure 15 illustrates the relative magnitudes of the various components of the overall benefits for each sub-region. Congestion management benefits make up the greatest value of overall benefits (60 percent of the total benefits), followed by the increase in economic output (22 percent), community development (11 percent) and enhanced mobility (8 percent)¹⁰. Figure 16 outlines the regional per capita benefits obtained from the DRTP implementation.

Figure 15: Breakdown of Estimated Benefits of the Draft Regional Transportation Plan, by Region, 2010-2031 (\$ billion, present value, 2006 dollars)

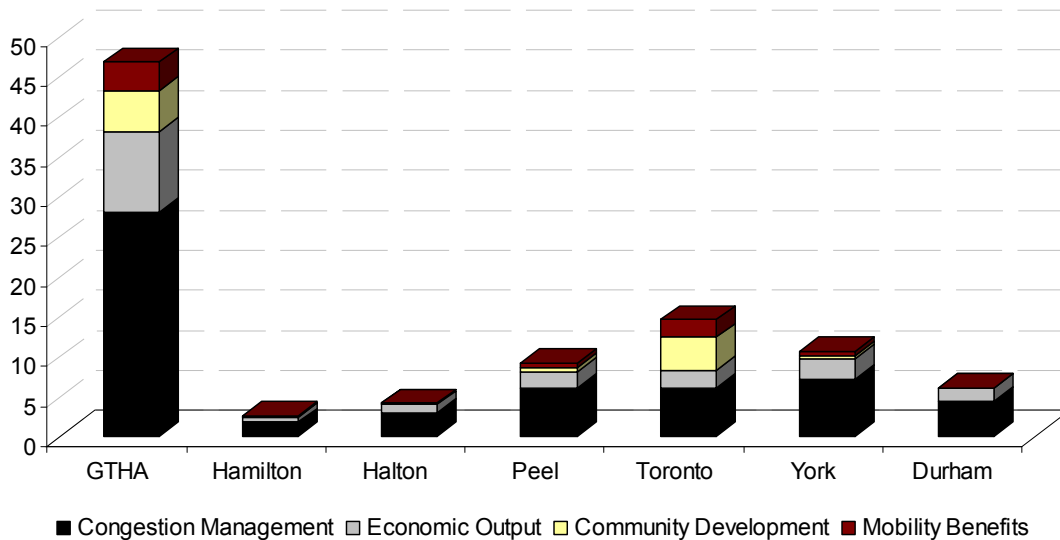
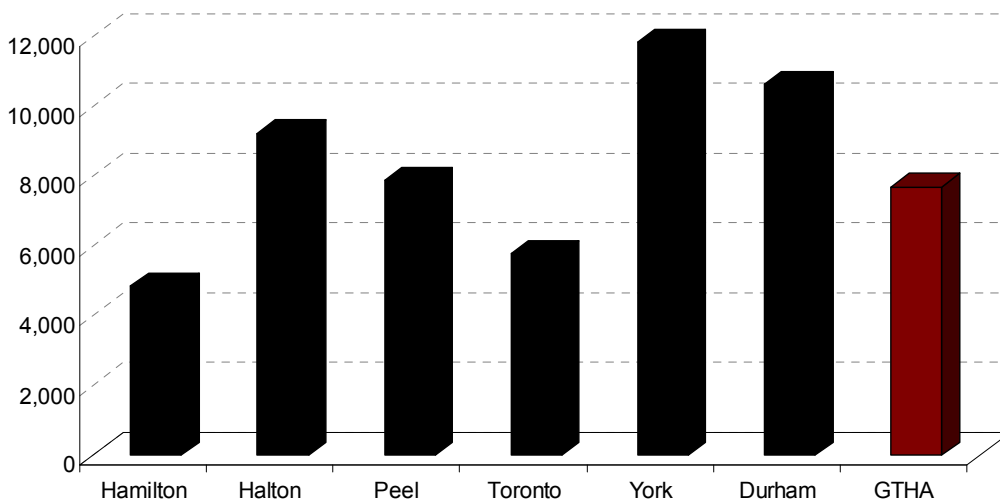


Figure 16: Comparison of Estimated Benefits per Capita of the 25-Year DRPT, by Region (\$/capita, present value, 2006 dollars)



¹⁰ Note that the sum exceeds 100 percent due to rounding.

The estimated benefits of the Draft Regional Transportation Plan significantly outweigh the expected costs of its implementation. The mean net present value (NPV) is \$15.5 billion (with a 90 percent confidence interval of \$12.6 billion to \$21.2 billion). This is equivalent to a 19 percent internal rate of return (IRR). These measures of the ‘value for money’ are outlined in Table 8.

Table 8: Evaluation Metrics of the 25-Year DRTP

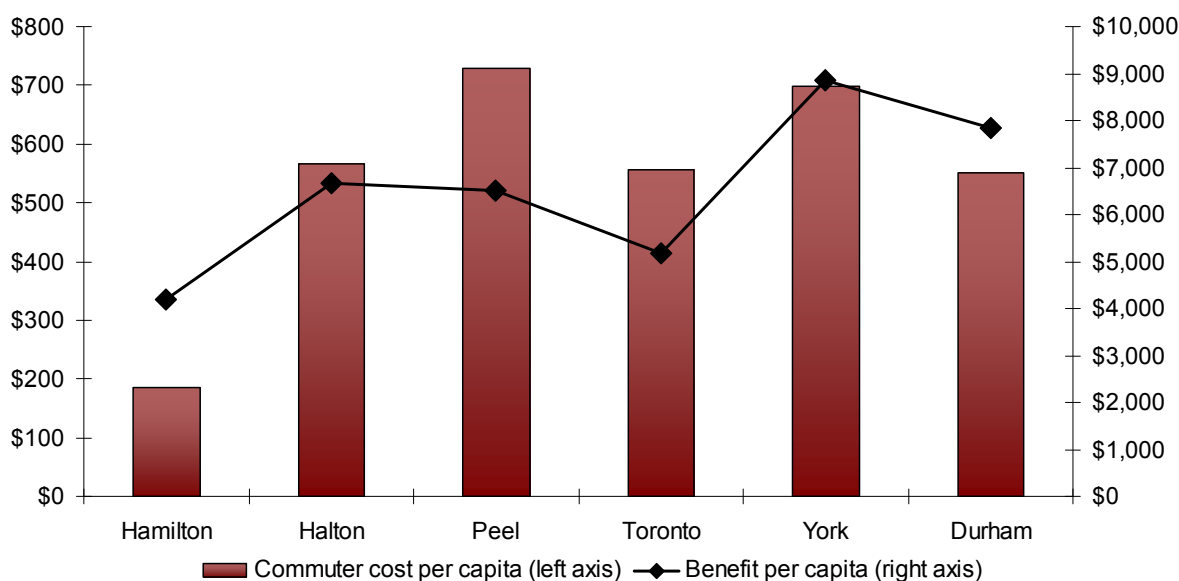
INDICATOR - VALUE FOR MONEY	MEAN	10 th PERCENTILE	90 th PERCENTILE
Total Costs (Present Value)	\$31,156	N/A	N/A
Total Benefits (Present Value)	\$46,674	\$43,811	\$52,408
Net Present Value (at 5%)	\$15,519	\$12,620	\$21,249
INTERNAL RATE OF RETURN	19.0%	18.1%	24.2%

Note: values are in millions of dollars (\$2006), in present value terms

The current level of congestion in the GTHA results in a reduction of 25,962 jobs. Over the study period of 2006-2031, the DRTP portends to create 18,000 jobs relative to the ‘business as usual case’ case, due to the reduction in excess congestion.

Finally, Figure 17 provides an indication of the equity of the DRTP across the sub-regions of the GTHA. It shows that the magnitudes of the anticipated benefits of the DRTP are strongly related to the current cost of congestion experienced in each region (on a per capita basis).

Figure 17: Regional Distribution of Benefits Relative to Current Congestion Cost, Over the 25-Year DRTP



Commuter cost per capita: 2006 cost of congestion to commuters, divided by regional population
Benefit per capita: present value of benefits due to RTP implementation, 2006-2031

Like any regional economy, there are two ways in which the GTHA regional economy can grow, by increased productivity (output per worker) or increased number workers. The preponderance of economic benefit from the DRTP arises in the form of greater productivity due to the reduction in traffic delays. But the DRTP creates more jobs as well. By reducing costs and expanding markets for retailers, service industries and manufacturers, these sectors will employ more people.

If, once fully implemented in 2031, the DRTP were to eliminate all excess congestion, there would be 42,000¹¹ more jobs in the region in any given year than would otherwise be the case. However, since the DRTP is not projected to eliminate all excess congestion, the number of additional jobs in the region would be somewhat less, about 18,000¹² more jobs in any given year.

The jobs above would arise across all sectors of the economy, such as retail, food service, entertainment, etc. Such jobs are on top of the temporary direct and indirect (and induced) jobs that DRTP construction projects would generate.

In any given year, there would be fully 18,000 more jobs in the region than would be the case without the plan. Another way of saying this is that by reducing congestion there would be 450,000 more person-years of employment (25 x 18,000). On top of this is the number of jobs created by the DRTP construction projects themselves, numbering some 430,000¹³. The jobs impact is calculated in the next chapter. It is important to note that these construction jobs are not counted as a benefit of the DRTP in the cost-benefit analysis, as these jobs to a large extent reflect a transfer of resources from other activities that would be undertaken.

Appendix 4 contains an overview of the theoretical cost-benefit framework employed, including an explanation of how the various benefits and costs are calculated.

¹¹ In the absence of excess congestion, the GTHA would have 26,000 more jobs in 2006 and, based on forecasted increases in congestion, would have 58,000 more jobs in 2031. 42,000 represents the average number of jobs that would be gained over the 25-year study period if excess congestion was eliminated.

¹² 18,000 jobs was calculated as follows:

$$42,000 \times \frac{\text{Present Value of DRTP Congestion Management Benefits}_{2010-2031}}{\text{Present Value of Congestion Cost}_{2006-2031}}$$

¹³ Metrolinx estimate, based on Ontario government estimates of 10,000 jobs created per billion of expenditure, is 500,000 jobs. The impact analysis below estimates the job impact to be slightly less.

CHAPTER 4: THE MACROECONOMIC IMPACT OF THE DRAFT REGIONAL TRANSPORTATION PLAN

The economic impacts of the Draft Regional Transportation Plan (DRTP) are estimated as direct, indirect, and induced impacts of the investment expenditures related to the DRTP. All impacts are estimated in terms of incremental business revenue, jobs, employment income, GDP, and tax revenues within the province of Ontario.

The impacts are estimated on the basis of the Ontario-share of the expenditures necessary to implement the proposed plan, including expenditures for the following goods and services:

1. Engineering, design, and management;
2. Construction and civil works;
3. Vehicles, locomotives, and rail cars, and
4. Machinery (non-vehicles equipment).

Table 9 shows the amount of expenditures related to the DRTP that would take place in Ontario and that provided the basis for impact estimation. As the table shows, the estimated DRTP expenditures to be made within Ontario amount to about \$33.9 billion, or 71 percent of the estimated total capital expenditure of \$48 billion.

Table 9: Estimated DRTP Expenditures for Goods and Services of Ontario Suppliers

CONSTRUCTION EXPENDITURES BY TYPE	AMOUNT OF ONTARIO EXPENDITURES (\$ MILLIONS)
Engineering, Design, Management	3,006
Construction and civil works	20,377
LRT vehicles	671
BRT vehicles	1,905
Subway Cars	999
Locomotives	402
Rail Fleet	5,807
Machinery (non-vehicles)	759
TOTAL	33,926

Source: Estimated by HDR based on expenditure shares by mode and category of expenditures provided by Metrolinx

The direct output, or business revenue impact, of expenditures shown in Table 9 is equal to the amount of expenditures itself. Direct employment, employment income, and GDP are estimated on the basis of economic impact ratios for direct effects that are available from Statistics Canada's inter-provincial input-output model. For example, the employment-output ratio gives the average number of jobs per \$1 million of business output. Therefore, multiplying the amount of expenditures for an industry product by its employment-output ratio will give an estimate of the number of incremental direct jobs that would be created as a result of the expenditure in question.

Indirect and induced impacts are estimated applying input-output techniques and using multipliers from Statistics Canada Inter-Provincial Input-Output Model. Tax revenue impacts are estimated on the basis of estimated employment and average tax revenues collections in the province (i.e. a number derived as total tax revenue in Ontario by type/category divided by total Ontario employment). Appendix 5 contains additional detail regarding the theory and application of the macroeconomic impact analysis.

In economic impact analysis, frequently evaluated metrics of impact are: output, employment, employment income, and GDP. Output is defined as the sum of gross business revenue across all affected business establishments. Employment is the number of jobs (both full-time and part-time). Employment income is the value of wages and salaries, supplementary labour income, and propriety income. GDP, or the Gross Regional Product, is the sum of a value added at every stage of production of final goods and services.

RESULTS

Table 10 presents the output, employment, employment income, and GDP impact in Ontario that would result from the DRTP investment expenditure. Table 11 presents the tax revenue impacts of the investment broken down by level of government.

Table 10 shows the total output impact of the DRTP investment projects amount to over \$69.6 billion, including \$33.9 billion of the original expenditures that would take place in Ontario, nearly \$21 billion in indirect or spin-off effects, and \$14.7 billion of induced impacts. The plan will create an estimated 429,528 jobs, including 153,795 direct jobs, 116,126 indirect jobs, and 159,607 induced jobs. These jobs would generate an employment income effect of nearly \$21 billion, including \$9.4 billion of direct employment income, \$5.9 billion of indirect income and \$5.6 billion induced income. The DRTP projects will result in an increase in Ontario's GDP of over \$31 billion. This estimate includes over \$12.4 billion of direct GDP, \$9.4 billion of indirect GDP, and \$9.4 billion of induced GDP

Table 11 shows that the total tax revenue impact of the DRTP is estimated at over \$14.8 billion. This includes \$1.9 billion in local and municipal tax revenues, \$6.8 billion of provincial tax revenues, and \$6 billion of federal tax revenues. These tax revenues include all sources of taxation, in particular personal income taxes, corporate income taxes, property taxes, and consumption taxes.

It should be noted that all results presented in the tables represent the cumulative impact over the period when expenditures shown in Table 11 would be made. The annual impact of the DRTP would be equal to the proportion of expenditures made in a particular year. For example, if all expenditures were equally distributed over a period of 25 years, the annual impact of the DRTP in each year (during this 25-year period) could be calculated by dividing all numbers shown in Table 10 and Table 11 by a factor of 25. After the 25-year period, all impacts would be zero.

A distinction should also be made in interpreting the output and GDP values provided in Table 10. These values are related to the economic impact that the DRTP investment would have through the construction of the various component projects of the plan. It is not related to the

impact that excess congestion has on the regional economy by decreasing output (as per Chapter 2), or the benefit of the DRTP in increasing output through a reduction in traffic congestion (as per Chapter 3).

Table 10: Output, Employment, Employment Income, and GDP Impacts in Ontario of the DRTP Investment

TYPE OF IMPACT	OUTPUT (\$M)	EMPLOYMENT (\$M)	EMPLOYMENT INCOME (\$M)	GDP (\$M)
<i>Direct Impacts by Type of Expenditures</i>				
Engineering, Design, Management	\$3,006.5	27,803	\$1,839.2	\$2,044.0
Construction and civil works	\$20,376.9	103,682	\$5,789.7	\$8,141.0
LRT vehicles	\$671.0	1,237	\$111.7	\$120.8
BRT vehicles	\$1,904.7	4,639	\$294.3	\$530.2
Subway Cars)	\$998.8	1,842	\$166.3	\$179.9
Locomotives	\$401.7	741	\$66.9	\$72.3
Rail Fleet	\$5,807.0	10,708	\$966.9	\$1,045.7
Machinery (non-vehicles)	\$759.1	3,144	\$205.2	\$323.5
TOTAL DIRECT IMPACT	\$33,925.6	153,795	\$9,440.2	\$12,457.5
INDIRECT IMPACTS	\$20,969.7	116,126	\$5,891.8	\$9,391.8
INDUCED IMPACTS	\$14,756.0	159,607	\$5,643.6	\$9,422.2
TOTAL IMPACTS	\$69,651.3	429,528	\$20,975.6	\$31,271.5

NOTES: Output is defined as the sum of gross business revenue across all affected business establishments. Employment is the number of jobs (both full-time and part-time). Employment income is the value of wages and salaries, supplementary labour income, and propriety income. GDP, or the Gross Regional Product, is the sum of a value added at every stage of production (the intermediate stages) of final goods and services.

Table 11: Tax Revenue Impact in Ontario of the DRTP Investment

LEVEL OF GOVERNMENT	TAX REVENUE (\$M)
Local/ Municipal	\$1,942.7
Provincial	\$6,846.3
Federal	\$6,028.1
TOTAL TAX REVENUE	\$14,817

APPENDIX 1: PROFILE OF CONGESTION BY TIME, PLACE AND TYPE

A1.1 Amount of Congestion by Region

Metrolinx has modeled and profiled the recurrent congestion on the road network of its regions for its DRTP report. As distinct from congestion that results from traffic incidents, recurrent congestion results from the interaction of limited road capacity and traffic volumes under normal conditions. The profile of this congestion was based on analysis with the Greater Golden Horseshoe travel demand model. The road network represented in the model encompasses all expressways, tollways, major and minor arterials, collectors, and important local roads.

Table 12: Daily Vehicle-kilometres Traveled by Sub-Region in the AM Peak Period, 2006

REGION	REGION NAME	AM PEAK	VKT IN REGION AS PERCENTAGE OF TOTAL VKT IN GTHA
1	City of Hamilton	1,791,463	5.8%
2	Halton Region	3,606,596	11.6%
3	Peel Region	6,421,952	20.6%
4	City of Toronto	9,296,614	29.9%
5	Region of York	6,134,044	19.7%
6	Durham Region	3,874,073	12.4%
TOTAL GREATER TORONTO AND HAMILTON AREA (GTHA)		31,124,742	100.0%

Source: IBI

Table 10 shows the Travel Time Index (TTI) for each sub-region in the GTHA. The TTI is the ratio of peak period travel time to free-flow travel time, expressing the average amount of extra time it takes to travel during congested time periods. As an example, in Toronto the TTI is 1.88, which indicates that a trip that would take 20 minutes in free-flow conditions will take 38 minutes during the peak travel time periods, an 18-minute (or 88 percent) travel time penalty.

Table 13: Travel Time Index Values for Sub-Areas within the GTHA, 2006

REGION	REGION NAME	HOURS OF DELAY PER 1,000 VEHICLE-KILOMETRES OF TRAVEL	TRAVEL TIME INDEX
1	City of Hamilton	653	1.31
2	Halton Region	876	1.44
3	Peel Region	1,798	1.75
4	City of Toronto	2,284	1.88
5	Region of York	1,369	1.59
6	Durham Region	1,021	1.46
TOTAL GREATER TORONTO AND HAMILTON AREA (GTHA)		1,494	1.63

Source: HDR Calculations

A1.2 Non-Recurrent Congestion Delay

Non-recurrent congestion can stem from any of the four causes identified by the United States Federal Highway Administration (FHWA): roadway construction, bad weather, special events (such as concerts), and incidents. “Incidents” includes traffic accidents, disabled vehicles, and spilled cargo. It should be noted that the impact of non-recurrent congestion delay was not accounted for explicitly in this model; however, to the extent that such non-recurrent “incidents” decrease the average travel speed observed in each sub-region, the effect of such delays will be included indirectly to some extent.

APPENDIX 2: APPROACH TO MEASURING EXCESS TRAFFIC CONGESTION

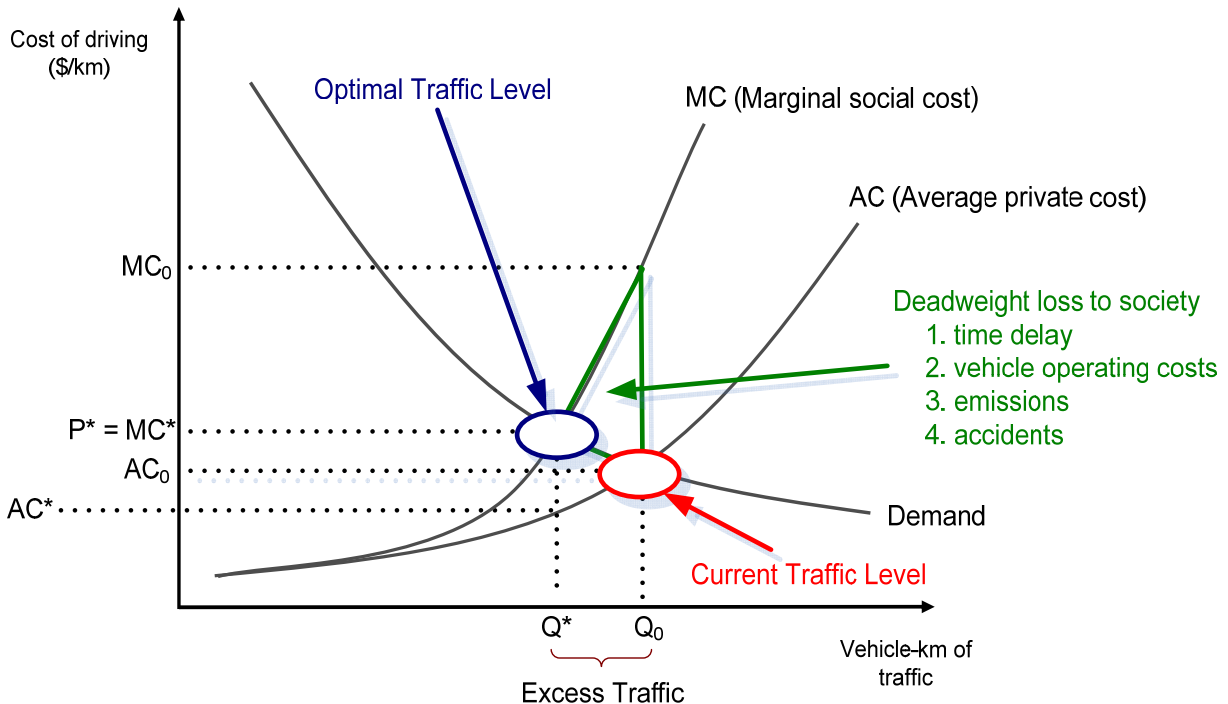
The focus of this section of the analysis is on the economic costs of *excess congestion*, above the level that represents efficient use of road capacity. To acknowledge that some level of congestion is efficient is simply to recognize that increased traffic means additional movements of people and goods, and that these movements yield benefits, for example by generating demand for goods and services offered by local businesses, or by establishing a system of deliveries for those businesses. Therefore, a study that focused on the economic costs of *total* road congestion, relative to travel times under free-flow conditions, would exaggerate the congestion problem.

This section defines in detail the concept of excess congestion and outlines the approach to its measurement.

A2.1 Economic Theory of Travel Demand in Congested Conditions

Figure 18 below presents the traditional modeling of travel demand and travel costs under conditions of high traffic congestion.

Figure 18: Approach to Estimation of Efficient Traffic Volume, or “Tipping Point”



- Average private cost = vehicle operating costs + personal value of time
- Marginal social cost = vehicle operating costs + personal value of time + external value of time + emissions + accidents

The figure above shows the demand for travel (in terms of vehicle-kilometres traveled), as a function of the costs of driving. Drivers face a cost of driving which includes both car operating costs (gasoline, oil, maintenance, tires, and insurance) as well as the time cost of driving. The time cost increases as traffic on the road increases because higher traffic volumes reduce the overall travel speed and thus increases the time cost of the driving component. The average private cost function is illustrated in Figure 18 by the curve labeled AC. The curve is upward sloping to show that the costs of driving increase as the number of vehicle-kilometres traveled increases. The curve is flat as it approaches the zero vehicle-kilometres traveled point to show that there are some fixed costs, such as insurance and perhaps car loan payments.

The curve labeled MC in the figure represents the social marginal costs of driving, or the incremental costs of driving imposed by each additional vehicle entering the road. A key property of this relationship is that the same increment in traffic produces a larger cost for existing traffic, the higher the level of existing traffic. Or, in other words, the marginal cost is increasing with the level of traffic. This is somewhat analogous to what happens when a person jumps to the front of a queue. The longer the line, the greater is the number of people in the line behind the queue-jumper who are delayed.

The MC curve, the marginal social cost of driving, is above the AC curve, the average private cost of driving, because of four factors: the cost of time, operating costs, and the social costs of pollution, and accidents.

That is to say, traffic congestion has costs in wasted time, increased operating costs (more fuel; oil; tires; maintenance and repairs; and depreciation), more accidents, and degraded air quality (local pollution and greenhouse gases).

The market equilibrium occurs at the traffic level that corresponds to the point where the average private cost of driving curve intersects the travel demand curve. This equilibrium is shown as the “Current Traffic Level” at a volume vehicle-kilometres traveled of Q_0 and the corresponding private cost of driving AC_0 .

The efficient traffic volume occurs at the traffic level that corresponds to the point where the marginal social cost curve intersects the travel demand curve. This point is denoted as the “Optimal Traffic Level”, which is at a volume of Q^* vehicle-kilometres traveled. The economically efficient level of congestion would occur if travelers altruistically took the external cost they impose on other road users into account when making their travel decisions. Any traffic volume beyond congestion above this level is excess congestion. In Figure 18, excess congestion is represented graphically by the distance between Q_0 and Q^* .

It is excess congestion, not total congestion, which should concern policy makers and transportation planners. If congestion is above the equilibrium, that is, above the tipping point, the transportation system is not running as efficiently as it could and resources (money, time, the environment etc.) are being wasted. If excess congestion above the tipping point is reduced, society will be better off.

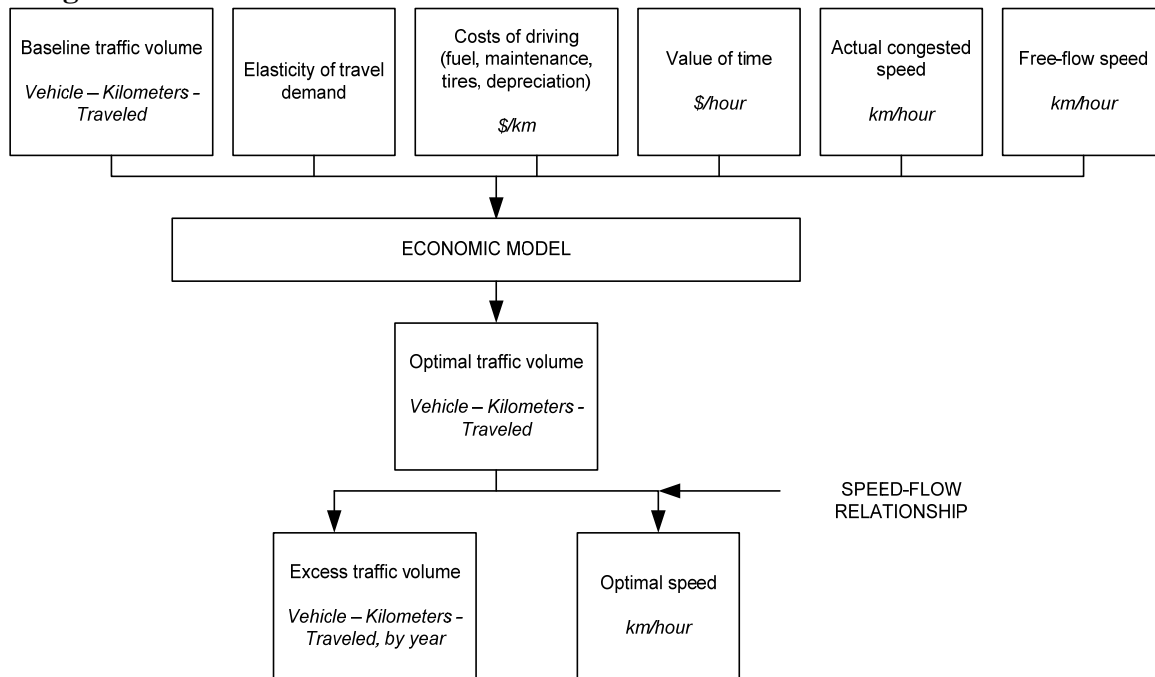
HDR uses the concepts of demand for auto travel, costs of auto travel, speed, and the value of time and other non-market costs in order to estimate the magnitude of the deadweight loss owing to excess congestion.

Deadweight loss is the term used by economists to describe the net loss in economic resources, or economic welfare, which arises under congestion. Mathematically, this deadweight loss is equal to the difference between the social benefit and the social cost of each incremental trip beyond the tipping; or in other words, the triangular area shown in Figure 18, which is equivalent to $\int_{Q^*}^{Q_0} (MC - AC)dQ$. Conceptually, the deadweight loss encompasses all losses in economic value due to the excess congestion.

A2.2 The Theory in Practice

Figure 19 below shows a high level summary of this approach to estimate excess congestion with key input variables. The variable called “elasticity of travel demand” measures the sensitivity of vehicle-kilometres traveled with respect to the generalized cost of driving, or the percent change in vehicle-kilometres traveled for each 1 percent change in costs of driving.¹⁴

Figure 19: High-level Summary of Modeling Framework for Estimation of Excess Congestion



¹⁴ For example, elasticity of travel demand equal to -0.9 would indicate that vehicle-kilometres traveled decline by 9 percent when costs of travel increase by 10 percent.

The rectangle labeled “Economic Model” represents the modeling exercise described above that involves calculation of average costs, marginal costs, and an iterative procedure¹⁵ to find the traffic volume at which the social marginal cost of driving is equal to the full market costs of driving (or where the social marginal cost curve intersects the demand curve).

The label “speed-flow relationship” refers to the calculation of the actual speed given the existing traffic and road capacity level using the expression (the BPR curve) introduced below.

The final outputs of this framework, excess traffic volume and economically optimal speed¹⁶ are then used to estimate various economy-wide cost impacts of congestion. These results are discussed in the next section.

A2.3 Detailed Framework Implementation

The quantitative magnitude of excess congestion as represented by distance $Q*Q_0$ in Figure 18 can be derived from the average cost curve, marginal cost curve, and the demand curve. Figure 19 provides a summary overview with key inputs required for framework implementation.

This section provides an overview of the specific concepts used in the economic model and the derivation of excess congestion.

Average Costs of Driving and Average Cost Curve (AC)

The average cost of driving is assumed to be equal to the monetary costs of driving (that includes fuel, maintenance, insurance, etc.) and opportunity cost of time spent driving. This cost can be expressed as:

$$AC = c + b/v,$$

where c is the monetary cost of driving and b/v is the value of time divided by average effective or congested speed, representing the time cost of driving. The monetary cost of driving is assumed to be constant on a per vehicle-kilometre basis. However, the time cost of driving increases as the average effective speed falls.

The average effective speed was modeled using the speed-flow relationship commonly referred to as the BPR curve.¹⁷ A speed-flow relationship calculates the actual speed as a function of road congestion and speed in conditions of ‘no congestion’ and ‘no travel delays’ (referred to as the “free-flow speed”). The speed-flow relationship used in this study is of the following form:

¹⁵ The iterative procedure involves finding the intersection point between the marginal cost curve and the demand curve. Assuming a certain travel demand function and calibrating it so that it is consistent with the average cost curve, one is able to determine the optimal equilibrium volume when the demand curve intersects with the marginal cost curve. The difference between the current market traffic volume and the economically optimal volume represents excess congestion. The speed-flow relationship (discussed below) can then be used to calculate the vehicle speeds corresponding to the economically optimal volume.

¹⁶ The ‘economically optimal speed’ refers to the implied speed that would result given that the optimal volume of traffic exists. It may not be economically optimal for many user groups, such as cyclists or pedestrians.

¹⁷ The BPR curve refers to the speed-flow relationship developed by the US Bureau of Public Roads. The BPR speed-flow relationship is frequently adopted for economic analysis and modeling of congestion.

$$v = v_0/[1 + a_1(Q/CAP)^{a_2}],$$

where

v = congested speed;

v_0 = free-flow speed;

Q = volume of travel;

CAP = road capacity, and

a_1 and a_2 are the coefficients on the BPR curve. ($a_1 = 0.05$ and $a_2 = 10$)

Note that volume of travel divided by road capacity is equal to the VC ratio, or congestion level at which travel occurs, i.e.:

$$Q/CAP = VC_Ratio$$

Marginal Social Cost Curve (MC)

The marginal cost curve is derived from the total cost curve as follows:

$$TC = AC \cdot Q,$$

where

TC = total social costs;

Q = volume of travel, and

AC = average private cost of driving shown earlier.

Then, using the definition of marginal costs as the differential of total costs¹⁸ and the expressions derived earlier we have:

$$MC = \partial TC / \partial Q = AC + Q \cdot \partial AC / \partial Q, \text{ and}$$

$$MC = c + b/v_0 \cdot [1 + d_1(Q/CAP)^{d_2}]$$

where MC is the marginal cost and d_1 and d_2 are coefficients on the marginal cost curve.

Demand Curve

The demand for auto traffic is a function of its generalized cost: $D = f(AC)$. The position of the demand curve is estimated based on observed traffic volumes relative to the estimated average and marginal cost curves. The shape of the demand curve is estimated by assuming a constant elasticity demand curve of the form: $X = aP^\epsilon$

where

¹⁸ Marginal costs can also be thought of the cost of the incremental, or marginal, unit of travel.

X = quantity demanded;
a = a constant;
P = generalized cost; and
ε = elasticity of demand with respect to the generalized cost.

The Value of Travel Time

The value of time is based on the U.S. Department of Transportation methodology. Household income was obtained from the Census and converted into an hourly wage rate. 50 percent of the hourly wage rate is then used to determine the base hourly value of time¹⁹. This value was then scaled up by a factor of 2.5 that applied to the proportion of traffic occurring during the highest peak travel times (which is 40 percent of the traffic that occurs during the 3 hour AM peak period). This is done to account for the higher value of time that is placed on the greater unreliability of travel times during peak periods²⁰; this is especially relevant for the case of trips made during AM peak periods where the arrival time is less flexible. More detail on the value of time can be found at the beginning of Appendix 6.

Emissions Costs

One social cost of road congestion is the damage to health and property and other adverse effects from increased vehicle emissions. For slow-moving traffic, particularly with frequent cycles of acceleration and braking, rates of vehicle emissions are relatively high. Among the vehicle emissions to be concerned about are pollutants such as carbon monoxide, volatile organic compounds, nitrous oxides, sulfur dioxide, and road dust and particulate matter. Vehicle emissions, particularly of carbon dioxide, may also impose costs on society by contributing to climate change, but the magnitude of these costs is very uncertain, and they are not estimated in the present study.

For the GTHA, emission volumes were provided by the travel demand model (see list of regional data below). The cost of emissions for autos is based on the average of values from Small and Verhoef (2007)²¹ and Transport Canada (2004)²².

Calculation of auto emissions cost:

\$0.016	\$US/vehicle-mile (2005 prices)
* 0.621	mile/km
* 1.212	CDN/US exchange rate (2005 average)
* <u>1.020</u>	<u>CDN inflation from 2005-2006</u>
= \$0.012	\$CDN/vehicle-km (2006 prices)
* Source: Small & Verhoef, 2007	

¹⁹ This approach is also that utilized in Transport Canada's TransDec framework.

²⁰ Valuation of Travel-Time Savings and Predictability in Congested Conditions for Highway User-Cost Estimation, National Cooperative Highway Research Program Report 431, Kenneth A. Small, Robert Noland, Xuehao Chu, David Lewis, Transportation Research Board, National Research Council, 1999.

²¹ Small & Verhoef, 2007, "The Economics of Urban Transportation"

²² Transport Canada, 2004, "Towards Estimating the Social and Environmental Costs of Transportation in Canada"

\$0.008	full cost of air pollution: urban auto (\$/pax-km, \$2002 CDN)
+ \$0.001	full cost of greenhouse gas emissions: urban auto (\$/pax-km, \$2002 CDN)
= \$0.010	total cost of urban auto emissions (\$/pax-km, \$2002 CDN)
* 1.202	average auto occupancy rate (# of passengers per vehicle)
* 1.091	CDN inflation from 2002-2006
= \$0.013	<u>\$CDN/vehicle-km, 2006 prices</u>

* Source: Transport Canada, 2004

Accident Costs

As the level of traffic increases, so too does the number of accidents (due to both the higher likelihood of an accident due to congestion, and a higher overall number of accidents due to the inefficiently high volume of traffic). The social cost of accidents is comprised of both health costs and property damage. The cost is based on the accident cost values found in Small and Verhoef (2007).

Calculation of accident cost:

\$0.140	\$US/vehicle-mile (2005 prices)
* 0.621	mile/km
* 1.212	CDN/US exchange rate (2005 average)
* 1.020	CDN inflation from 2005-2006
= \$0.107	<u>\$CDN/vehicle-km (2006 prices)</u>

* Source: Small & Verhoef, 2007

APPENDIX 3: CONGESTION COST MODEL RESULTS

A3.1 The Cost of Congestion to GTHA Commuters

The focus of this section of the analysis is the economic costs of *excess congestion*, above the level that represents efficient use of road capacity. To acknowledge that some level of congestion is efficient is simply to recognize that increased traffic means additional movements of people and goods, and that these movements yield benefits; for example, by generating demand for goods and services offered by local businesses, or by establishing a system of deliveries for those businesses. Therefore, a study that focused on the economic costs of *total* road congestion, relative to travel times under free-flow conditions, would exaggerate the congestion problem.

Appendix 2 outlined the theory used to compute the excess cost of congestion; Appendix 3 provides details on the results of the economic analysis.

Excess Traffic and Economically Optimal Speed

Table 14 below shows the estimated excess volume of traffic. The table demonstrates that the excess traffic amounted to over 4.5 million vehicle-kilometres each day during morning peak hours.

The extent of excess traffic varies slightly between sub-regions, from 13.7 percent to 15.4 percent.

Table 14: Estimated Excess Daily VKT by Sub-Region in the AM Peak Period, 2006

REGION	REGION NAME	EXCESS VKT	EXCESS VKT AS PERCENTAGE OF ACTUAL
		AM PEAK VKT	AM PEAK VKT
1	City of Hamilton	245,928	13.7%
2	Halton Region	538,769	14.9%
3	Peel Region	988,210	15.4%
4	City of Toronto	1,302,580	14.0%
5	Region of York	925,504	15.1%
6	Durham Region	584,266	15.1%
TOTAL GREATER TORONTO AND HAMILTON AREA (GTHA)		4,585,257	14.7%

Source: AM Peak VKT from IBI, Excess VKT based on HDR calculations

Table 15 shows the estimated average speeds that would result under the economically optimal volume of traffic (i.e. if current traffic was reduced by the amount of the excess traffic). In order to facilitate comparison with the actual conditions, actual average speeds are also shown in this table.

Table 15: Comparison of Actual and Economically Optimal Speeds²³ by Sub-Region, 2006

REGION	REGION NAME	ACTUAL SPEEDS	ECONOMICALLY OPTIMAL SPEEDS	REDUCTION IN ACTUAL SPEED COMPARED TO ECONOMICALLY OPTIMAL
		(KM/HR)	(KM/HR)	(%)
		AM PEAK	AM PEAK	AM PEAK
1	City of Hamilton	60.8	75.0	19.0%
2	Halton Region	63.3	84.5	25.1%
3	Peel Region	47.5	73.7	35.6%
4	City of Toronto	42.0	69.0	39.2%
5	Region of York	52.4	75.7	30.7%
6	Durham Region	57.1	77.1	25.9%
TOTAL GREATER TORONTO AND HAMILTON AREA (GTHA)		50.6	74.6	32.1%

Source: Actual speeds from IBI, optimal speeds based on HDR calculations.

Excess Total Travel Delay and Cost

Table 16 reports the total hours of excess travel delay in the GTHA for auto users. Overall, the entire region experiences almost 360,000 hours of delay each day in the AM peak period. These delays translate into 11 minutes of delay per Region's resident per day (assuming delays in the morning and afternoon rush hours), or almost 50 hours per year.

The costs of these delays (or the value of lost travel time) in the entire GTHA amount to \$8.6 million per day, or \$2.2 billion per year (see Table 17). These total costs are equivalent to a cost of \$4.62 per GTHA resident per day or almost \$1,200 per year.

Table 18 shows the cost of delay to transit users; the value is much smaller than that for auto users, but still amounts to nearly \$330 million per year in the GTHA.

²³ Note that these speeds are based on a weighted average of travel between highways and within city centers, with a majority of the vehicle-kilometres occurring on highways, thus accounting for the actual and optimal speeds being higher than the typical posted speed limits within city centres.

Table 16: Excess Total Travel Delay, 2006

REGION	REGION NAME	AM PEAK		MINUTES PER DAY, PER COMMUTER	HOURS PER YEAR, PER COMMUTER
		HOURS PER DAY	HOURS PER YEAR		
1	City of Hamilton	9,002	2,340,523	4.8	21
2	Halton Region	24,314	6,321,584	7.8	34
3	Peel Region	88,844	23,099,566	11.1	48
4	City of Toronto	163,319	42,463,052	15.6	67
5	Region of York	64,596	16,794,912	12.9	56
6	Durham Region	30,419	7,909,060	8.8	38
TOTAL GREATER TORONTO AND HAMILTON AREA (GTHA)		357,759	93,017,265	11.5	50

Source: HDR calculations

Table 17: Monetary Value of Excess Travel Delays – Auto Users, 2006

REGION	REGION NAME	PER DAY	PER YEAR
1	City of Hamilton	\$106	\$27,437
2	Halton Region	\$545	\$141,712
3	Peel Region	\$2,451	\$637,133
4	City of Toronto	\$3,803	\$988,841
5	Region of York	\$1,634	\$424,728
6	Durham Region	\$754	\$196,100
TOTAL GREATER TORONTO AND HAMILTON AREA (GTHA)		\$8,635	\$2,245,129
GTHA REGION TOTAL PER CAPITA (\$)		\$4.62	\$1,200.36

Source: HDR calculations

Table 18: Monetary Value of Excess Travel Delays – Transit Users, 2006

REGION	REGION NAME	PER DAY	PER YEAR
1	City of Hamilton	\$98	\$25,525
2	Halton Region	\$68	\$17,608
3	Peel Region	\$165	\$43,009
4	City of Toronto	\$704	\$183,031
5	Region of York	\$168	\$43,562
6	Durham Region	\$59	\$15,334
TOTAL GREATER TORONTO AND HAMILTON AREA (GTHA)		\$1,262	\$328,069
GTHA REGION TOTAL PER CAPITA (\$)		\$0.21	\$54.13

Source: HDR calculations

Excess Commuting Delay and Delay Cost

Table 19 converts travel delays experienced by workers who commute to work by car into monetary values (the value of lost travel time).

Table 19: Monetary Value of Excess Commuting Delay (Value of Lost Travel Time) by Sub-Region of Travel, \$ per Auto Commuter, 2006

REGION #	REGION NAME	PER DAY	PER YEAR
1	City of Hamilton	\$0.94	\$245
2	Halton Region	\$2.91	\$757
3	Peel Region	\$5.08	\$1,322
4	City of Toronto	\$6.04	\$1,570
5	Region of York	\$5.44	\$1,415
6	Durham Region	\$3.65	\$949
TOTAL GREATER TORONTO AND HAMILTON AREA (GTHA)		\$4.62	\$1,200

Source: HDR calculations

As Table 19 shows, the total average cost of the commuting delays in the GTHA amounts to \$1,200 per commuter per year; in the City of Toronto the cost is \$1,570 per year. Tables 20- 22 summarize the daily and annual cost of excess vehicle operating costs, excess accident costs and excess vehicle emissions costs, respectively.

Table 20: Excess Vehicle Operating Costs, 2006

REGION	REGION NAME	DAILY TOTAL COST, \$	TOTAL ANNUAL, \$ MILLIONS
1	City of Hamilton	\$98,863	\$26
2	Halton Region	\$216,585	\$56
3	Peel Region	\$397,260	\$103
4	City of Toronto	\$523,637	\$136
5	Region of York	\$372,052	\$97
6	Durham Region	\$234,875	\$61
TOTAL GREATER TORONTO AND HAMILTON AREA (GTHA)		\$1,843,273	\$479
GTHA REGION TOTAL PER CAPITA (\$)		\$0.15	\$39.5

Source: HDR calculations

Table 21: Excess Accident Costs, 2006

REGION	REGION NAME	DAILY TOTAL COST, \$	TOTAL ANNUAL, \$ MILLIONS
1	City of Hamilton	\$52,865	\$14
2	Halton Region	\$115,813	\$30
3	Peel Region	\$212,425	\$55
4	City of Toronto	\$280,002	\$73
5	Region of York	\$198,945	\$52
6	Durham Region	\$125,593	\$33
TOTAL GREATER TORONTO AND HAMILTON AREA (GTHA)		\$985,643	\$256
GTHA REGION TOTAL PER CAPITA (\$)		\$0.16	\$42.3

Source: HDR calculations

Table 22: Excess Vehicle Emissions Costs, 2006

REGION	REGION NAME	DAILY TOTAL COST, \$	TOTAL ANNUAL, \$ MILLIONS
1	City of Hamilton	\$6,114	\$2
2	Halton Region	\$13,395	\$3
3	Peel Region	\$24,569	\$6
4	City of Toronto	\$32,385	\$8
5	Region of York	\$23,010	\$6
6	Durham Region	\$14,526	\$4
TOTAL GREATER TORONTO AND HAMILTON AREA (GTHA)		\$113,999	\$30
GTHA REGION TOTAL PER CAPITA (\$)		\$0.02	\$4.9

Source: HDR calculations

A3.2 The Cost of Congestion to the GTHA Economy

This section presents the general methodology for estimating the economy-wide impacts of excess traffic congestion, as a result of:

- Excess traffic (compared to the economically optimal volume of traffic); and,
- Reduced average speed.

These two key measures and the implications of congestion are estimated within an economic travel demand framework under conditions of high traffic congestion, as outlined in Figure 18.

All of the impact measures are estimated for the current 2006 baseline scenario.

Travel Delay, Commuter Costs, and Related Impacts

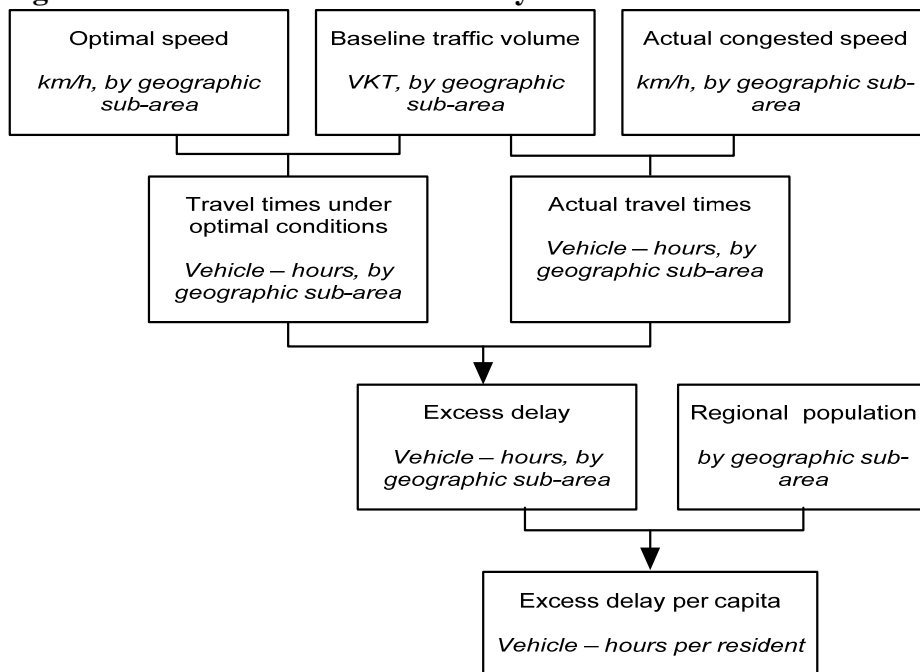
This sub-section presents the methodology behind the calculations of travel delay and the related impacts resulting from congestion, including the following:

1. Excess delay, i.e. travel delay above the economically justified level (total and per capita);
2. Excess commuting costs (total and per commuter);
3. Reduction in demand for labour and employment;
4. Increase in industry operating costs;
5. Decrease in industry revenues; and,
6. The overall reduction in regional economic output.

Excess Delay

The economically optimal speed resulting under the “economically optimal congestion conditions” can then be applied to the current traffic volume in order to calculate the economically optimal travel times. This can be then subtracted from the actual travel times (i.e. under actual travel speeds) to calculate total excess travel time. This result in turn can be divided by the total population in the GTHA to obtain an estimate of excess travel delay per resident. This logic is illustrated in Figure 20.

Figure 20: Calculation of Excess Delay



The excess delay per capita could also be expressed in monetary terms by multiplying the vehicle hours of delay by the assumed consensus value of time.

Excess Commuting Costs

The travel delay impacts can be narrowed down by focusing on car commuters, the group of people who are likely most impacted by excess delay, as they have to use the road network during the times of day when it is most congested.

Calculation of commuting delays by geographic sub-region, or commuting delays for work trips destined to each geographic area analyzed, may be challenging as it requires some assumptions regarding the typical travel routes from home to work and back home to determine the geographic areas that a commuter passes and average trip length in each of these areas. Then, knowing the actual and economically optimal speed in each of the areas, the excess commuting delays could be estimated and averaged over an entire geographic area. This task would require detailed data on the number of trips and vehicle-kilometres traveled by origin and destination and thus could not be implemented within this engagement.

Impact on Demand for Labour and Business Activity

Excess congestion increases workers' commuting costs, including the cost of their own time spent in traffic. Since workers factor these costs into their choices of where to work, increased congestion may force employers to remunerate more generously to attract the workers they need. In some cases, the salary that would be sufficient to compensate for a long commute will be more than the employer can afford. In this case, employers may have to scale down their employee expansion plans, or devote more resources to recruitment, or settle on less suitable employees, with a consequent decrease in labour demand, labour productivity, or both. Congestion on a region's roads, particularly unanticipated congestion, can also have other consequences for employers, such as when an employee misses a meeting because of a traffic jam while en route to work. There is some empirical evidence (although limited and with some qualifications) indicating that employers are sensitive to these delays and costs.

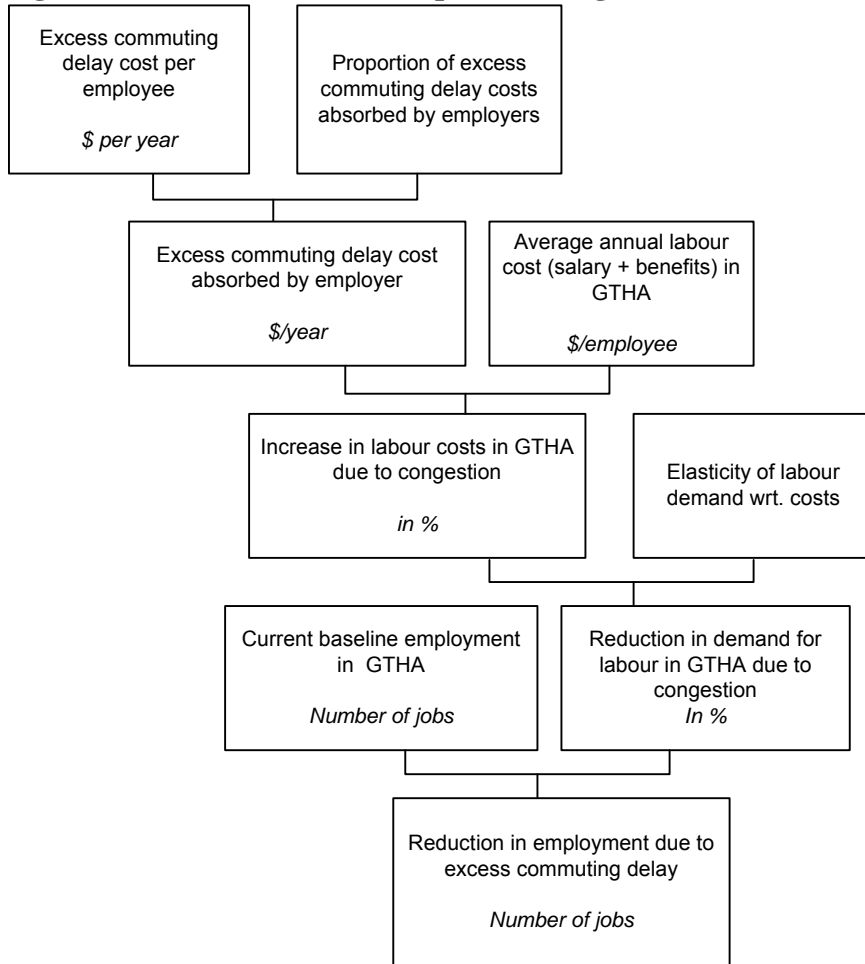
After reviewing the limited evidence on the relationship between pay and commuting costs, NCHRP Report 463 assumed for a modeling exercise similar to this one that in the long run, higher pay offsets half of any increase in commuting costs in a metropolitan region.²⁴ Using this assumption and the excess commuting delay cost per employee calculated earlier, one can estimate the average commuting cost per employee absorbed by local employers in the form of higher salaries. This can then be compared with the average labour costs (salaries plus benefits) in the region to calculate the percentage increase in average labour costs due to congestion. This can then be combined with the elasticity of demand for labour with respect to labour costs to calculate the percentage reduction in labour demand. Applying this percentage to the current employment data, one can estimate the reduction in employment due to congestion in absolute terms. These effects are illustrated graphically in Figure 21.

As mentioned earlier, excess commuting costs can, in addition to forcing up the cost per worker, reduce worker productivity, but evidence on the magnitude of this effect is lacking. NCHRP

²⁴ Weissbrod, G., Vary, D. and Treyz, G. 2001. *Economic Implications of Congestion*, National Cooperative Highway Research Program Report 463, National Academy Press, Wash., D.C., 2001, esp. pp. 16, 26 (also available at: gulliver.trb.org/publications/nchrp/nchrp_rpt_463-a.pdf).

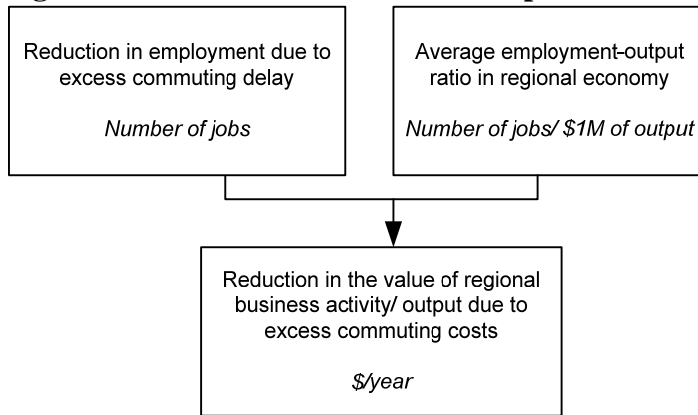
Report 463 simulated region-wide reductions in commuting travel time for the Chicago and Philadelphia metropolitan areas and found the effect on labour productivity to be very small relative to the straight change in labour cost (though this may partly have stemmed from the limitations of their model). Therefore, this effect – as somewhat speculative – is not estimated here.

Figure 21: Estimation of the Impact of Congestion on Labour Demand



One could, however, continue the logic illustrated in Figure 21 and argue that reduced employment also results in lost business activity and lost business output or revenues. This effect is illustrated graphically in Figure 22.

Figure 22: Estimation of Business Output Lost due to Congestion



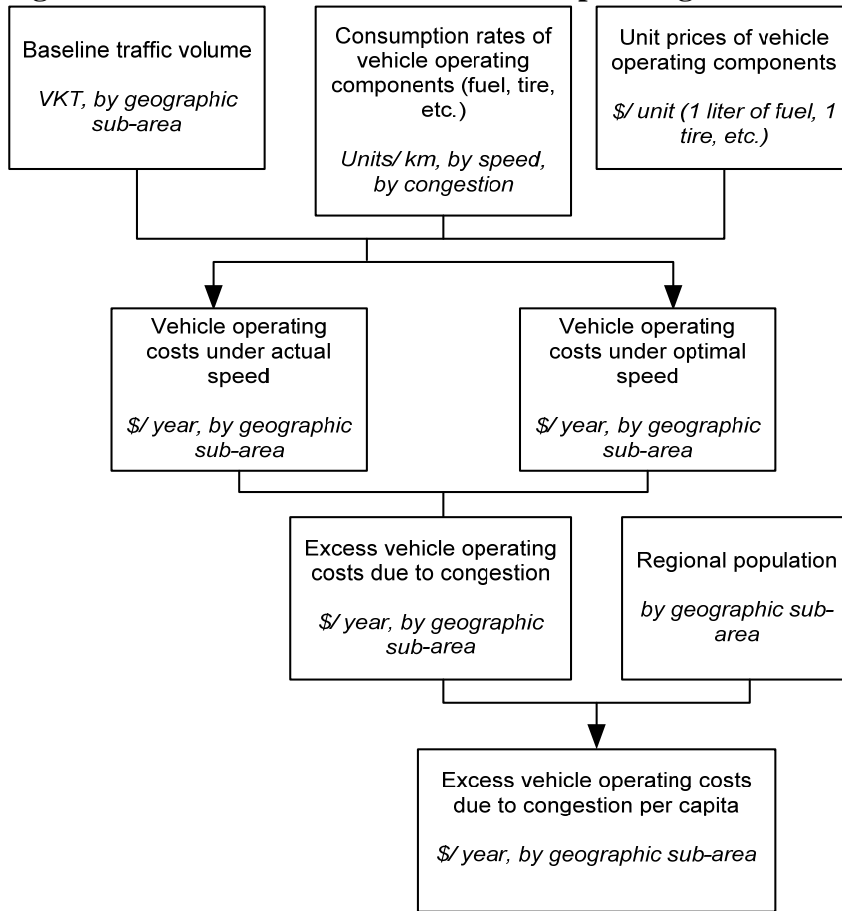
Vehicle Operating Costs Impacts

Over a considerable range of average speed, the technologies embodied in motor vehicles produce a positive relationship with fuel economy. Congestion thus reduces fuel economy because at lower average vehicle speed fuel usage actually increases. In addition, the stop-and-go driving that frequently results from congestion results in speed cycling that further increases fuel consumption.

Our calculation of excess vehicle operating costs are based on readily available estimates of consumption rates per vehicle-kilometre (broken down by average speed and congestion level), unit prices, and vehicle-kilometres traveled (VKT) under baseline conditions. For example, the fuel consumption rate at the baseline speed is multiplied by the baseline VKT and fuel price to obtain total cost of fuel under baseline conditions. On the other hand fuel consumption rate at the economically optimal speed multiplied by the baseline VKT and fuel price will give total fuel cost under conditions of no excess congestion.

Figure 23 below shows the logic of these calculations for the entire range of vehicle operating costs (fuel, oil, tires, maintenance and depreciation) for autos. A similar logic model can be adopted for estimation of excess vehicle operating costs for trucks using consumption rates of vehicle operating cost components for trucks (although truck data was not available for this study).

Figure 23: Estimation of Excess Vehicle Operating Costs



Effects on Overall Logistic Costs

The congestion that trucks experience on the road inhibits the adoption of cost-saving logistic strategies that depend on transportation being fast and reliable. With less congestion, businesses may reorganize their logistics in the following and other ways.

- Increases in speed reduce the cost per shipment, encouraging businesses to arrange for more frequent shipments to economize on inventory cost.
- Improved reliability of travel time enables carriers to reduce the buffer times built into their schedules, and for receivers to reduce the inventory they maintain to safeguard against delayed delivery.
- Distributors may reduce the number of warehouses they operate, thereby realizing economies of scale in warehouse operation. In addition, because each remaining warehouse now serves a larger number of markets, the need for precautionary inventory decreases. (The market-specific fluctuations in demand do average out to some extent.)
- Manufacturers that previously had to start their work shifts early to meet the cut-off times for pick-ups may be able to offer their employees more attractive hours, making worker recruitment and retention easier.

- Carriers may be able to avoid expenses from driver changes or rest breaks needed to comply with hours of service regulations.

The costs of congestion this report has presented thus far do not reflect the savings from undertaking logistic reorganizations such as these. For one thing, measures of congestion cost presume no change in vehicle-kilometres of travel — they simply indicate the cost of the extra time and fuel it takes to travel those kilometres. But some of the logistic reorganizations entail changes in vehicle-kilometres of travel, as when receivers economize on inventory by having more frequent shipments. In addition, the valuation of congestion delay focuses on average speed and average travel time, thus missing the costs that arise from unreliability (variability around the average). These omissions largely reflect the state of the art in benefit-cost analysis related to road projects or congestion. The fact is that the logistic reorganization costs or benefits are hard to quantify and generalize.

To mitigate this gap in conventional practice, HDR Decision Economics (HDR) has developed a freight logistics cost-benefit analysis tool for the Federal Highway Administration. The tool enables the user to evaluate a highway investment more fully by adding logistic reorganization benefits to the conventionally measured savings in trucking costs. The measurement of logistic reorganization benefits involves estimation of “consumer surplus,” an indirect approach that economists often rely on because it permits enormous savings in data collection and analytical effort.

The essence of this model can be explained with a simple example. Suppose a manufacturer’s cost of shipping widgets 100 kilometres declines by 10 cents per kilometre; then the saving per shipment is \$10. Imagine that the manufacturer increases the number of weekly shipments from one to two in order to hold down inventory. What is the weekly net benefit to the manufacturer for making this adjustment? The lower bound on this benefit is zero, because the manufacturer would not make this adjustment without deriving a benefit. The upper bound is \$10, because if it were anything higher, it would already have paid the manufacturer to schedule two shipments per week even before the cost of shipments declined. Without knowing where the net benefit falls within this range, many benefit-cost analyses will simply use the average of the upper and lower bounds, in this instance, \$5 — the so-called “rule of half.” Two things about this measurement approach are worth noting. First, it does not require any information beyond road transportation outcomes: the savings in trucking costs per kilometre and increase in road VKT. Second, it produces an estimate of *net* benefit – the savings in inventory costs minus the increase in shipping costs.

The HDR freight cost-benefit analysis tool employs a more sophisticated variant of this approach, but the underlying logic is basically the same – the net benefit that parties derive from using more road transportation services can be inferred by how much they are willing to pay for those services. Key to implementing the tool was the econometric modeling of truck volumes using combined time-series data on 59 highway corridors across the U.S. HDR estimated an equation with these data that explained the volume of truck traffic – a measure of demand for trucking use of the corridor – as a function of highway performance. Application of the cost-benefit tool to the studied highway corridors indicates that logistic reorganization benefits

typically add about 16 percent²⁵ to the savings in trucking costs that result from an infrastructure improvement. If data were available, one could apply this same ratio to the estimate of the annual time cost of congestion delay to trucks on GTHA region roads to obtain the cost of foregone logistic reorganization.

Since data is not available to estimate the impacts on logistics in this manner, this is handled below in the retail sector discussion.

Industry Level Impacts

This section develops a methodology for the assessment of industry-level congestion impacts. We consider industries that appear particularly sensitive to congestion problems, including the following:

- Retail trade;
- Wholesale trade;
- Agriculture industry;
- Manufacturing industry;
- Construction;
- Accommodation and Food services;
- Arts and Entertainment; and,
- Transportation industry.

The impacts measured are changes in industry revenue, operating costs, and employment, though not all of these impacts are estimated or considered for each industry.

The estimation framework was built up from “structure and logic models”, which represent in a flowchart or graph the causal relationships among the relevant factors as well as the underlying logic. The models are grounded in economic theory and coded in a series of equations; values for parameter and variables in these equations are obtained from related published studies, statistical data series, local data, and other data sources. The graphical representation facilitates client and stakeholder evaluation of the model logic.

The models frequently utilize the concept of elasticity. As explained earlier in the context of elasticity of travel demand with respect to cost of driving, elasticity measures the sensitivity of response when one of the underlying driving factors changes. The response is measured in terms of percent change of the variable in interest when the driving factor of this variable changes by 1 percent. For example, elasticity of vehicle kilometres traveled with to cost of driving equal to -0.8 indicates that vehicle-kilometres of travels increase by 8 percent when the cost of driving goes down by 10 percent.

It should be noted that chronic traffic congestion induces certain adaptive responses that evolve only gradually over the long-run. Since these tend to be especially hard to model with much confidence, our analysis is largely limited to congestion's short-to medium-term impacts. For

²⁵ “The Costs of Road Congestion in the Chicago Metropolitan Area”, HDR|Decision Economics Report, July 11, 2008.

example, we do not estimate the inhibiting effects of congestion on the consolidation of wholesale operations with the resulting change in cost or employment structure.

The industry impacts are estimated for the entire GTHA Region. This is because a model with sub-regional impacts would require a more complex model than it was possible to develop within this engagement.

All results are derived using the peak travel congestion impacts estimates, as only peak period travel data was available. In order to account for possible mitigation of congestion costs impacts during off-peak hours, all industry level costs calculated using average speed and delay results for peak hours are divided by two.

As in the case of travel delays and related impacts, all industry-level impacts are estimated for the current 2006 baseline.

Retail Trade Industry

The impact of congestion on the retail industry could manifest itself in two types of effects, which are discussed in turn:

1. Effect on shopping habits, or behaviour, and number of shopping trips; and,
2. Effect on the costs of logistics and inventory held by shop owners.

Effect of congestion on shopping habits

The literature on the effects of travel times and traffic congestion in particular on shopping behaviour and retail sales in a geographic region is very limited, if not non-existent. Casual observations suggest that traffic congestion can affect at least the distribution of shopping and retail sales across a geographic region.

However, it seems that high traffic congestion can also impact the net number of shopping trips and retail sales. For example, in conditions of high congestion some individuals may be discouraged to go shopping for some discretionary purposes or items as they want to avoid aggravation and loss of time. The sales lost from that trip may not necessarily be recovered when the individuals go on their next shopping trip. A related marketing study found that consumers do combine multiple shopping purposes and destinations on one trip but the scope for this behaviour is considerably smaller than could be expected if shopping trips were planned based purely on travel cost minimization.²⁶

We acknowledge here this possibility. However, in view of lacking general evidence on the issue, or insights from local data or a local transportation model on trip patterns under various travel costs and travel conditions, we treat this type of impact as somewhat speculative. Although retail shops in some congested areas in the region could be negatively affected by the current

²⁶ See Dellaert, Benedict, Theo Arentze, Michael Bierlaire, Aloys Borgers, and Harry Timmermans ((1998), “Investigating Consumers’ Tendency to Combine Multiple Shopping Purposes and Destinations”; also published in *Journal of Marketing Research*, Vol. 35, No. 2 (May 1998), pp. 177-1888.

traffic situation, shops in other parts of the region may actually be benefiting in the form of a larger number of shoppers and revenues. The net effect on the industry in the entire region may well be close to zero. This issue would require more complex research that was not possible within the scope of this study. As a result, this effect is not estimated here.

Effect of congestion on the costs of logistics and inventory in the retail industry

Congestion also can add to the logistics costs of local retailers by reducing travel speeds and the reliability of delivery times for merchandise and supplies. The literature indicates that in a wide range of industries these types of effects add to operation costs directly, and also indirectly, by inhibiting businesses from adopting inventory-saving strategies such as just-in-time inventory systems.²⁷

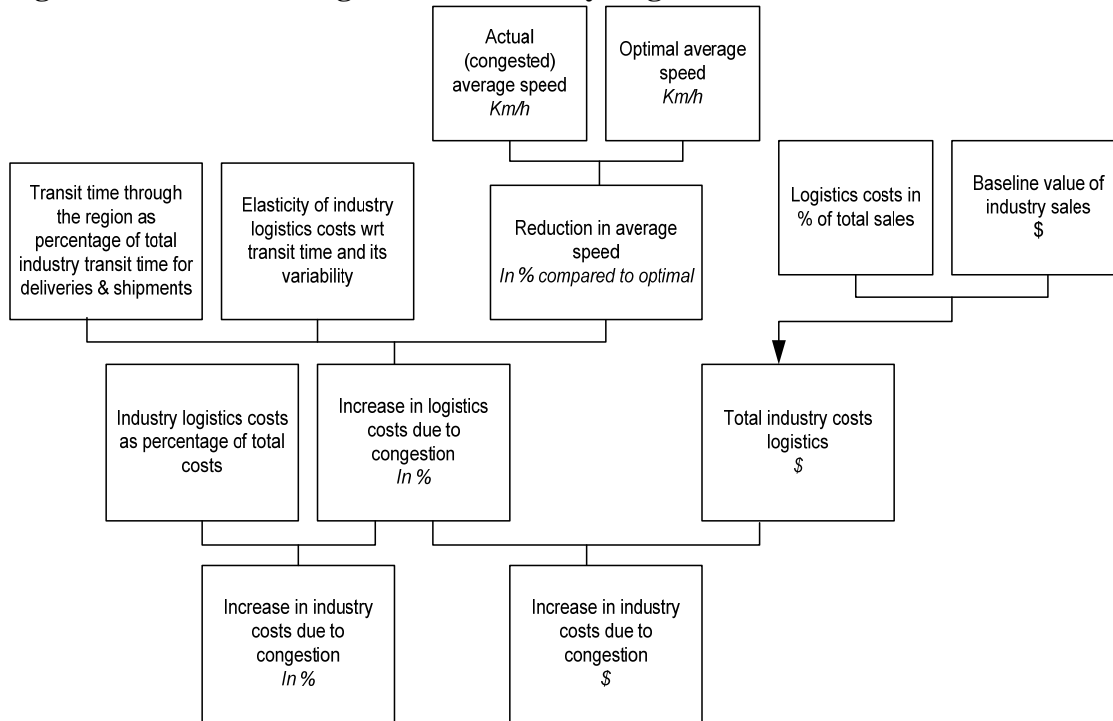
The overall increase in logistics costs can be estimated using information on the ratio of logistics costs to total sales of the sector, existing elasticity estimates of this cost item, and estimates of the increase in average delivery time resulting from congestion.

Figure 24 shows the structure and logic of these costs. The difference between the actual congested speed and economically optimal speed is transformed into a percent reduction in actual speed compared to the economically optimal speed. This is combined with the industry's elasticity of logistics costs with respect to transit time to give an estimate of the increase in industry logistics costs. This calculation is adjusted by the percentage of the industry transit time for deliveries and shipments that take place in the region in order to capture the idea that transit through heavily congested road network within the GTHA may account for only a fraction of total transportation distance and time.

The increase in industry logistics costs is, in turn, combined with estimates of industry logistics costs as percentage of total industry costs to give an estimate of the increase in industry costs.

²⁷ See for example: Freight Benefit-Cost Study, a report for Federal Highway Administration, Office of Freight Management and Operations, by ICF Consulting, HLB Decision Economics, and Louis Berger Group, July 2002.

Figure 24: Effect of Congestion on Industry Logistics Costs



Manufacturing Industry

Traffic congestion impairs the operations of manufacturing businesses by adding to delays and reducing the reliability of deliveries of materials and components as well as shipments of finished products to markets. These effects tend to increase inventory and logistics costs by an amount than can be estimated in our model framework according to a similar approach as that illustrated in Figure 24.

In addition, the literature indicates that high congestion may reduce the market area for a firm’s output, leading to a reduction in sales.²⁸ To illustrate this point, let’s assume that congestion leads to an increase in production costs because a firm may have to purchase more expensive inputs and supplies from another location, increase its inventories, etc. An increase in production costs may require a firm to increase the price of its product, or make changes in the terms of delivery of a product. This in turn may reduce sales as buyers will be looking for less expensive alternatives. In some industries where final products are highly homogeneous, even a small price differential may induce switching to another supplier who offers a lower price. The reduction in sales (and possibly a reduction in economies of scale in production) results in a loss of output and business revenue.

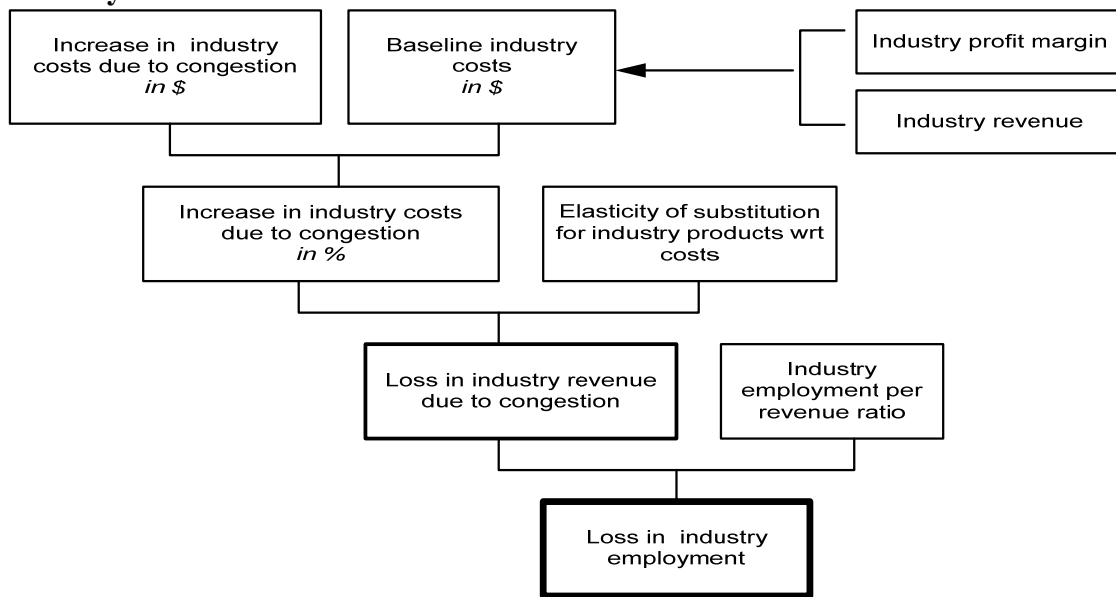
In the GTHA, transportation efficiency and reliability is also likely to play an extremely important role in the development and success of manufacturing, given that an increasing

²⁸ See Weisberg G., D. Vary, and G. Treyz (2001) “Economic Implications of Congestion”, NCHRP Report 463, Transportation Research Board, National Cooperative Highway Research Program.

proportion of manufacturers export goods outside the region to destinations elsewhere in Ontario, Canada, and the US where they would be directly competing with similar local products or other imported products.

The structure and logic diagram for the estimation of the revenue loss is shown below in Figure 25. The increase in industry costs due to congestion estimated in earlier steps is transformed into a percentage increase based on the industry cost structure and is combined with the elasticity of substitution for that industry’s products with respect to costs, to obtain an estimate of revenue loss due to congestion. The lost revenue is then combined with statistical industry employment per \$1 million of revenue to estimate the resulting loss in employment.

Figure 25: Effect of Congestion on Revenues and Employment in the Manufacturing Industry



Construction

Traffic congestion impairs the operations of construction businesses by adding to delays in deliveries and reducing reliability of the transportation network. Again, these effects add to inventory and logistics costs by an amount than can be estimated in our model framework and using similar approach as that laid out in Figure 24.

Wholesale Industry

For the wholesale industry, congestion, reduced average speeds, and less reliable delivery times will push up inventory levels and logistics costs. This effect can be estimated using an approach similar to that shown in Figure 24.

In addition, the industry may also suffer from congestion indirectly, through the adverse effects on sales in retail trade, manufacturing, and other industries from which the wholesale industry draws business. The wholesale trade can be seen, however, as further down the production/supply chain, which means that including these indirect impacts on the industry's

revenues would involve some double-counting. Therefore, this indirect effect of congestion on wholesale trade revenue is omitted here.

Agriculture Industry

Traffic congestion impairs the operations of agricultural businesses by adding to delays, adding to delivery times, and reducing the reliability of deliveries of production inputs and final products to consumer markets. This may lead to a direct increase in industry logistics, warehousing, and transportation cost by inhibiting cost-saving innovations in storage and transportation management.

In addition, as in the case of the manufacturing industry, higher logistics costs and longer delivery times may induce some buyers to switch to an alternative supplier who can provide the product at a lower cost and deliver it within a shorter period of time. The NCHRP report cited earlier found that the scope for product switching in the agriculture business is particularly high due to the highly homogenous nature of these products.²⁹

Both the logistics cost and the output effect of excess congestion discussed above can be estimated using similar approaches and logic models as those for the manufacturing industry.

Transportation Industry

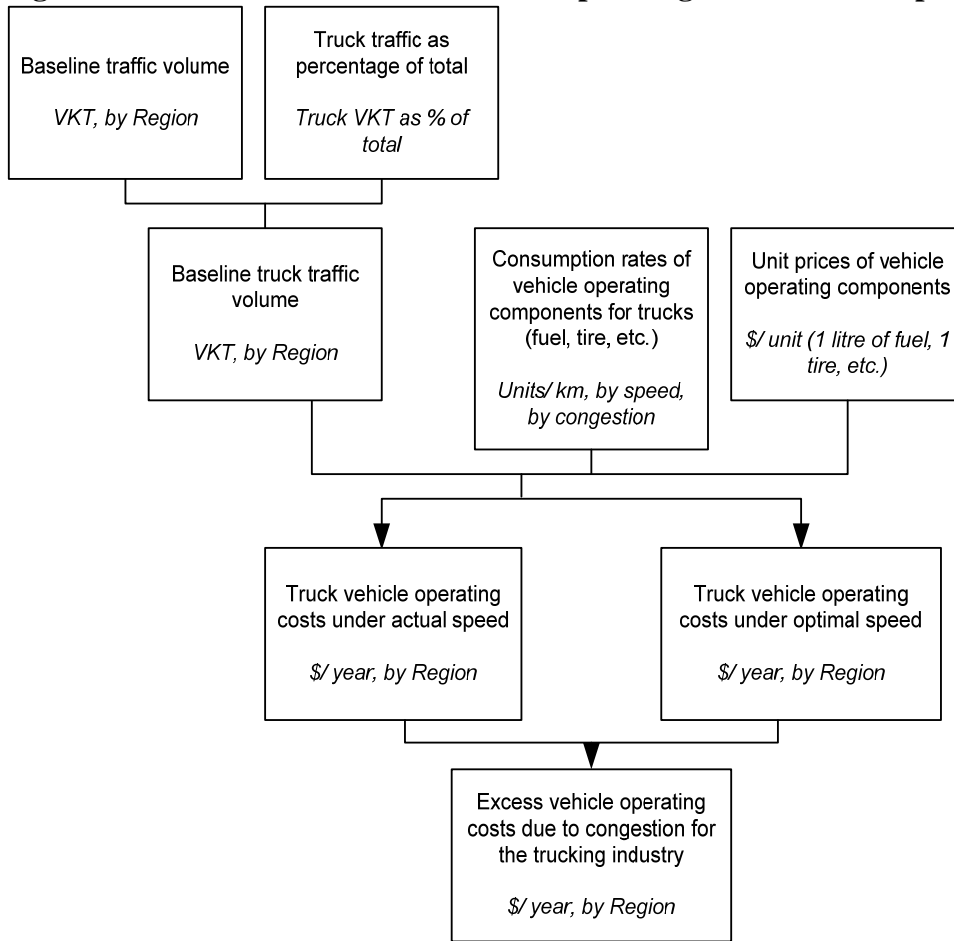
Excess congestion can affect the trucking industry in a number of ways, including the following:

- 1) Increase in the consumption of fuel and other operating costs due to an increase in the consumption rates of operating cost components under lower average speeds;
- 2) Increase in labour costs (i.e. trucker time costs) for a given shipment due to an increase in transit/delivery times;
- 3) Reduction in demand for services due to reduction in output of the industries directly affected by congestion that use the services of the trucking industry for the transportation of their supplies and transportation of finished products; and,
- 4) Reduction in opportunities for backhaul loads due to longer transit times and regulations with respect to work hours.

Figure 26 below illustrates the specific methodology.

²⁹ See Weisberg G., D. Vary, and G. Treyz (2001) “Economic Implications of Congestion”, NCHRP Report 463, Transportation Research Board, National Cooperative Highway Research Program

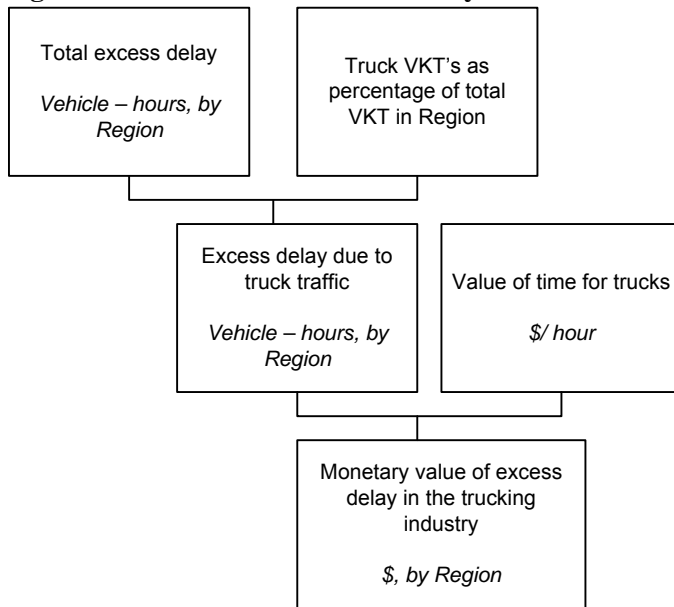
Figure 26: Estimation of Excess Vehicle Operating Costs for Transportation Industry



The increase in operating costs (#1) is included in the calculations via the effect of logistics costs on revenues and costs; however, the increase in delay costs (#2) were not captured in the present study due to data limitations.

Figure 27 below illustrates the typical calculations involved.

Figure 27: Estimation of Excess Delay Costs for Trucking Industry



Item (3) will be captured within the revenue and output impacts of the other industries. In order to avoid double counting of the same or related effects in functionally related industries, these effects will not be estimated separately here.

Item (4) is more complex in nature and would require more detailed knowledge and research of the local trucking industry, their structure, and markets. A series of interviews would also be likely required in order to understand the dependencies between transit times and operations. This effort will not be possible within this study due to the scope of the study. We acknowledge here the potential impacts but do not estimate them quantitatively.

Demand for Labour and Business Activity Impacts

Table 23 shows the implication of congestion costs related to commuting for work (excess time cost of travel delays and excess vehicle operating costs) on demand for labour and economic activity. The costs vary depending on the assumed value of times. If a higher value of time is assumed (with a mark-up for decreased reliability in travel times due to congestion), congestion has the following effects in 2006:

- A reduction of 25,962 jobs;
- A reduction in business revenues of \$4.7 billion; and,
- A reduction in regional GDP of over \$2.7 billion.

Table 23: Impact of Congestion on Regional Labour Demand and Economic Activity, 2006

CATEGORY OF IMPACT	VALUE
Reduction in employment due to excess commuting to work costs, number of jobs	25,962
Reduction in the value of regional economic activity (business revenues), \$ millions	\$4,744
Reduction in regional GDP, \$ millions	\$2,733

Source: HDR Calculations

Industry-Level Impacts

Table 24 provides the industry-level congestion cost impacts for selected industries (note that not all cost impacts are estimated for all industries and that not all impacts are additive; the totals don't sum to those shown in Table 23 since not all industries are accounted for at the micro-level).

Table 24: Industry-Level Congestion Costs Impacts, 2006

INDUSTRY	INCREASE IN INDUSTRY COSTS (\$ MILLIONS)	REDUCTION IN INDUSTRY REVENUES (\$ MILLIONS)	REDUCTION IN INDUSTRY EMPLOYMENT (FTE JOBS)
Retail Trade	22.1	27.5	467
Construction	63.1	-	-
Manufacturing	97.6	804.0	1,959
Wholesale Trade	56.3	-	-
Agriculture	4.1	52.5	429
Accommodation and Food services	-	40.4	849
Arts and Entertainment	-	6.2	94
Transportation	16.7	6.0	43
SUBTOTAL	259.9	936.6	3,841

Source: HDR Calculations

Table 24 shows that total industry congestion cost impacts include \$264.38 million in increased industry costs, \$952.34 million reduction in revenue and a reduction in jobs of 3,815.

APPENDIX 4: COST-BENEFIT ANALYSIS OF THE METROLINX DRAFT REGIONAL TRANSPORTATION PLAN

The Draft Regional Transportation Plan (DRTP) would bring with it several different types of benefits. The benefits measured in this study are summarized in Table 25. Table 26 provides the calculated benefits for each category across the sub-regions of the GTHA, and the remainder of this section illustrates how these benefits are calculated. The costs of the DRTP are then outlined and the cost-benefit analysis metrics are provided.

Table 25: The Nature of Benefits Arising from the Draft Regional Transportation Plan

CATEGORY OF BENEFITS	DESCRIPTION
TIME SAVINGS	Better and more reliable travel times; gains in productivity
AFFORDABLE MOBILITY	Cash savings to low income households for reallocation to housing, nutrition, childcare etc.
CROSS-SECTOR BENEFITS	Savings in social service agency budgets
SAVINGS IN VEHICLE AND SYSTEM OPERATING COSTS	Reduced outlays on fuel, oil, tires, maintenance and repairs and depreciation
SAFETY	Reduced fatalities, injuries, property damage
ENVIRONMENT	Reduced air pollution and greenhouse gas emissions
ECONOMIC DEVELOPMENT	Higher residential and commercial property values

Table 26: Estimated Benefits of the Draft Regional Transportation Plan, by Source and by Sub-Region (2010-2031)

CATEGORY	GTHA	CITY OF HAMILTON	HALTON REGION	PEEL REGION	CITY OF TORONTO	YORK REGION	DURHAM REGION
BENEFITS							
CONGESTION MANAGEMENT							
Time Savings - Auto Users	\$21,656	\$1,245	\$2,360	\$4,589	\$4,315	\$5,619	\$3,527
Savings in Vehicle Operating Costs	\$4,812	\$288	\$323	\$988	\$1,543	\$1,115	\$554
Emission Savings	\$823	\$96	\$112	\$196	\$2	\$256	\$161
Accident Cost Savings	\$669	\$58	\$56	\$132	\$164	\$148	\$111
<i>Total Congestion Management</i>	<i>\$27,959</i>	<i>\$1,688</i>	<i>\$2,850</i>	<i>\$5,905</i>	<i>\$6,024</i>	<i>\$7,138</i>	<i>\$4,354</i>
MOBILITY							
Time Savings - Transit Users	\$3,249	\$3	\$59	\$599	\$2,109	\$551	-\$74
Value to Low-Income Travelers	\$307	\$27	\$40	\$55	\$73	\$69	\$43
Cross Sector Benefits	\$49	\$2	\$4	\$8	\$22	\$5	\$6
<i>Total Mobility Benefits</i>	<i>\$3,604</i>	<i>\$33</i>	<i>\$103</i>	<i>\$663</i>	<i>\$2,205</i>	<i>\$626</i>	<i>-\$25</i>
COMMUNITY DEVELOPMENT							
Commercial Development	\$1,887	\$52	\$31	\$224	\$1,483	\$66	\$30
Residential Development	\$3,173	\$67	\$53	\$216	\$2,612	\$184	\$41
<i>Total Community Development</i>	<i>\$5,060</i>	<i>\$119</i>	<i>\$84</i>	<i>\$440</i>	<i>\$4,095</i>	<i>\$251</i>	<i>\$71</i>
ECONOMIC OUTPUT							
<i>Economic Output</i>	<i>\$10,051</i>	<i>\$607</i>	<i>\$1,025</i>	<i>\$2,123</i>	<i>\$2,166</i>	<i>\$2,566</i>	<i>\$1,565</i>
ALL BENEFITS	\$46,674	\$2,446	\$4,062	\$9,131	\$14,489	\$10,581	\$5,966

Note: values are in millions of dollars (\$2006), in present value terms

Note that the sub-regional distributions are based on the distribution of trip *origins*, and thus do not correspond to the residents of each region.

A4.1 The Sources of Economic Value from Improved Transportation

Economic Benefits

Taxonomy of Benefits

The sources of economic value in this study fall into four main categories, which are as follows:

A) Congestion Management and Related Environmental Benefits

Congestion management benefits are social cost savings associated with mode shifts and highway congestion relief, including travel time savings, vehicle operating cost savings, savings associated with emissions and greenhouse gases, and safety benefits. They accrue in various degrees to highway users and to the community as a whole.

Congestion results from vehicle traffic on the roadway network in excess of the network's capacity. At low volumes, traffic flows smoothly at the speed limit. But as traffic volume increases during peak hours, additional vehicles eventually slow the traffic flow and increase the travel time of other vehicles. At this point congestion level increases and, as traffic volumes grow, the costs associated with congestion increase. The social cost of a trip on a congested road includes travel time, vehicle operating cost, safety cost, and environmental cost. An increase in transportation services results in social costs savings.

Time-related benefits of transportation investment projects occur as a result of total travel time reduction and changes in the attributes of travel time. These may include the following:

- Reduction in highway use (and vehicle-kilometres traveled, or VKT) due to some highway users switching to transit for at least some trips; and,
- Improvements in speed-flows for existing highway users due to reduction in highway use.

Other categories of costs that may be reduced due to improved transportation services include:

- Vehicle operating costs, i.e. costs of fuel consumption, oil consumption, maintenance and repairs, tire wear, insurance, license registrations, taxes, roadway related vehicle depreciation;
- Accident costs, i.e. monetary costs of fatal accidents, injuries, and property damage accidents; and,
- Environmental costs, i.e. costs associated with vehicular emissions and their impact on public health and air quality.

B) Mobility Benefits

The mobility-related benefits of transit arise in three distinct ways:

- 1. Time Savings to Transit Users:** Time-related benefits to transit users occur as a result of total travel time reduction and changes in the quality or attributes of travel time, such as less time spent waiting and/or walking.
- 2. Affordable Mobility Benefits:** Affordable mobility benefits are benefits to low-income households stemming from the availability of transportation at a lower price than taxis and other more expensive alternatives. Mobility benefits can vary substantially across transit investment type, area and corridor. Affordable mobility benefits are estimated on the basis of generalized transit price, generalized price of alternative modes of transportation, and demand for transportation by low-income people.
- 3. Cross-Sector Benefits:** Cross-sector benefits are resource savings arising from reduced social service agency outlays when people are able to travel to centralized points of service rather than receiving home-based care or able to travel to work using transit options. Cross sector benefits are estimated on the basis of passenger trips by low-income individuals eliminated due to lack of transit provision, percentage of lost trips that lead to home-care or result in unemployment and then welfare assistance, as well as average costs of home-care visits and average welfare benefits.

C) Livable Community Benefits

Transit-oriented development can increase the value of commercial and residential properties. Increases in property value that enter the Cost-Benefit Analysis framework are those arising over and above the effects of travel time savings on rents. Such increases represent non-user benefits, namely consumers' willingness to pay for locational attributes associated with transit ("urbanization") that extend beyond the use of transit as a travel mode.

Transportation research finds that transit-oriented development has positive social and economic impact on the economic vitality of communities. These include impacts such as:

- More scope and demand for walk and bicycle trips;
- Reduction in demand for auto trips and dependence on auto;
- Higher residential property values; and,
- Greater demand for commercial floor space and higher commercial property values.

D) Economic Output

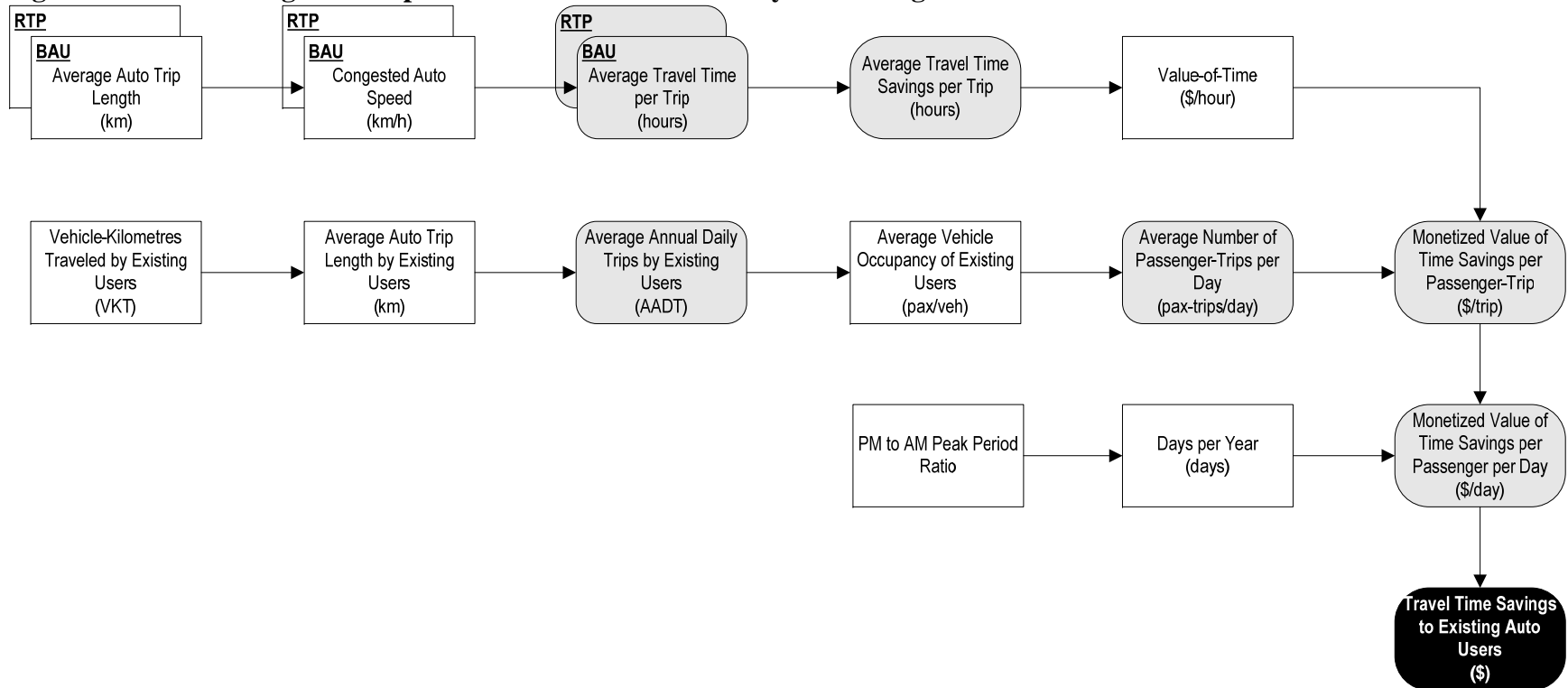
When city streets, roads and highways are in short-supply and choked with long queues, the economy will be perform at a lower level - less goods and services will be produced. Improved regional transportation planning, aimed at easing congestion levels, can mitigate the amount of output that would have otherwise been forever lost.

Time Savings and Improved Travel Time Reliability to Existing Automobile Users

Time-related benefits occur as a result of total travel time reduction and changes in the quality or attributes of travel time.

Time savings are evaluated on the basis of projected reductions in highway use (vehicle kilometres traveled – VKT) that arise from mode shift: car or taxi users, by shifting to transit, free up some capacity on highways, thereby improving traffic flows and average vehicle speed to existing automobile users.

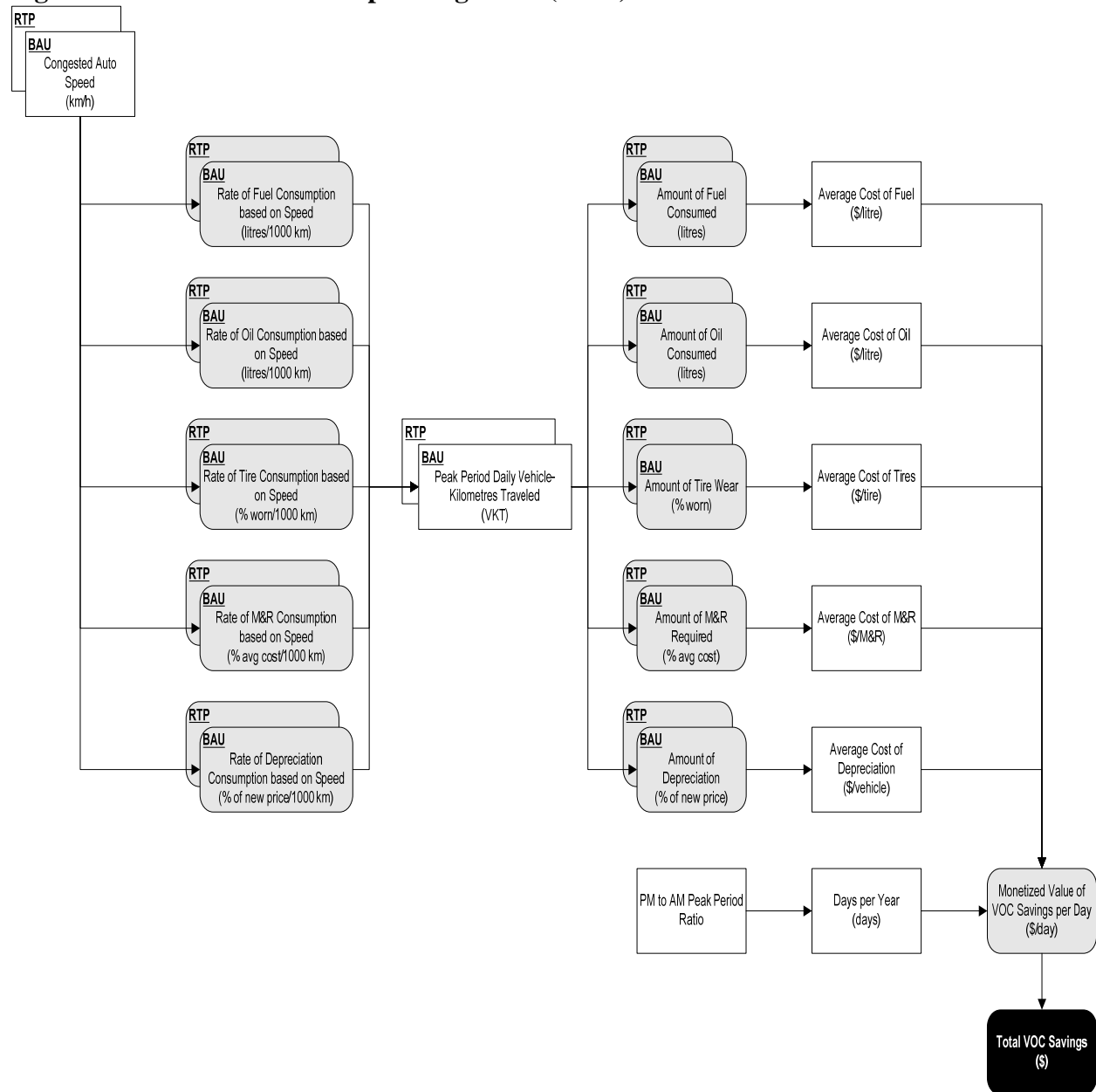
Figure 28: Time Savings and Improved Travel Time Reliability to Existing Automobile Users



Reduced Vehicle Operating and Maintenance Costs

Vehicle operating costs are an integral element of computing highway user costs. They generally are the most recognized of user costs because they typically involve the out-of-pocket expenses associated with owning, operating, and maintaining a vehicle. The cost components associated with operating a vehicle are: fuel consumption, oil consumption, maintenance and repairs, tire wear, insurance, license, registration, taxes, and roadway related vehicle depreciation. Each component is a unique function of vehicle class, vehicle speed, grade level, and surface condition. Thus overall vehicle operating costs can vary significantly between different facility types, geographic areas, and traffic patterns.

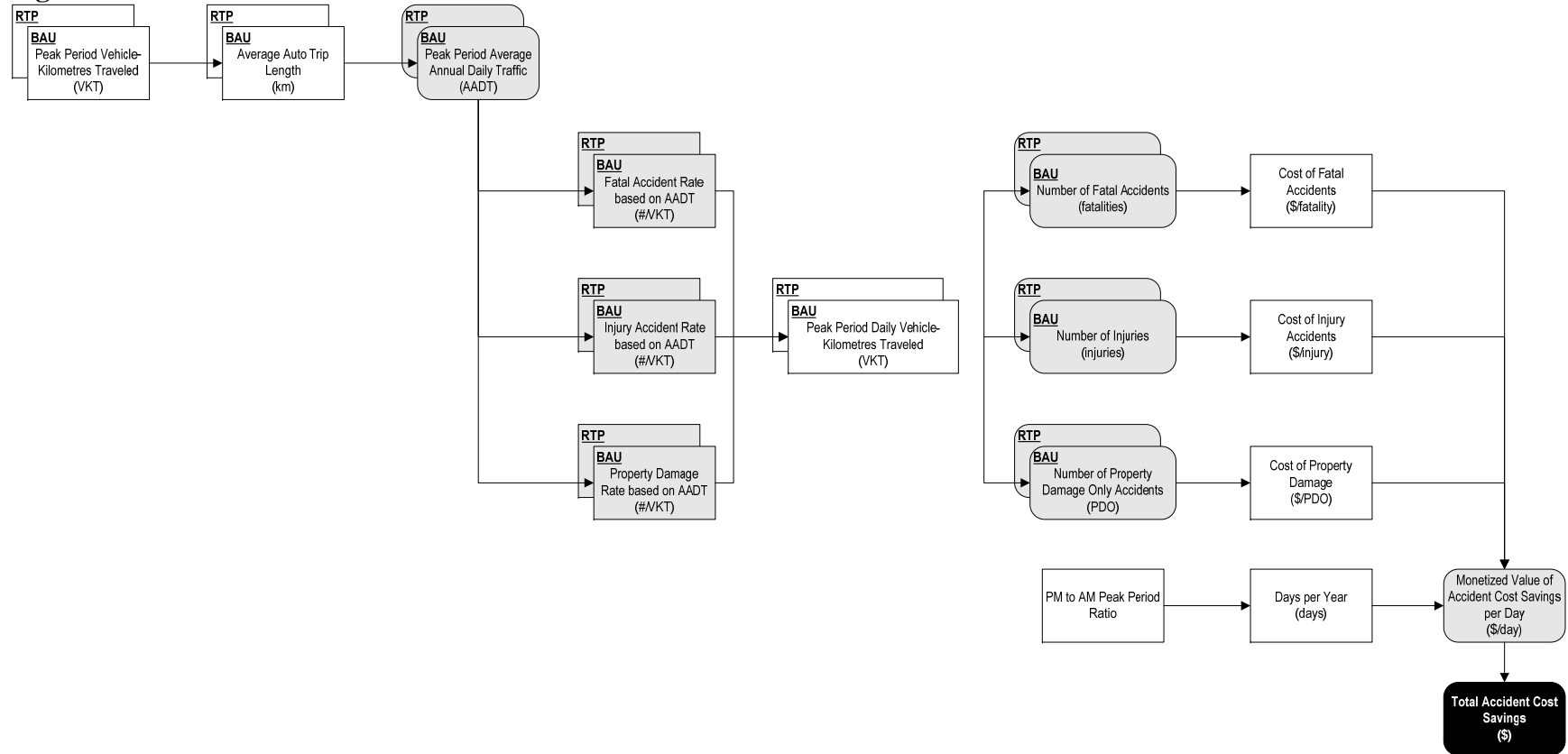
Figure 29: Reduced Vehicle Operating Costs (VOC) and Maintenance Costs



Reduced Incidence of Accidents

Accident costs are a significant component of highway user costs. Highway safety is a key economic factor in the planning of roads, as well as an important indicator of transportation efficiency. Outside of the economic context, highway safety is often the object of public concern and a leading social issue. However, since improved safety requires the use of real resources, it competes with alternative goals and aspects of transportation efficiency.

Figure 30: Reduce Incidence of Accidents



Improved Environmental Conditions

Environmental costs are gaining increasing acceptance as an important component in the economic evaluation of transportation and infrastructure projects. The main environmental impacts of vehicle use and exhaust emissions can impose wide-ranging social costs on people, material, and vegetation. The negative effects of pollution depend not only on the quantity of pollution produced, but on the types of pollutants emitted and the conditions into which the pollution is released.

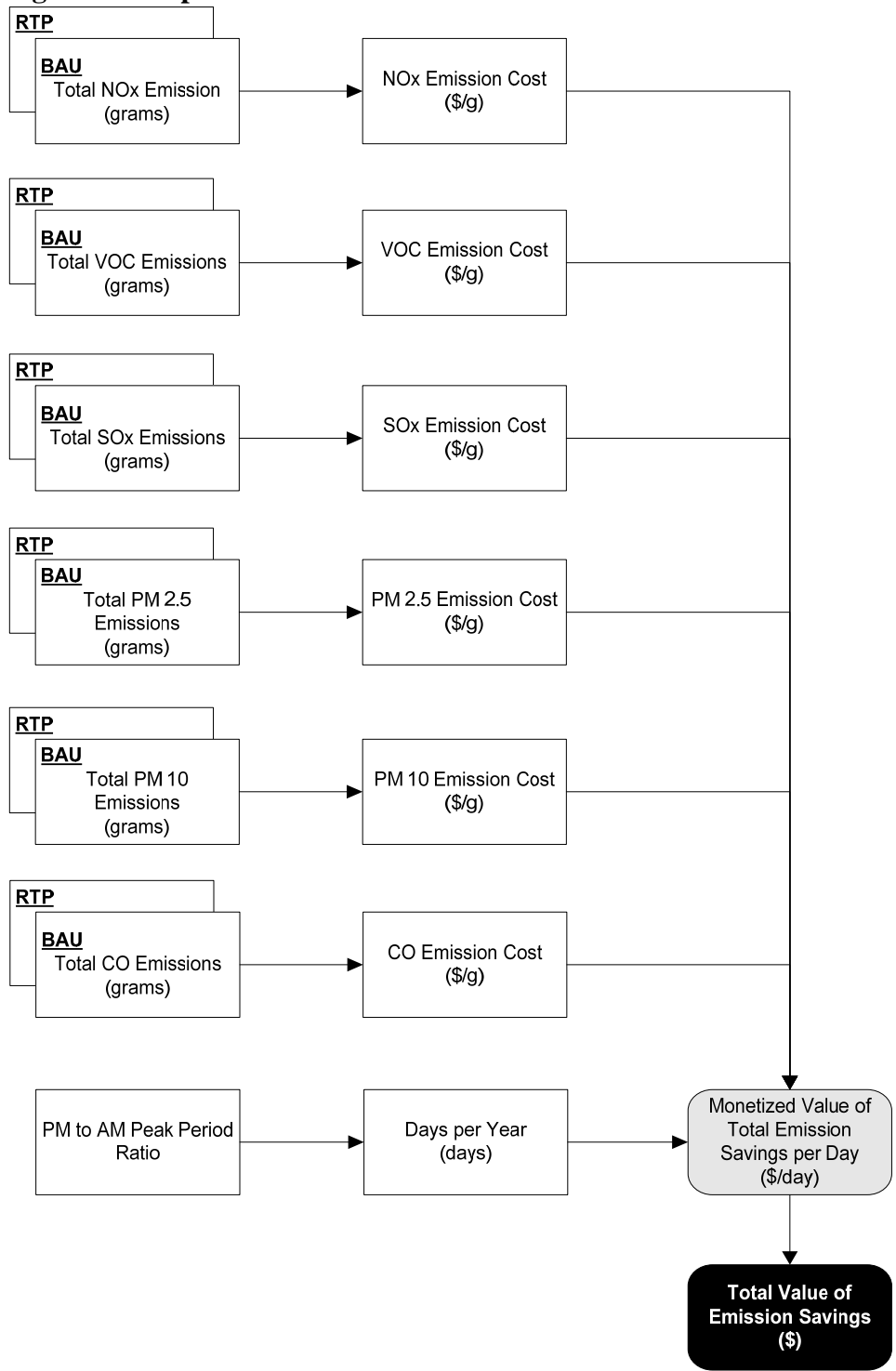
The analysis covers the major pollutants for which solid data inputs are available:

Criteria Air Contaminants:

- Nitrogen Oxides (NO_x);
- Volatile Organic Compounds (VOCs);
- Sulphur Oxides (SO_x);
- Particulate Matter of 10 microns or less (PM10 and PM2.5); and,
- Carbon Monoxide (CO).

Changes in the level of emissions from the BAU to the DRTP case are combined with unit emission costs (unit damage values) to arrive at total emission cost savings. This is illustrated in Figure 31 below.

Figure 31: Improved Environmental Emissions



Mobility Benefits

The mobility-related benefits of transit arise in three distinct ways. The first is time-related benefits to transit users that occur as a result of total travel time reduction and changes in the quality or attributes of travel time, such as less time spent waiting and/or walking.

The second is the benefit to low-income households stemming from the availability of transportation at a more affordable price than taxis and other more expensive alternatives. These are called “affordable mobility” benefits. Many transit users in Canada live in households that do not own an automobile and many more are without access to the family car. Affordable mobility is of disproportionate importance to them.

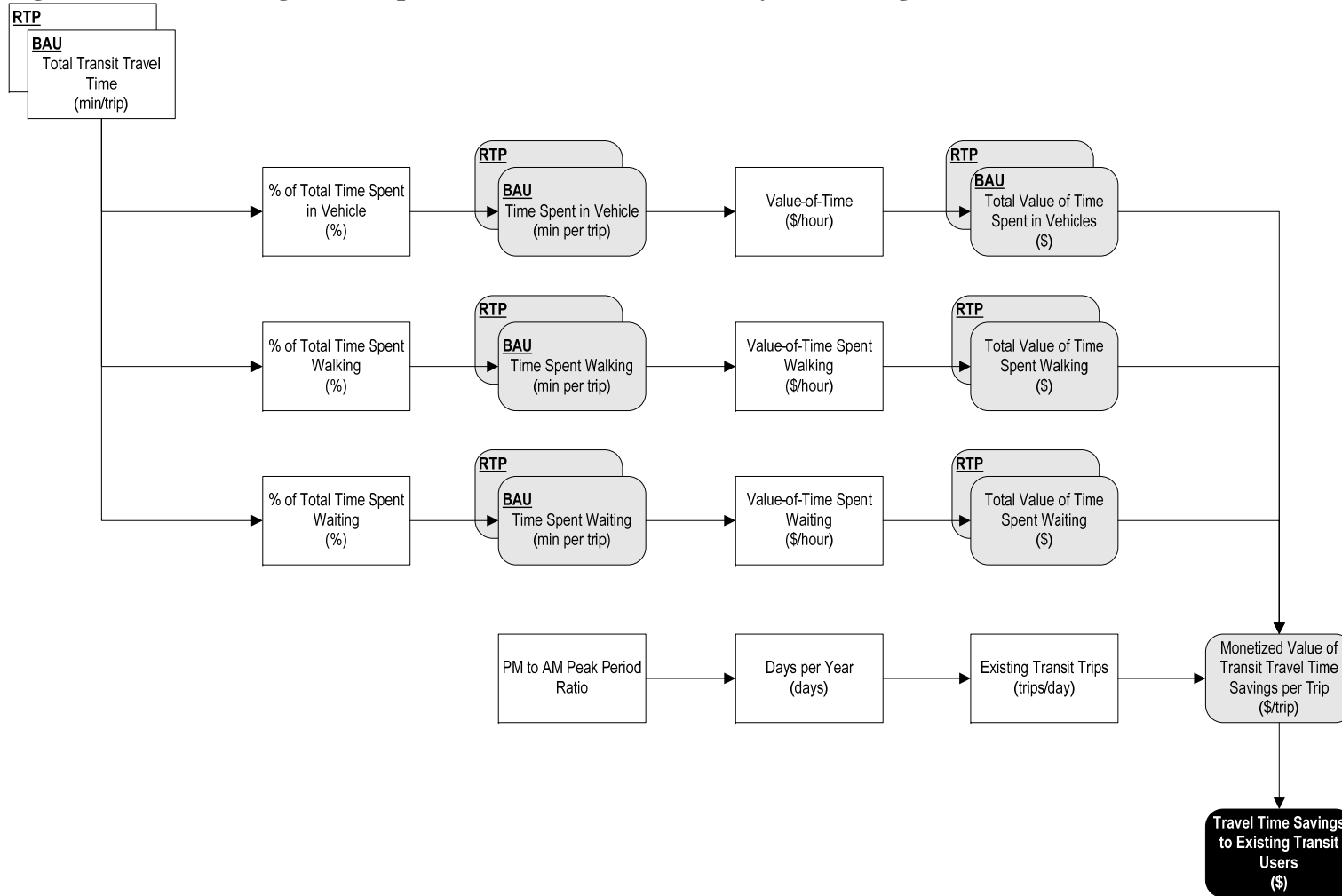
The third form of benefit is the resource savings arising from reduced social service agency outlays when people are able to travel to centralized points of service delivery rather than receiving home-based care. These are called “cross-sector benefits.” A disproportionate share of Canada’s transit riders (compared to the population at-large) receives welfare benefits. Federal Transit Administration research indicates that incremental additions to the availability of mass transit would help alleviate this budgetary pressure.

Time Savings and Improved Travel Time Reliability to Existing Transit Users

Time-related benefits occur as a result of total travel time reduction and changes in the quality or attributes of travel time.

Transit investment can reduce time savings for *existing* transit users independent of shifting modal choices. Adding more vehicles per hour to a bus route can improve waiting times. Track improvements and signal modernization can reduce schedule unreliability.

Figure 32: Time Savings and Improved Travel Time Reliability to Existing Transit Users

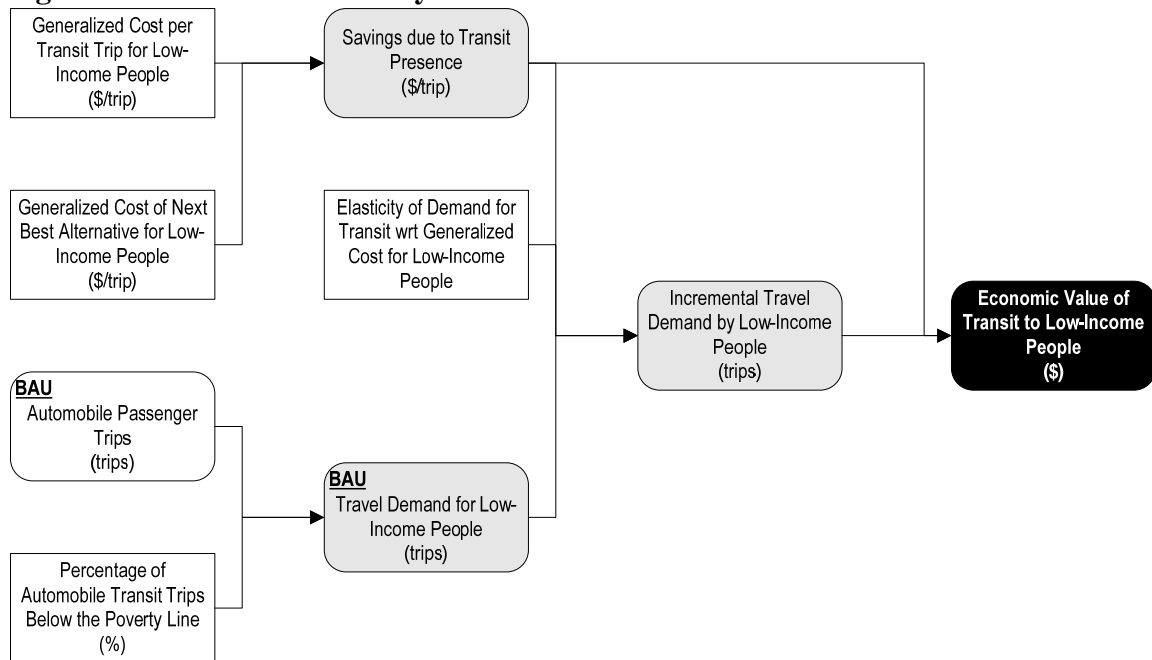


Affordable Mobility Benefits

In estimating the affordable mobility benefits of transit, we develop a model incorporating corridor trip characteristics by car, taxi, and transit. The forecast to be developed from these variables permits calculation of the value of consumer surplus for transit service. For the base case, we derive the number of low-income individuals (below the poverty line) who have no other choice but to drive, car-pool, or take a taxi as a form of daily transportation. Using elasticity coefficients and trips data, we estimate the number of trips that shift to the new, or improved, transit system given the availability of such service.

These diverted trips are calculated by including trip length data, the corresponding taxi fare, bus fare, and vehicle operating costs. The increase in trips diverted to the transit as a result of the new transit service is then derived. Given the change in trips and the associated price of each alternative service, the resulting consumer surplus is measured. If we compare this change in usage over modes of service, low-income individuals now experience a gain in consumer surplus because they bear a lower generalized cost. In addition, more trips are taken as the overall transportation expenditure decreases for these individuals. The gain in consumer surplus value may be viewed as the benefit of transit.

Figure 33: Affordable Mobility



Cross-Sector Benefits

Studies³⁰ have shown that low cost mobility programs alleviate pressure on other, non-transportation safety-net entitlement programs. Cross-sector benefits are defined to be benefits achievable in other sectors of the economy as a result of public transport.³¹ The FTA model of cross sector benefits used by HDR in this study accounts for savings in home-based services and social service agency transportation systems associated with the availability of mass transit. Home-based and other social services included in the model are home health care visits and welfare benefits.

The model assesses the impact of a reduction in the level of mobility on the level of social services. In quantifying the resulting increase in costs, such as increased home health care costs, the benefits due to transit services can be estimated. These costs would not exist if transit services were provided, and thus are qualified as cross-sector benefits of transit provision in the study area.

The diagram presented in Figure 34 provides a graphical illustration of the methodology, identifying all the model inputs and the relationships between these inputs.

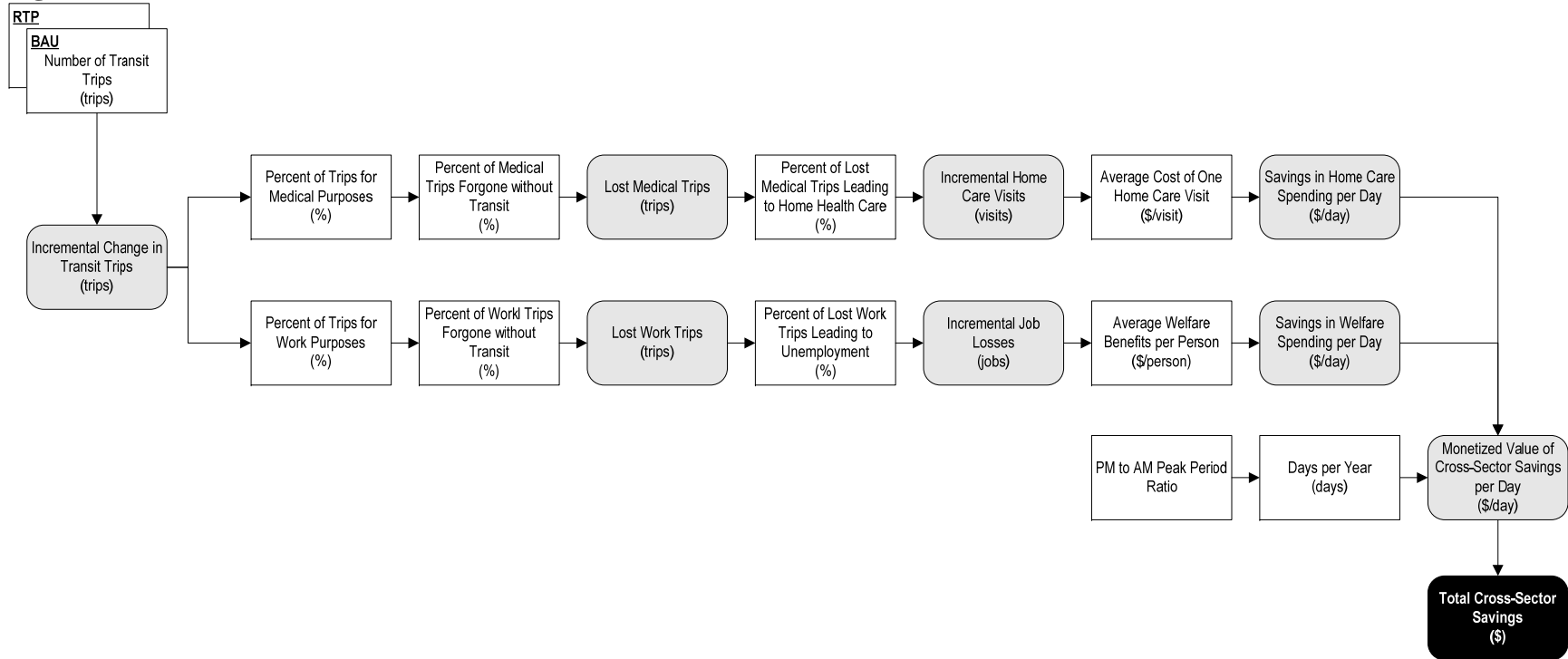
The starting point assumes a level of passenger trips by low-income individuals *eliminated* due to a lack of transit provision. These trips must be translated into trips by purpose to estimate social spending impacts. The percentage of lost medical trips leading to home health care and lost work trips leading to unemployment generates estimates of the number of added home health care visits and number of lost jobs. The average cost of a home health care visit is multiplied by the number of added visits to estimate the monetary value of these trips.³² Likewise, the added welfare costs per lost job are multiplied by the number of lost jobs to arrive at estimates of the monetary value of lost employment.

³⁰ Hickling Lewis Brod. “*The Benefits of Modern Transit*” Prepared for the Federal Transit Administration, p 2-28

³¹ Melanie Carr, Tim Lund, Philip Oxley and Jennifer Alexander. (1993) *Cross-sector Benefits of Accessible Public Transport*. Environment Resource Center, Crowthorne, Berkshire.

³² In converting passenger trips into the number of medical visits, we account for the fact that ridership data report one-way trips. Dividing the total number of trips made for medical purposes by a factor of 2 gives the number of medical visits.

Figure 34: Cross-Sector Benefits



Economic Development

Federal Transit Administration research finds that transit-oriented development has positive social and economic impacts on the economic vitality of communities. These impacts include:

- More scope and demand for walk and bicycle trips;
- A corresponding decline in the demand for motorized trips;
- Reduced auto-ownership requirements and dependence on automobiles;
- Greater demand for commercial floor-space and correspondingly higher commercial property values; and,
- More highly valued residential property due to the locational and environmental benefits of transit-oriented development, yet without higher residential taxes.³³

The model combines data collected from the Multiple Listing Service (MLS) and the Commercial Information Exchange (ICX), and Statistics Canada. For a representative sample of residential dwellings located within the study area the 2006 Census' Federal Electoral District Subdivision was used. Again, the hypothesis of this research is that transit improves the livability of transit-oriented neighbourhoods, producing benefits across the neighborhood, whether or not a particular resident uses transit. Finding a property value benefit with transit access, regardless of use, helps to confirm the notion of a neighbourhood benefit apart from the benefit from transit use.

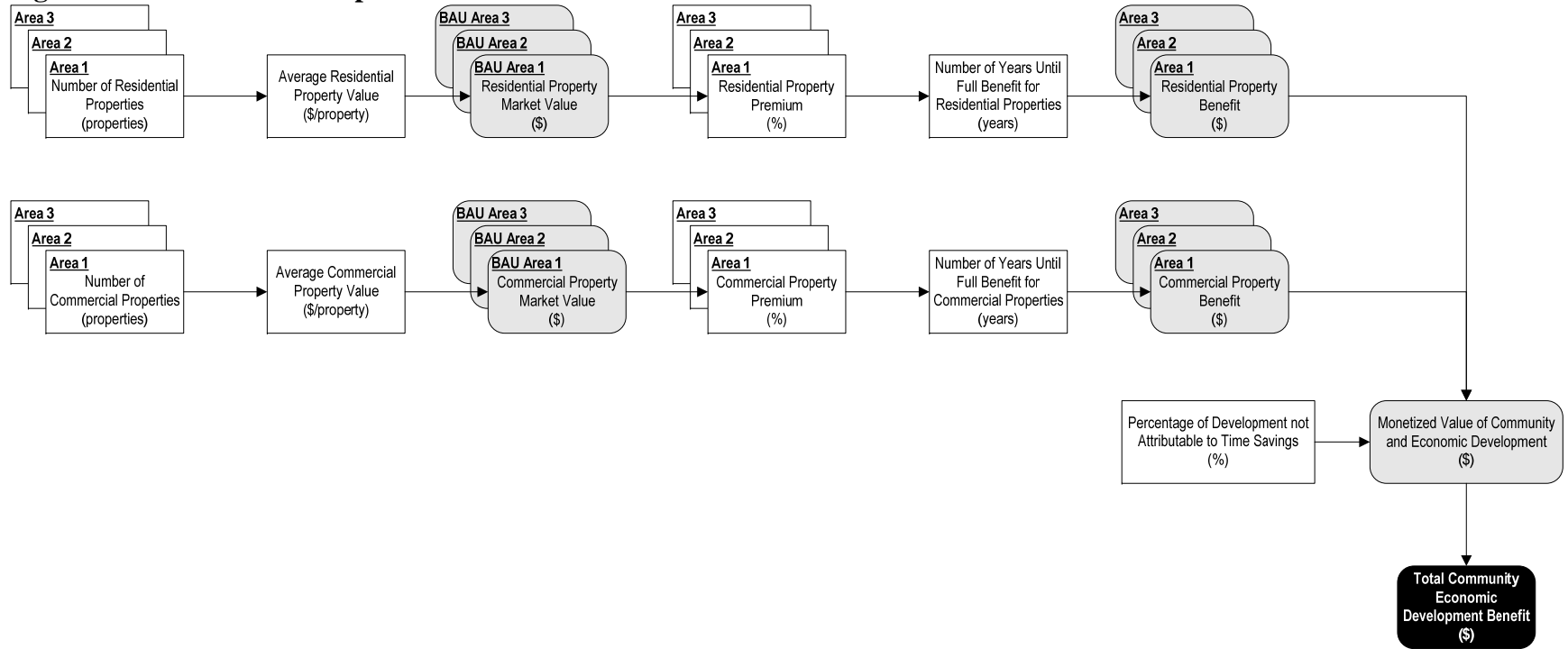
In many studies, however, the property value "premium" cannot be estimated by looking at property values along a transit alignment because the alignment does not exist yet. Instead, findings from other cities or corridors to derive the *likely* impact of transit on residential and commercial development have been used. Findings from national experience, expressed as property value increment per foot of proximity to transit, are combined with estimates of the number of properties along alignment, with the actual walking distance between each property in the study sample and the alignment, and with the current assessed property values to arrive at an estimate of total community development benefits.

Note that the benefit estimates include both transportation benefits and any non-use benefits of transit derived from neighborhood attributes and general livability. Currently, there is no sure way to separate these effects.

Figure 35 below illustrates the methodology.

³³ Residential tax rates are mitigated by the larger commercial tax base and the increase in population densities in transit-oriented communities.

Figure 35: Economic Development



Ramp-up

Ramp-up is the notion that benefits from a transportation investment is not realized instantaneously; in point of fact, many years may pass until an investment's benefits are fully realized. The lag is a result of individuals' preferences being "sticky" in the short-run. In the long-run, however, individuals' preferences are flexible and the individuals are better able to adapt their behaviour.

The model incorporates risk-adjusted ramp-up factors to take into account that: a) benefits are not fully realized immediately after construction completion; and b) that the exact time for benefits to be fully realized is not known with certainty.

Employment and Related Macroeconomic Impacts

It should be noted that in general employment is not considered a benefit in evaluating such investments. This is due to the fact that cost-benefit analysis only measures *incremental* effects. Employment effects are typically transfers; an investment in one sector results in a shift of employment from another sector. To the extent that investments create jobs that would not otherwise exist, these benefits should be included.

In most applications of cost-benefit analysis, the effect of an investment in transportation infrastructure on economic output would be capitalized within the monetary valuation of time savings. In this study, however, the effect of the DRTP on regional business output (in terms of increased GDP) is, to an extent, additional to the value of time benefits. This is because the valuation of time savings in this study are exclusively focused on observed and forecast volumes of auto and transit users, and commercial activity is not included in this valuation (since truck vehicle-kilometres are not included in the model, and the value of time is derived from regional household income).

Congestion reduces economic activity in two ways:

1. A reduction in the quantity demanded of labour due to employees expecting higher remuneration in order to be compensated for longer travel times; and
2. An increase in operations and logistics costs for businesses (higher inventory requirements, reduced economies of scale, and so forth).

This effect of congestion on the logistics costs is completely additive to the value of time savings, since it is not being measured in the cost of congestion model. The labour market effect, however, is only partially additive. On the demand side, the increase in wages will be captured by the value of time calculations and would thus be double-counting if included. On the supply side of the labour market, the effect of congestion would be additive to the value of time calculations (since this reduction in supply would translate into fewer work trips being taken, due to the higher cost of travel, and would thus not be accounted for in the value of time calculations).

In implementing the DRTP, traffic congestion would be reduced and these two effects on economic output would be vitiated to some extent. The present value of the forecast benefits

related to congestion management are then compared relative the cost of congestion that would occur absent the DRTP; this calculation determines the amount of lost economic output that would be avoided by implementing the DRTP and reducing congestion. As Figure 12 shows, the value of lost economic output due to congestion was estimated to be \$2.7 billion in 2006. This value is forecast to increase to over \$7 billion by 2031 if the DRPT is not implemented. The DRTP would reduce a portion of this loss in potential GDP over the study period, and it is this value that is included in the cost-benefit calculus (which is distinct from the economic impact of constructing the DRTP projects, which is the focus of Chapter 4 and discussed in Appendix 5).

Conversely, the reduction in business revenues embodies a transfer and is thus not additive with respect to the other benefits of reduced congestion.

A4.2 Economic Costs

The taxonomy in relation to economic costs covers four cost categories:

- Capital expenditures;
- Incremental operating and maintenance costs; and,
- The opportunity cost of capital employed.

At the time of the analysis maintenance and storage facilities and refurbishment costs were not included. Also, the operations and maintenance estimate did not include Program and Policy Operating Costs.

Capital Costs

Capital spending has been divided into three phases over the 25-year investment plan.

CATEGORY	CAPITAL SPENDING BY PLAN			
	10 YEAR	15 YEAR	25 YEAR	ALL YEARS
UNDISCOUNTED COSTS				
Capital Expenditures	\$17,510	\$11,150	\$19,190	\$47,850

Note: values are in millions of dollars (\$2006)

Operating and Maintenance Costs

Incremental operating and maintenance costs are over the three phases of the 25-year investment plan.

CATEGORY	CAPITAL SPENDING BY PLAN			
	10 YEAR	15 YEAR	25 YEAR	ALL YEARS
UNDISCOUNTED COSTS				
Operating and Maintenance Costs	\$1,497	\$2,621	\$7,824	\$11,943

Note: values are in millions of dollars (\$2006)

The Opportunity Cost of Capital

Time Value and Discounting

All project costs and benefits are quantified and translated into monetary values for each year of the project life cycle. Calculation of the life-cycle stream of project benefits, costs, and net benefits is done in terms of the present-day value. Present-day value calculation involves discounting the stream of costs and benefits with an annual real discount rate of five percent.

Discounting expresses the idea that future years' benefits and costs are worth less than current year benefits and costs and should be discounted to make them comparable to current year benefits and costs and allow adding them up over the project life-cycle years. This definition of projects total costs, benefits and net benefits indicates the importance of both the magnitude as well as timing of costs and benefits. For example, large up-front costs will tend to depress project evaluation metrics (such as net benefits) compared to a situation where costs are spread more evenly over a period of a few years. Also, benefits occurring only later during the project life cycle will tend to depress project evaluation metrics compared to a situation where benefits can be realized in the first few years of the project life.

A4.3 Measures of Economic Worth

The Base Case

Prudence in transportation investment planning counsels that major new projects be approved only if they can be justified after accounting for efforts designed to make the most efficient and productive use of existing facilities, called the “base case.” The base case is the alternative to the project, in other words, the changes or modifications to existing infrastructure that would occur in the absence of the project. The base case can include certain transportation system management innovations; small-scale spot infrastructure capacity improvements (such as interchange improvements); expanded bus service, and so on. For this study, the base case is the “business as usual” scenario, which assumes no major investment in infrastructure for the transportation network.

Net Present Value

The *Net Present Value (NPV)* is the principal criterion used to evaluate an investment proposal. Project worth is assessed with the NPV: the present-day value of the entire stream of future net benefits. Annual net benefits are estimated as: total benefits in a year (congestion management benefits, mobility benefits, community development benefits, and economic output) *minus* total costs in that year. The streams of costs and benefits are discounted with an annual real discount rate of five percent

The Importance of Risk Analysis

Each investment project typically carries some uncertainty, or risk, as to the magnitude and timing of costs and benefits. There is a risk of cost over-runs due to a number of factors including underestimated scope of required work, unavailability of equipment and supplies from

lower-priced sources, poor management, etc. There is also a risk that benefits will not be as large as initially expected due to longer ramp-ups, lower public interest in the investment, etc. Similarly, there is a chance that project cost will actually be lower and/or project benefits actually higher than initially expected.

This uncertainty associated with costs³⁴ and benefits is explicitly taken into account in the model by specifying the median values of each model variable as well as its range i.e. a lower estimate of possible values and higher estimate of possible values. For example, initial research may reveal that a transit investment project will reduce the average waiting time for bus users by 10 minutes. A further analysis may then reveal that the reduction in waiting time may be as low as only 5 minutes (with a 90 percent probability of such outcome), or as high 17 minutes (with a 10 percent probability of such outcome). The model uses the variables with its specified mean, lower and upper values to translate them into probability distributions, and calculates evaluation metrics together with their probability distribution. An example using the value of time is given at the beginning of Appendix 6.

Taking into account the uncertainty associated with the magnitude and timing of costs and benefits and generating evaluation metrics with their probability distribution allows making the decision with respect to the proposed investment project on the basis of its risk profile and the attitude to risk. For example, if the institution granting capital funds for the project is in general risk-averse, projects that have a relatively small risk of negative NPV could be selected over projects that have a significant risk of a downside. By the same argument, if there is some willingness to accept risks, projects with a large possible upside could be promoted under certain conditions such as when risk mitigation seems feasible and manageable.

Table 27 summarizes the ‘value for money’ results of the DRTP cost-benefit analysis.

Table 27: Evaluation Metrics of the DRTP, 25-Year Study Period

INDICATOR - VALUE FOR MONEY	MEAN	10th PERCENTILE	90th PERCENTILE
Total Costs (Present Value)	\$31,156	N/A	N/A
Total Benefits (Present Value)	\$46,674	\$43,811	\$52,408
Net Present Value (at 5%)	\$15,519	\$12,620	\$21,249
Internal Rate of Return	19.0%	18.1%	24.2%

³⁴ An estimate of +/- 10% on costs was applied to each of the capital and operating cost items. However, this variance is lost in the analysis when costs are aggregated and then discounted. As such, while there is uncertainty applied to the costs, it is not shown here. As the plan and projects become better defined a more detailed analysis of cost risk can be done by project.

APPENDIX 5: MACRO-ECONOMIC IMPACT ANALYSIS MODEL

A5.1 Key Concepts in Economic Impact Analysis

Economic impact analysis is the study of the effect of a change in the demand for goods and services on the level of economic activity in a given geographic area. This change in economic activity is typically measured by business output (sales), value added (gross regional product), employment (number of jobs), and labour income (earnings).

The change in demand can be the result of decisions made by the government, firms, or households, for example a new investment project. When a company, an organization, or individuals, make changes in their expenditures, a series of changes in incomes and expenditures of economic agents through the supply chain is induced. For example, a new investment in infrastructure increases demand for certain goods and services. Experiencing higher demand and income, producers of these goods and services increase their private consumption as well as increase orders for inputs necessary to produce the higher amount of goods and services. These changes in turn generate additional revenues and incomes for other businesses down the supply chain that provide inputs to the production process. Experiencing higher demand and income, they too place new orders with their suppliers and those suppliers place new orders with their suppliers, and so on. It is quite apparent that the sum of all these changes is larger than the initial change in the expenditures, or the initial investment.

Frequently, various stakeholders are interested in the economic impact (or the contribution to the economy) of certain local companies, their current operations, and/ or investment projects.

Traditionally, economic impact analysis involves the estimation of three distinct types of expenditures and production activities that capture the various rounds of expenditures and economic activity described briefly above. They are commonly referred to as “direct impacts,” “indirect impacts,” and “induced impacts” and can be defined as follows:

- Direct impacts refer to immediate economic outcomes occurring as the result of activity related to operations or project being evaluated (such as operations of a local company, or its investment projects). These immediate outcomes include business output or revenues/sales, employment of workers, their employment earnings, value added, and tax revenues.
- Indirect impacts refer to the “spin-off” economic activities that result from purchases of production inputs, goods and services, by those businesses that generated the direct effects described in the previous bullet. These purchases of production inputs allow for production activities and employment at the supplier firms. The spending by these supplier firms for goods and services necessary for the production of their products or services creates output of other firms further down the production chain, thus bringing about additional business output, employment, and earnings.
- Induced impacts represent the increase in business output, employment, and earnings over and above the direct and indirect impacts, generated by re-spending of employment income from direct and indirect employment. Induced impacts are thus changes in

output, employment, and earnings that are the result of personal (household) spending for goods and services by employees of the business that generated the direct effect and employees of all other firms comprising the indirect impact.

The total economic impact is the sum of the direct, indirect and induced effects of the company or the project being evaluated.

Indirect and induced impacts are often referred to as “multiplier effects,” since they increase the overall economic impacts of the original activity and expenditure that initiated all subsequent rounds of spending and effects described above.

Multipliers typically are expressed in terms of output, jobs, or employment income per \$1 of the initial investment (or expenditure, or business revenue). For example, an output multiplier is the increase in business output for all industries per one dollar of initial expenditure. A multiplier of 2.10 for the construction industry means that an investment or expenditure of \$1 for products of a construction company (or an increase of \$1 in revenues in this company) increases business revenues across the entire economy by \$2.10.

It should be noted that that input-output analysis and multipliers provide an average and static assessment of impact that is based on the technology and economic structure at the time of the analysis and assessment. Over time, as the economic conditions and the technology change, the multipliers and their implications may change as well.

Also, the traditional input-output multipliers techniques to calculating economic impact assume no capacity constraints, i.e. all resources needed to satisfy the increased demand would be available at their current prices. If that is not the case, some of the forecast impacts could not materialize.

A5.2 Scope and Approach

This study assesses the economic impacts of DRTP in terms of incremental business revenue, jobs, employment income, and tax revenues within the province of Ontario. The specific effects estimated are described in some detail below.

A5.2.1 Direct Effects

The direct effects of the DRTP are estimated on the basis of the Ontario-share of the expenditures necessary to implement the proposed plan, including expenditures for the following goods and services:

1. Engineering, design, and management;
2. Construction and civil works;
3. Vehicles, locomotives, and rail cars; and,
4. Machinery (non-vehicles equipment).

The direct output, or business revenue impact is equal to the amount of expenditures related to the DRTP that would take place in Ontario (as assessed by Metrolinx), or the amount of goods

and services purchased from Ontario suppliers. Direct employment, employment income, and GDP are estimated on the basis of economic impact ratios for direct effects that are available for a wide range of industries from Statistics Canada's inter-provincial input-output model.

For example, the employment-output ratio gives the average number of jobs per \$1 million of business output. Therefore, multiplying the amount of expenditures for an industry product by its employment-output ratio will give an estimate of the number of incremental jobs that would be created as a result of the expenditure in question. The employment income ratio gives the amount of employment income for each \$1 of expenditures for an industry product. Therefore, multiplying the amount of total expenditures by this ratio will give an estimate of employment income. Finally, the GDP ratio gives the value of GDP resulting from each \$1 of these expenditures. Therefore, multiplying the amount of total expenditures by this ratio will give an estimate of GDP that will result from the original expenditure.

A5.2.2 Indirect Effects

The indirect effects are estimated using indirect multipliers from the Statistics Canada Interprovincial Input-Output Model. The inter-provincial input-output model captures flows of goods and services between the various industries across each province and Canada, and the multipliers provide an aggregate measure of the average effect of an industry on all other industries.

There are indirect input-output multipliers for output, employment, and employment income. In other words, multiplying the direct output of an industry indirect output multiplier will give the value of indirect output across all industries in the province that is attributable to that initial output. Multiplying the same value of direct output by indirect employment multiplier will give the number of indirect jobs across the province. Finally, multiplying the value of direct output by indirect employment income multiplier will give employment income of all indirect employees across the province.

Multipliers for output, employment, and employment income are available for a wide range of industries defined at various levels of North American Industrial Classification System (NAICS) classification. Therefore, the expenditures/costs related to the DRTP have to be broken down by type and classified into industrial sectors consistent with and corresponding to NAICS industrial codes. The expenditures classified in this way are then combined with the closest relevant multiplier from the Inter-Provincial Input-Output Model as outlined above to obtain an estimate of indirect output, employment, and employment income attributable to the DRTP.

The sum of indirect effects attributable to each type of expenditures lines will represent total indirect effects province-wide.

A5.2.3 Induced Effects

Statistics Canada's Inter-Provincial Input-Output Model does not simulate induced economic impacts and does not generate induced multipliers. Therefore, a different approach is needed to determine induced effects.

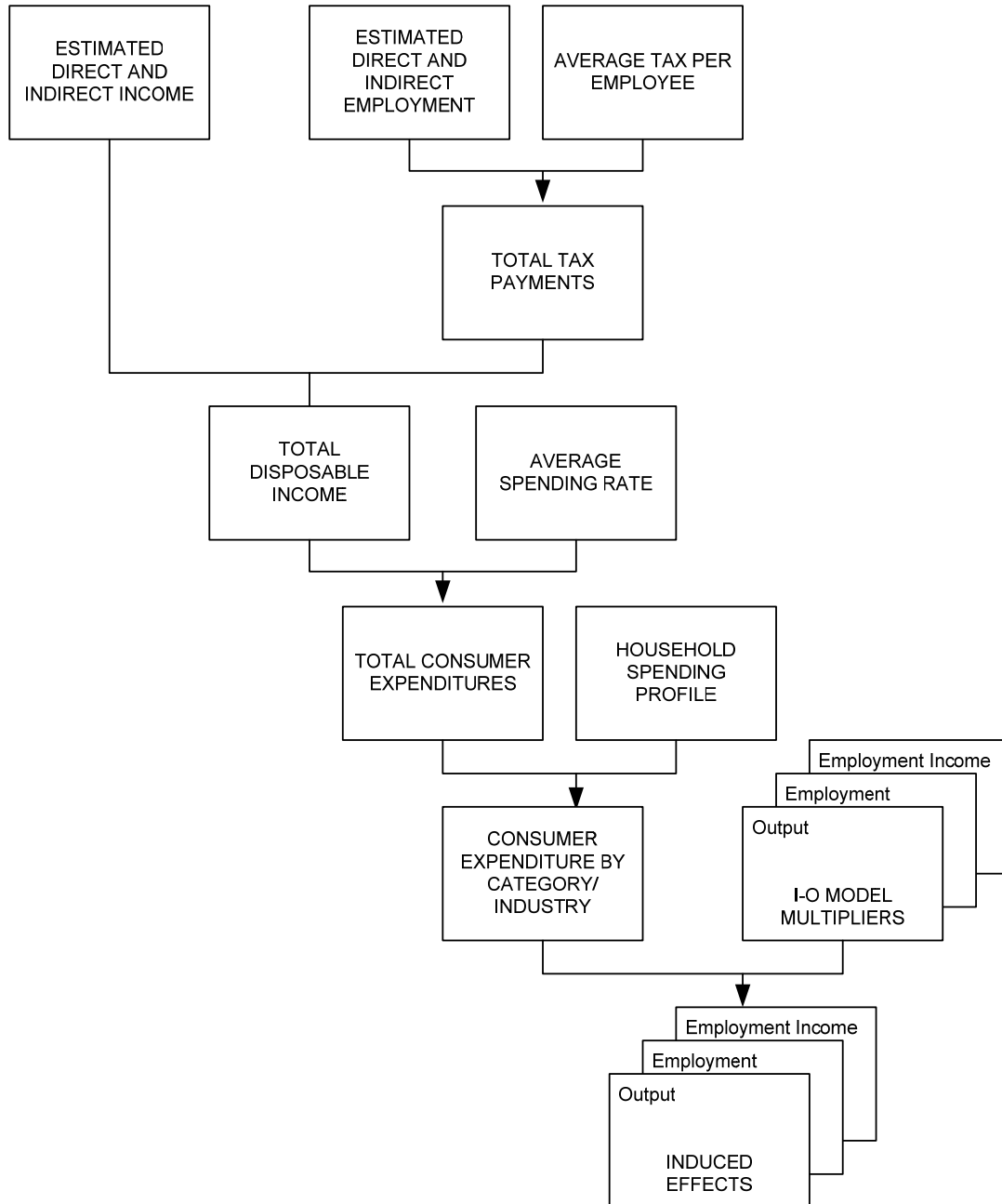
The approach utilized here is based on the notion that induced impacts are driven by re-spending of employment wages and salaries. Estimates of total direct and indirect employment income and other additional economic data from Statistics Canada (including Ontario consumer spending patterns, savings rate, or average taxes) can be used to determine where/on what the employment income is spent. These amounts of expenditures are then combined with appropriate aggregate input-output multipliers from Statistics Canada (for output, employment, and employment earnings) to determine total induced impacts.

In summary, the approach for estimation of induced impacts involves the following steps:

1. Estimate total disposable employment income attributable to direct and indirect impact;
2. Estimate total consumption expenditure;
3. Allocate total consumption expenditure estimated in step (2) to expense categories (such as food, clothing, housing, etc.); and,
4. Multiply each expenditure item (i.e. expenditure by expense category) by total input-output multipliers relevant for the given expense category (or industry to which the expense category corresponds, for example: food bought in stores would be multiplied by multipliers for the retail industry).

The methodology is illustrated in Figure 36.

Figure 36: Estimation of Induced Province-wide Impact



In economic impact analysis, frequently evaluated metrics of impact are: output, employment, employment income, and GDP. Output is defined as the sum of gross business revenue across all affected business establishments. Employment is the number of jobs (both full-time and part-time). Employment income is the value of wages and salaries, supplementary labour income, and propriety income. GDP, or the Gross Regional Product, is the sum of a value added at every stage of production of final goods and services.

A5.3 Input Assumptions

Table 28 shows the amount of expenditures related to the DRTP that would take place in Ontario and that provided the basis for impact estimation. As the table shows, the estimated DRTP expenditures to be made within Ontario amount to about \$12.8 billion, or 26 percent of the estimated total capital expenditure of \$48 billion.

Table 28: Estimated DRTP Expenditures for Goods and Services of Ontario Suppliers

CONSTRUCTION EXPENDITURES BY TYPE	AMOUNT OF ONTARIO EXPENDITURES (\$)
Engineering, Design, Management	3,006,463,996
Construction and civil works	20,376,923,659
LRT vehicles	670,951,190
BRT vehicles	1,904,705,126
Subway Cars	998,828,175
Locomotives	401,676,296
Rail Fleet	5,806,955,211
Machinery (non-vehicles)	759,062,408
TOTAL	33,925,566,060

Source: Estimated by HDR based on expenditure shares by mode and category of expenditures provided by Metrolinx

Table 29 shows the tax revenue per employee, by level of government that is used for estimation of tax revenue impacts.

Table 29: Tax Revenues per Employee

LEVEL OF GOVERNMENT	REVENUES PER EMPLOYEE, 2007 ONTARIO
Local/ Municipal	\$4,523
Provincial	\$15,939
Federal	\$14,034
TOTAL REVENUE	\$34,496

Source: Calculated based on Statistics Canada CANSIM Table 385-001, tax revenues by level of government, as well as Ontario and Canada employment

Table 30 presents the direct economic ratios and multipliers that were used in the analysis. For each expenditure type, the table shows the corresponding IO model industry, direct effects (i.e. direct employment output ratio, direct employment income ratio, and direct GDP), and indirect multipliers (i.e. indirect multipliers for output, employment, employment income, and GDP). Note that the ratio for direct output is omitted in the table as by definition it is equal to 1, the amount of the expenditure itself.

Table 31 presents the total economic impact multipliers (the sum of direct effects and indirect multipliers) that correspond to consumer expenditures and that are used for estimation of induced impacts.

Table 30: Economic Impact Ratios and Multipliers for Economic Impact Assessment

CONSTRUCTION EXPENDITURES BY TYPE	CORRESPONDING IO INDUSTRY	DIRECT EFFECTS			INDIRECT MULTIPLIERS			
		EMPLOYMENT (PER \$1M OF DIRECT OUTPUT)	INCOME (PER \$1 OF DIRECT OUTPUT)	GDP (PER \$1 OF DIRECT OUTPUT)	OUTPUT (PER \$1 OF DIRECT OUTPUT)	EMPLOYMENT (PER \$1M OF DIRECT OUTPUT)	INCOME (PER \$1 OF DIRECT OUTPUT)	GDP (PER \$1 OF DIRECT OUTPUT)
Engineering, Design, Management	Legal, accounting and architectural, engineering and related services	9.80	0.612	0.68	0.350	2.829	0.131	0.201
Construction and civil works	Transportation engineering construction	5.39	0.284	0.40	0.669	3.674	0.187	0.309
Light Rail Transit (LRT) vehicles	Railroad rolling stock manufacturing	1.95	0.167	0.18	0.641	3.288	0.171	0.247
Bus Rapid Transit (BRT) vehicles	Manufacturing	2.580	0.155	0.278	0.484	2.642	0.131	0.211
Subway Cars	Railroad rolling stock manufacturing	1.95	0.167	0.18	0.641	3.288	0.171	0.247
Locomotives	Railroad rolling stock manufacturing	1.95	0.167	0.18	0.641	3.288	0.171	0.247
Rail Fleet	Railroad rolling stock manufacturing	1.95	0.167	0.18	0.641	3.288	0.171	0.247
Machinery (non-vehicles)	Machinery manufacturing	4.39	0.270	0.43	0.413	2.394	0.123	0.192

Source: Statistics Canada, *Interprovincial Input-Output Model*

NOTE: For BRT Vehicles, multipliers for the 2-digit manufacturing industry are used rather than multipliers for a more specific industry, such as motor vehicle manufacturing, as direct ratios for the more specific industry were suppressed by Statistics Canada for confidentiality reasons.

Table 31: Total Economic Impact Ratios for Calculation of Induced Economic Impacts

CATEGORY OF EXPENDITURE	PERCENT SHARE OF TOTAL EXP.	CORRESPONDING IO INDUSTRY	TOTAL ECONOMIC IMPACT RATIOS			
			OUTPUT (PER \$1 OF DIRECT OUTPUT)	EMPLOYMENT (PER \$1M OF DIRECT OUTPUT)	INCOME (PER \$1 OF DIRECT OUTPUT)	GDP (PER \$1 OF DIRECT OUTPUT)
Food	13.9%	4A Retail Trade	1.43	20.80	0.618	0.89
Shelter	28.8%	5A0 Finance, Insurance, Real Estate	1.34	4.76	0.401	0.92
Household Operations	6.7%	4A Retail Trade	1.43	20.80	0.618	0.89
Household Furnishings and Equipment	4.2%	4A Retail Trade	1.43	20.80	0.618	0.89
Clothing	6.0%	4A Retail Trade	1.43	20.80	0.618	0.89
Private Transportation	16.2%	Composite	1.38	17.71	0.51	0.89
Public Transportation	2.1%	4850 Transit and Ground Passenger Transportation	1.56	19.48	1.02	0.80
Health Care	3.1%	62 Health Care Services	1.28	17.74	0.722	0.88
Personal Care	2.3%	81 Other Services	1.37	27.58	0.522	0.87
Recreation	8.0%	71 Arts, Entertainment and Recreation	1.55	21.20	0.382	0.82
Education	2.7%	61 Educational Services	1.29	29.27	0.782	0.94
Tobacco and Alcohol	2.6%	4A Retail Trade	1.43	20.80	0.618	0.89
Other	3.2%	4A Retail Trade	1.43	20.80	0.618	0.89

Source: Percent Shares of Total Expenditures are based on "Spending Patterns in Canada", 2006 Edition, Statistics Canada, Cat. #62-2002, household spending pattern for Ontario. Total Economic Impact Ratios were obtained from Statistics Canada, Inter-Provincial Input-Output Model.

A5.4 Results

Table 28 presents the output, employment, employment income, and GDP impact in Ontario that would result from the DRTP investment expenditure. Table 26 presents the tax revenue impacts of the investment broken down by level of government.

Table 28 shows the total output impact of the DRTP investment projects amount to over \$69.6 billion, including \$33.9 billion of the original expenditures that would take place in Ontario, nearly \$21 billion in indirect or spin-off effects, and \$14.7 billion of induced impacts. The plan will create an estimated 429,528 jobs, including 153,795 direct jobs, 116,126 indirect jobs, and 159,607 induced jobs. These jobs would generate an employment income effect of nearly \$21 billion, including \$9.4 billion of direct employment income, \$5.9 billion of indirect income and \$5.6 billion induced income. The DRTP projects will result in an increase in Ontario's GDP of over \$31 billion. This estimate includes over \$12.4 billion of direct GDP, \$9.4 billion of indirect GDP, and \$9.4 billion of induced GDP.

Table 29 shows that the total tax revenue impact of the DRTP is estimated at over \$14.8 billion. This includes \$1.9 billion in local and municipal tax revenues, \$6.8 billion of provincial tax revenues, and \$6 billion of federal tax revenues. These tax revenues include all sources of taxation, in particular personal income taxes, corporate income taxes, property taxes, and consumption taxes.

It should be noted that all results presented in Table 32 and Table 33 represent the cumulative impact over the period when expenditures shown in Table 28 would be made. The annual impact of the DRTP would be equal to the proportion of expenditures made in a particular year. For example, if all expenditures were equally distributed over a period of 25 years, the annual impact of the DRTP in each year (during this 25-year period) could be calculated by dividing all numbers shown in Table 32 and Table 33 by a factor of 25. After the 25-year period, all impacts would be zero.

A distinction is necessary in interpreting the output and GDP values provided in Table 32. These values are related to the economic impact that the DRTP investment would have through the construction of the various component projects of the plan. It is not related to the impact that excess congestion has on the regional economy by decreasing output (as per Chapter 2), or the benefit of the DRTP in increasing output through a reduction in traffic congestion (as per Chapter 3 and discussed in Appendix 4).

Table 32: Output, Employment, Employment Income, and GDP Impacts in Ontario of the DRTP Investment

TYPE OF IMPACT	OUTPUT (\$M)	EMPLOYMENT (\$M)	EMPLOYMENT INCOME (\$M)	GDP (\$M)
Direct Impacts by Type of Expenditures				
Engineering, Design, Management	\$3,006.5	27,803	\$1,839.2	\$2,044.0
Construction and civil works	\$20,376.9	103,682	\$5,789.7	\$8,141.0
LRT vehicles	\$671.0	1,237	\$111.7	\$120.8
BRT vehicles	\$1,904.7	4,639	\$294.3	\$530.2
Subway Cars)	\$998.8	1,842	\$166.3	\$179.9
Locomotives	\$401.7	741	\$66.9	\$72.3
Rail Fleet	\$5,807.0	10,708	\$966.9	\$1,045.7
Machinery (non-vehicles)	\$759.1	3,144	\$205.2	\$323.5
TOTAL DIRECT IMPACT	\$33,925.6	153,795	\$9,440.2	\$12,457.5
INDIRECT IMPACTS	\$20,969.7	116,126	\$5,891.8	\$9,391.8
INDUCED IMPACTS	\$14,756.0	159,607	\$5,643.6	\$9,422.2
TOTAL IMPACTS	\$69,651.3	429,528	\$20,975.6	\$31,271.5

NOTES: Output is defined as the sum of gross business revenue across all affected business establishments. Employment is the number of jobs (both full-time and part-time). Employment income is the value of wages and salaries, supplementary labour income, and propriety income. GDP, or the Gross Regional Product, is the sum of a value added at every stage of production (the intermediate stages) of final goods and services.

Table 33: Tax Revenue Impact in Ontario of the DRTP Investment

LEVEL OF GOVERNMENT	TAX REVENUE (\$M)
Local/ Municipal	\$1,942.7
Provincial	\$6,846.3
Federal	\$6,028.1
TOTAL TAX REVENUE	\$14,817

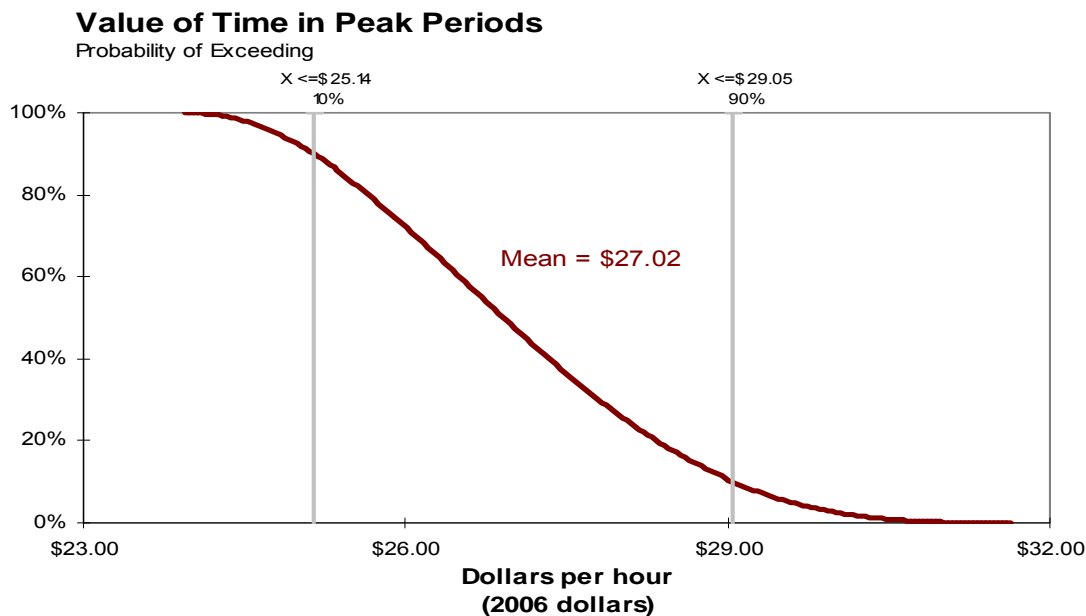
APPENDIX 6: DATA USED IN MODEL

This section summarizes the relevant input data that was used in populating the models of the costs and benefits that were developed in both the congestion cost model and the cost-benefit analysis process. The data values and sources are indicated, with assumptions provided where necessary, in Tables 28-36.

It should be noted that the values presented in Tables 28-36 are central estimates. While a central estimate may provide the best guess, it offers no information about the range of possible outcomes. For this reason, each variable is assigned a range (low, central and high estimate) to represent the degree of uncertainty. These distributions are combined using Monte Carlo simulation which allows all variables to vary simultaneously from their expected values. The result is a probability distribution on all inputs and outputs from the model.

For example, Figure 37 graphically depicts the range of values an individual places on one hour of their time during the peak period. There is 90 percent probability that the value of time will exceed \$25.14/hour and a 10 percent probability that costs will exceed \$29.05/hour. The mean outcome is \$27.02/hour.

Figure 37: Descending Cumulative Distribution of Possible Outcomes for the Value of Time in Peak Periods



Source: The value of time per hour is calculated by taking 50 percent of the average hourly wage rate. The average hourly wage was calculated by dividing the average household income for the Toronto CMA (Census data) by 2000 working hours per year. It should be noted that the value of time was scaled-up by a factor of 2.5³⁵, for the peak hour only, to take into account the increased cost of traveling in uncertain conditions.

³⁵Small, K., R. Noland, X Chu and D. Lewis. 1999. Valuation of Travel-Time Savings and Predictability in Congested Conditions for Highway User-Cost Estimates. National Cooperative Highway Research Program.

The value of time variable describes the average value of travel time for commuter trips. The variable is expressed as dollars per hour. The model uses the average value of travel time to translate minutes saved (or improved) due to a transit investment project to dollar benefits.

The value of time is greater than the default value in the TransDEC model because the average wage has been updated and the scaling factor of 2.5. The update value uses 50 percent of the average household income in GTA of \$64,128 adjusted for inflation from 2005 to 2006 divided by 2,000 hours. The graph and table below compares the TransDEC (2001) default and the updated value of time used in this analysis.

Figure 38: Descending Cumulative Distribution of Possible Outcomes for the Value of Time in Peak Periods and TransDEC Default Values

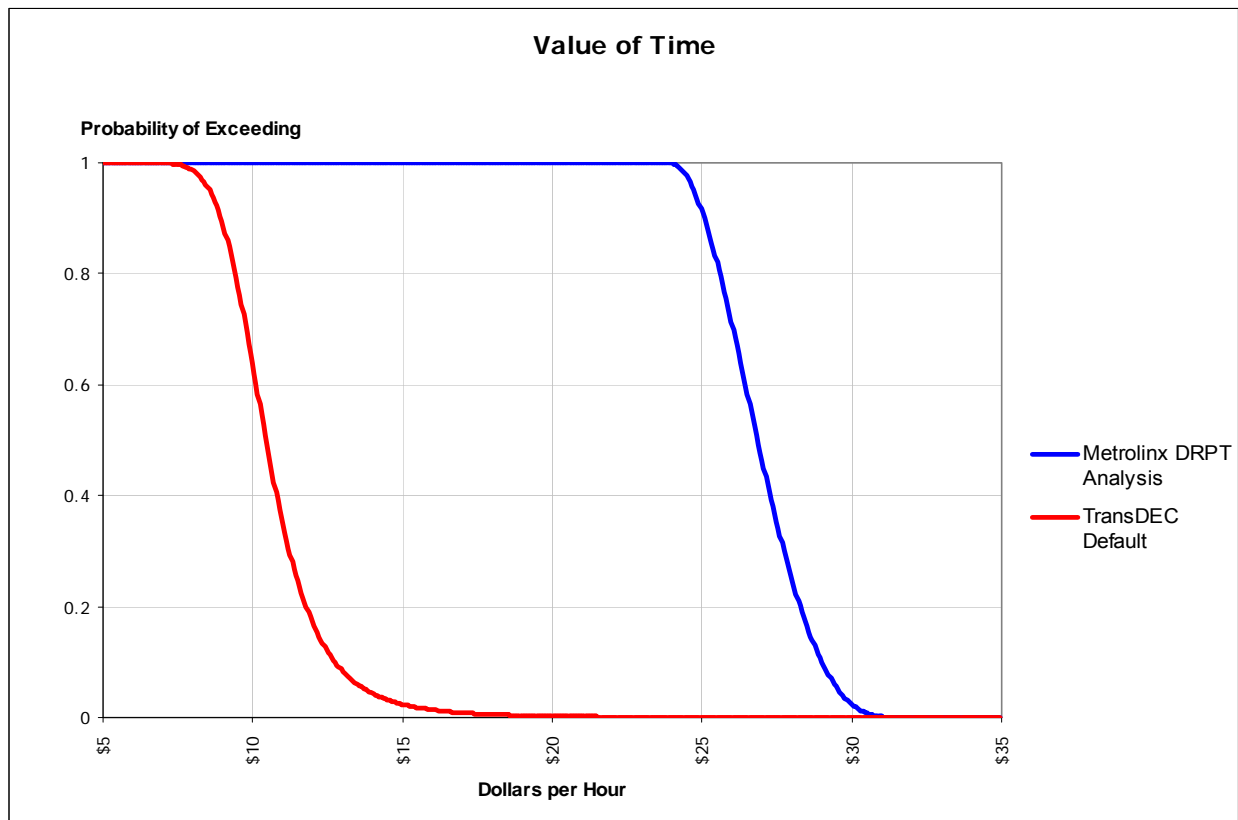


Table 34: Data Required for the Model of Congestion Costs

	TRANSDEC DEFAULT	METROLINX DRTP COST-BENEFIT ANALYSIS
Value of time in vehicle (\$)		
Median Estimate	\$10.50	\$27.02
10% Lower Limit	\$9.00	\$25.14
10% Upper Limit	\$12.80	\$29.15

Table 35: Data Required for the Model of Congestion Costs

DATA INPUT	DATA SOURCES AND COMMENTS	ASSUMED DATA VALUE												
Baseline traffic volume (vehicle-kilometres traveled, VKT)	Metrolinx modeling to support DRTP. For more information on the modeling methodology, as well as more detailed results, please see the technical backgrounder available on the Metrolinx website.	Varies by region, see Table 9 for details.												
Elasticity of travel demand (with respect to generalized cost)	Elasticity estimates specific for the GTHA were not available. Economics literature and other travel studies indicate that travel demand elasticities are typically in the range of about -0.3 to -1. Elasticities tend to be higher (in absolute terms) in cities with a good transit network.	-0.5												
Average costs of driving (fuel, maintenance, depreciation), \$/km	Provided by IBI; same value used in Metrolinx modeling	\$0.201/vehicle-km												
Value of time, \$/hour	Value based on 50 percent of the average wage rate in the GTHA (according to Census data); value used includes a scale factor to increase the value to account for the willingness-to-pay of commuters to reduce travel time variability and uncertainty	\$26.57/person-hour												
Actual baseline congested speed (km/hr)	Provided by IBI; same value used in Metrolinx modeling	Varies by region, see Table 12 for details.												
Free-flow speed (km/hr)	Provided by IBI; same value used in Metrolinx modeling	Varies by region												
Regional population	Statistics Canada, 2006 Census data	<table> <tr> <td>Hamilton</td> <td>504,559</td> </tr> <tr> <td>Halton</td> <td>439,526</td> </tr> <tr> <td>Peel</td> <td>1,159,405</td> </tr> <tr> <td>Toronto</td> <td>2,503,281</td> </tr> <tr> <td>York</td> <td>892,712</td> </tr> <tr> <td>Durham</td> <td>561,258</td> </tr> </table>	Hamilton	504,559	Halton	439,526	Peel	1,159,405	Toronto	2,503,281	York	892,712	Durham	561,258
Hamilton	504,559													
Halton	439,526													
Peel	1,159,405													
Toronto	2,503,281													
York	892,712													
Durham	561,258													

Table 35: Data Required for the Model of Congestion Costs (Cont'd)

DATA INPUT	DATA SOURCES AND COMMENTS	ASSUMED DATA VALUE
Proportion of excess commuting delay costs absorbed by employers	Economics literature, e.g. Weisberg G., D. Vary, and G. Treyz (2001) "Economic Implications of Congestion", NCHRP Report 463, Transportation Research Board	0.5
Average labour cost (annual salary plus benefits) in GTHA	Statistics Canada, 2006 Census data (persons who worked full-time, full-year); 2006 figure (\$30,350) marked-up by 13 percent to account for benefits (based on multipliers from Statistics Canada input-output model)	\$35,595
Elasticity of labour demand with respect to costs	Based on references reported in HDR study for Partnership for New York City, "The Economic Costs of Congestion in the New York City Region", Section 3.6.1	1
Baseline employment in GTHA	Statistics Canada, 2006 Census data. Total employment (3,144,855) adjusted by proportion commuting to work (92.6 percent)	2,912,296
Average employment-output ratio in regional economy	Calculated as the weighted average of employment-output ratios (by industry) from Statistics Canada Inter-Provincial Input-Output Model. Weights based on employment share by industry.	5.7
Consumption rates of vehicle operating components	HighwayDEC, a Cost-Benefit Model for Highway Infrastructure Investment; model developed by HDR Decision Economics for Transport Canada, December 2007.	See Table 33
Prices of vehicle operating components	HighwayDEC	See Table 32
Elasticity of industry logistics costs with respect to transit time (by industry)	"Freight Benefit-Cost Study", a report for Federal Highway Administration, Office of Freight Management and Operations, by ICF Consulting, HLB Decision Economics, and Louis Berger Group, July 2002.	0.27
Logistics costs in percentage of total sales (by industry)	"Freight Benefit-Cost Study", a report for Federal Highway Administration, Office of Freight Management and Operations, by ICF Consulting, HLB Decision Economics, and Louis Berger Group, July 2002	2.5 percent for retail industry; 5 percent for manufacturing, wholesale trade, construction, and agriculture.

Table 35: Data Required for the Model of Congestion Costs (Cont'd)

DATA INPUT	DATA SOURCES AND COMMENTS	ASSUMED DATA VALUE
Transit time through the region as proportion of total transit time for shipment and deliveries	This variable captures the idea that transit time through the GTHA regions may account for a fraction of total transportation time, as shipments may go to destinations beyond the GTHA and deliveries may be coming from outside of the GTHA. No actual data values were identified for this variable. For modeling purposes, reasoned assumptions were adopted.	1 for retail industry and construction; 0.25 for manufacturing, wholesale trade, and agriculture.
Industry profit margins, by industry	No direct data is available. Components of multipliers from Statistics Canada's inter-provincial input-output model, specifically operating surplus components of output, can serve as proxy estimates.	15 percent
Elasticity of substitution for industry products with respect to congestion induced costs	Economics literature, e.g. Weisberg G., D. Vary, and G. Treyz (2001) "Economic Implications of Congestion", NCHRP Report 463, Transportation Research Board, National Cooperative Highway Research Program.	7 for manufacturing; 11 for agriculture
Elasticity of travel demand with respect to travel time.	Economics literature, e.g. <i>Economic Impacts of Wait Times at the San Diego-Baja California Border</i> , report prepared by HDR HLB Decision Economics for San Diego Association of Governments and California Department of Transportation (District 11), January 19, 2006 and other studies reported there.	0.12

Table 36: Region of Hamilton Inputs

INPUT NAME	UNITS	2006	2021 DRTP	2031 BAU	2031 DRTP
Peak AM Period Vehicle-Kilometres Traveled (VKT)	VKT	1,791,463	2,673,223	3,148,709	2,631,677
Volume-to-Capacity Ratio	ratio	0.25	0.29	0.37	0.29
Average Automobile Trip Length	km	20.1	16.3	15.5	14.4
Congested Speed	km/h	61.3	52.5	46.7	53.9
Free-Flow Speed	km/h	78.9	75.3	73.5	75.2
Average Vehicle Occupancy	pax/veh	1.19	1.24	1.22	1.28
Transit Travel Time	mins	35.9	44.7	41.5	43.1
Average Transit Travel Distance	km	7.5	17.5	8.2	15.6
Transit Travel Speed	km/hr	12.6	23.5	11.9	21.7
Percent of Transit Time Spent in Vehicles	%	52.0%	61.3%	53.5%	58.6%
Percent of Transit Time Spent Walking	%	27.5%	23.3%	27.7%	25.8%
Percent of Transit Time Spent Waiting	%	20.5%	15.3%	18.9%	15.6%
Peak AM Period Transit Trips	trips	15,000	30,894	19,838	38,680
Peak AM Period Transit Ridership	pax-km	119,165	296,468	147,913	372,808
Total NOx Emitted - Autos	million kg/year	0.884	0.539	0.492	0.412
Total VOC Emitted - Autos	million kg/year	0.010	0.013	0.014	0.012
Total SOx Emitted - Autos	million kg/year	1.593	0.770	0.767	0.643
Total PM 2.5 Emitted - Autos	million kg/year	0.039	0.055	0.064	0.053
Total PM 10 Emitted - Autos	million kg/year	0.019	0.025	0.028	0.024
Total CO Emitted - Autos	million kg/year	27.184	21.604	22.927	19.209
Total NOx Emitted - Transit	million kg/year	0.204	0.202	0.207	0.174

Table 36: Region of Hamilton Inputs (Cont'd)

INPUT NAME	UNITS	2006	2021 DRTP	2031 BAU	2031 DRTP
Total VOC Emitted - Transit	million kg/year	0.007	0.007	0.007	0.006
Total SOx Emitted - Transit	million kg/year	0.007	0.007	0.007	0.006
Total PM 2.5 Emitted - Transit	million kg/year	0.000	0.000	0.000	0.000
Total PM 10 Emitted - Transit	million kg/year	0.000	0.000	0.000	0.000
Total CO Emitted - Transit	million kg/year	0.028	0.027	0.028	0.024

Source: IBI Group

Table 37: Region of Halton Inputs

INPUT NAME	UNITS	2006	2021 DRTP	2031 BAU	2031 DRTP
Peak AM Period Vehicle-Kilometres Traveled (VKT)	VKT	3,606,596	4,595,548	5,024,103	4,525,338
Volume-to-Capacity Ratio	ratio	0.48	0.48	0.57	0.47
Average Automobile Trip Length	km	23.9	19.0	17.4	15.7
Congested Speed	km/h	63.3	55.0	43.7	49.3
Free-Flow Speed	km/h	91.2	83.1	80.4	82.0
Average Vehicle Occupancy	pax/veh	1.17	1.24	1.22	1.29
Transit Travel Time	mins	46.6	47.3	44.1	44.6
Average Transit Travel Distance	km	8.6	19.8	8.9	16.0
Transit Travel Speed	km/hr	11.1	25.1	12.1	21.5
Percent of Transit Time Spent in Vehicles	%	48.1%	59.9%	47.3%	55.9%
Percent of Transit Time Spent Walking	%	27.6%	25.2%	35.3%	29.0%
Percent of Transit Time Spent Waiting	%	24.2%	14.9%	17.4%	15.1%
Peak AM Period Transit Trips	trips	4,300	40,365	27,783	60,520
Peak AM Period Transit Ridership	pax-km	246,351	1,095,060	271,252	1,685,345
Total NOx Emitted - Autos	million kg/year	1.780	0.926	0.785	0.709
Total VOC Emitted - Autos	million kg/year	0.020	0.022	0.023	0.021
Total SOx Emitted - Autos	million kg/year	3.208	1.323	1.224	1.105
Total PM 2.5 Emitted - Autos	million kg/year	0.079	0.095	0.102	0.092
Total PM 10 Emitted - Autos	million kg/year	0.038	0.043	0.045	0.040
Total CO Emitted - Autos	million kg/year	54.728	37.139	36.582	33.031

Table 37: Region of Halton Inputs (Cont'd)

INPUT NAME	UNITS	2006	2021 DRTP	2031 BAU	2031 DRTP
Total NOx Emitted - Transit	million kg/year	0.422	0.747	0.380	0.785
Total VOC Emitted - Transit	million kg/year	0.014	0.025	0.013	0.027
Total SOx Emitted - Transit	million kg/year	0.014	0.026	0.013	0.027
Total PM 2.5 Emitted - Transit	million kg/year	0.001	0.000	0.000	0.000
Total PM 10 Emitted - Transit	million kg/year	0.000	0.000	0.000	0.000
Total CO Emitted - Transit	million kg/year	0.058	0.101	0.051	0.106

Source: IBI Group

Table 38: Region of Peel Inputs

INPUT NAME	UNITS	2006	2021 DRTP	2031 BAU	2031 DRTP
Peak AM Period Vehicle-Kilometres Traveled (VKT)	VKT	6,421,952	7,720,030	8,334,139	7,162,008
Volume-to-Capacity Ratio	ratio	0.53	0.47	0.55	0.44
Average Automobile Trip Length	km	17.0	17.2	16.8	17.0
Congested Speed	km/h	47.5	45.3	36.9	48.0
Free-Flow Speed	km/h	82.9	75.2	72.9	76.3
Average Vehicle Occupancy	pax/veh	1.21	1.27	1.24	1.32
Transit Travel Time	mins	54.6	47.5	49.0	46.1
Average Transit Travel Distance	km	13.6	16.3	12.0	17.9
Transit Travel Speed	km/hr	14.9	20.5	14.7	23.2
Percent of Transit Time Spent in Vehicles	%	63.7%	65.3%	60.1%	63.8%
Percent of Transit Time Spent Walking	%	19.3%	19.7%	23.2%	21.0%
Percent of Transit Time Spent Waiting	%	17.1%	15.0%	16.7%	15.2%
Peak AM Period Transit Trips	trips	25,600	121,317	85,857	151,880
Peak AM Period Transit Ridership	pax-km	526,635	2,004,600	1,008,842	2,778,248
Total NOx Emitted - Autos	million kg/year	3.170	1.556	1.302	1.122
Total VOC Emitted - Autos	million kg/year	0.036	0.037	0.038	0.032
Total SOx Emitted - Autos	million kg/year	5.712	2.223	2.030	1.749
Total PM 2.5 Emitted - Autos	million kg/year	0.140	0.160	0.168	0.145
Total PM 10 Emitted - Autos	million kg/year	0.067	0.072	0.074	0.064
Total CO Emitted - Autos	million kg/year	97.450	62.389	60.684	52.277

Table 38: Region of Peel Inputs (Cont'd)

INPUT NAME	UNITS	2006	2021 DRTP	2031 BAU	2031 DRTP
Total NOx Emitted - Transit	million kg/year	0.902	1.368	1.414	1.294
Total VOC Emitted - Transit	million kg/year	0.030	0.046	0.048	0.044
Total SOx Emitted - Transit	million kg/year	0.031	0.047	0.049	0.045
Total PM 2.5 Emitted - Transit	million kg/year	0.001	0.000	0.000	0.000
Total PM 10 Emitted - Transit	million kg/year	0.001	0.000	0.000	0.000
Total CO Emitted - Transit	million kg/year	0.124	0.185	0.191	0.175

Source: IBI Group

Table 39: City of Toronto Inputs

INPUT NAME	UNITS	2006	2021 DRTP	2031 BAU	2031 DRTP
Peak AM Period Vehicle-Kilometres Traveled (VKT)	VKT	9,296,614	9,200,120	9,894,794	8,433,504
Volume-to-Capacity Ratio	ratio	0.62	0.61	0.66	0.56
Average Automobile Trip Length	km	19.0	15.7	14.7	16.8
Congested Speed	km/h	42.0	38.4	31.4	42.9
Free-Flow Speed	km/h	79.0	74.2	72.9	76.2
Average Vehicle Occupancy	pax/veh	1.23	1.30	1.27	1.36
Average Transit Travel Time	mins	40.0	35.9	38.3	35.0
Average Transit Travel Distance	km	11.4	12.8	11.0	13.5
Average Transit Travel Speed	km/hr	17.1	21.5	17.2	23.2
Percent of Transit Time Spent in Vehicles	%	69.7%	67.6%	68.6%	65.9%
Percent of Transit Time Spent Walking	%	20.0%	20.9%	20.0%	22.0%
Percent of Transit Time Spent Waiting	%	10.3%	11.5%	11.5%	12.1%
Peak AM Period Transit Trips	trips	398,000	534,424	426,923	607,984
Peak AM Period Transit Ridership	pax-km	4,200,873	9,247,145	7,152,009	11,335,362
Total NOx Emitted - Autos	million kg/year	4.589	1.854	1.546	1.321
Total VOC Emitted - Autos	million kg/year	0.052	0.045	0.045	0.038
Total SOx Emitted - Autos	million kg/year	8.269	2.649	2.411	2.060
Total PM 2.5 Emitted - Autos	million kg/year	0.203	0.190	0.200	0.171
Total PM 10 Emitted - Autos	million kg/year	0.097	0.085	0.088	0.075
Total CO Emitted - Autos	million kg/year	141.071	74.351	72.047	61.557

Table 39: City of Toronto Inputs (Cont'd)

INPUT NAME	UNITS	2006	2021 DRTP	2031 BAU	2031 DRTP
Total NOx Emitted - Transit	million kg/year	7.195	6.311	10.023	5.278
Total VOC Emitted - Transit	million kg/year	0.238	0.212	0.340	0.179
Total SOx Emitted - Transit	million kg/year	0.247	0.218	0.348	0.185
Total PM 2.5 Emitted - Transit	million kg/year	0.009	0.001	0.001	0.001
Total PM 10 Emitted - Transit	million kg/year	0.008	0.001	0.001	0.001
Total CO Emitted - Transit	million kg/year	0.989	0.853	1.357	0.716

Source: IBI Group

Table 40: Region of York Inputs

INPUT NAME	UNITS	2006	2021 DRTP	2031 BAU	2031 DRTP
Peak AM Period Vehicle-Kilometres Traveled (VKT)	VKT	6,134,044	8,903,511	9,439,086	8,119,537
Volume-to-Capacity Ratio	ratio	0.47	0.49	0.59	0.47
Average Automobile Trip Length	km	25.7	18.8	17.6	18.0
Congested Speed	km/h	52.4	50.4	37.3	50.4
Free-Flow Speed	km/h	83.4	77.4	75.2	77.9
Average Vehicle Occupancy	pax/veh	1.19	1.25	1.23	1.31
Transit Travel Time	mins	57.6	52.3	53.8	51.5
Average Transit Travel Distance	km	15.8	18.5	14.5	20.8
Transit Travel Speed	km/hr	16.4	21.2	16.2	24.2
Percent of Transit Time Spent in Vehicles	%	64.9%	67.7%	62.7%	66.0%
Percent of Transit Time Spent Walking	%	18.8%	20.0%	22.4%	20.9%
Percent of Transit Time Spent Waiting	%	16.3%	12.2%	14.9%	13.1%
Peak AM Period Transit Trips	trips	14,600	104,924	88,525	132,855
Peak AM Period Transit Ridership	pax-km	435,222	1,600,315	1,410,859	1,992,323
Total NOx Emitted - Autos	million kg/year	3.028	1.794	1.475	1.272
Total VOC Emitted - Autos	million kg/year	0.034	0.043	0.043	0.037
Total SOx Emitted - Autos	million kg/year	5.456	2.564	2.300	1.983
Total PM 2.5 Emitted - Autos	million kg/year	0.134	0.184	0.191	0.165
Total PM 10 Emitted - Autos	million kg/year	0.064	0.083	0.084	0.073
Total CO Emitted - Autos	million kg/year	93.081	71.954	68.729	59.266

Table 40: Region of York Inputs (Cont'd)

INPUT NAME	UNITS	2006	2021 DRTP	2031 BAU	2031 DRTP
Total NOx Emitted - Transit	million kg/year	0.745	1.092	1.977	0.928
Total VOC Emitted - Transit	million kg/year	0.025	0.037	0.067	0.031
Total SOx Emitted - Transit	million kg/year	0.026	0.038	0.069	0.032
Total PM 2.5 Emitted - Transit	million kg/year	0.001	0.000	0.000	0.000
Total PM 10 Emitted - Transit	million kg/year	0.001	0.000	0.000	0.000
Total CO Emitted - Transit	million kg/year	0.102	0.148	0.268	0.126

Source: IBI Group

Table 41: Region of Durham Inputs

INPUT NAME	UNITS	2006	2021 DRTP	2031 BAU	2031 DRTP
Peak AM Period Vehicle-Kilometres Traveled (VKT)	VKT	3,874,073	5,011,408	6,145,898	5,155,209
Volume-to-Capacity Ratio	ratio	0.31	0.31	0.41	0.32
Average Automobile Trip Length	km	23.4	22.0	20.9	19.9
Congested Speed	km/h	57.1	54.3	40.6	51.4
Free-Flow Speed	km/h	83.5	78.6	75.8	79.2
Average Vehicle Occupancy	pax/veh	1.18	1.24	1.22	1.29
Transit Travel Time	mins	42.7	60.8	56.5	62.2
Average Transit Travel Distance	km	6.0	32.3	13.0	34.6
Transit Travel Speed	km/hr	8.4	31.9	13.8	33.4
Percent of Transit Time Spent in Vehicles	%	31.9%	68.9%	54.4%	68.0%
Percent of Transit Time Spent Walking	%	41.4%	17.6%	27.4%	19.5%
Percent of Transit Time Spent Waiting	%	26.7%	13.5%	18.2%	12.5%
Peak AM Period Transit Trips	trips	8,600	71,905	51,494	99,708
Peak AM Period Transit Ridership	pax-km	187,830	1,308,081	668,433	1,607,823
Total NOx Emitted - Autos	million kg/year	1.912	1.010	0.960	0.808
Total VOC Emitted - Autos	million kg/year	0.022	0.024	0.028	0.023
Total SOx Emitted - Autos	million kg/year	3.446	1.443	1.497	1.259
Total PM 2.5 Emitted - Autos	million kg/year	0.085	0.104	0.124	0.104
Total PM 10 Emitted - Autos	million kg/year	0.040	0.047	0.055	0.046
Total CO Emitted - Autos	million kg/year	58.787	40.500	44.750	37.629

Table 41: Region of Durham Inputs (Cont'd)

INPUT NAME	UNITS	2006	2021 DRTP	2031 BAU	2031 DRTP
Total NOx Emitted - Transit	million kg/year	0.322	0.893	0.937	0.749
Total VOC Emitted - Transit	million kg/year	0.011	0.030	0.032	0.025
Total SOx Emitted - Transit	million kg/year	0.011	0.031	0.032	0.026
Total PM 2.5 Emitted - Transit	million kg/year	0.000	0.000	0.000	0.000
Total PM 10 Emitted - Transit	million kg/year	0.000	0.000	0.000	0.000
Total CO Emitted - Transit	million kg/year	0.044	0.121	0.127	0.102

Source: IBI Group

Table 42: Unit Costs of Auto Operating Cost Components

VEHICLE OPERATING COST COMPONENT	UNIT COST	SOURCE
Fuel cost per litre - 2006	\$0.97	www.ontariogasprices.com/retail_price_chart.aspx
Oil cost per litre - 2006	\$2.60	HighwayDEC (2003 values adjusted to 2006 dollars)
Cost per tire (\$) - 2006	\$92.33	HighwayDEC (2003 values adjusted to 2006 dollars)
Number of tires	4	-
Average M&R Cost per 1,000 KM, Auto - 2006	\$32.32	HighwayDEC (2003 values adjusted to 2006 dollars)
Average Depreciable Value, Auto – 2006	\$29,976	HighwayDEC (2003 values adjusted to 2006 dollars)

Table 43: Average Use of Vehicle Operating Cost Components (Autos)

OPERATING COST COMPONENT	USAGE RATE AT VARIOUS SPEEDS (KM/HR)										
	15	20	25	30	35	40	45	50	55	60	65
Fuel, litres/1000km	93.53	83.28	74.04	66.82	61.11	56.41	54.23	53.05	53.39	55.75	58.82
Oil, litres/1000km	1.45	1.18	1.00	0.93	0.87	0.82	0.80	0.78	0.78	0.79	0.79
Tire, Percent wear per 1000 km	0.05	0.07	0.08	0.08	0.08	0.09	0.10	0.11	0.12	0.14	0.16
M&R, Percent of Average M&R per 1000 km	49.19	49.81	50.54	51.49	52.60	53.82	55.31	56.91	58.67	60.65	62.73
Depreciation, % of depreciable value per 1000 km	0.50	0.46	0.43	0.41	0.39	0.37	0.35	0.34	0.33	0.32	0.31

Source: HighwayDEC

Model Used to Forecast Traffic Data from 2006 - 2031

The volume of traffic across the 6 regions of the GTHA was a crucial input into the analysis: 2006 traffic data was used to assess the current costs of excess congestion, while forecasts of traffic flows with the Draft RTP in place and the “business-as-usual” base case were the basis of the cost-benefit analysis.

The following is a brief overview of the traffic data inputs, which were provided by IBI:

The data used for this analysis were developed as part of the modeling and planning process of the Draft RTP network. The data reflect the model results for the existing situation and both the ‘business-as-usual’ (BAU) and the Draft RTP scenarios, including post-process adjustments made to reflect the substantial policy changes proposed in the Draft RTP.

The model used was developed recently under the auspices of the Ministry of Transportation of Ontario (MTO) for transportation planning in the Greater Golden Horseshoe (GGH) region and is referred to as the GGH model.

The GGH model is a computer simulation of transportation demand and supply interactions, which represents the transportation network by links and nodes, all with specified capacities, speeds, costs and access times. Land use throughout the GGH is represented by more than 3,000 traffic zones with current and projected population, jobs; densities, land use, socio-economics, and demographics specified for each. The model estimates users’ travel decisions including trip purposes, start and end times, origins and destinations, travel routes and travel modes, which leads to estimated volumes of travelers and vehicles on each link by mode (e.g. commuter rail, local transit, automobile, etc.). As applied in developing the Draft RTP, the model was used to simulate the morning three hour peak period (6:00 a.m. – 9:00 am) of a typical workday in 2031 or 2020, the hours of maximum demand in the transportation system when work and school trips are most concentrated. Some model results, such as transit ridership levels and greenhouse gas (GHG) emissions, were also extended to daily and/or annual levels based on observed and projected “peaking factors” relating peak period travel volumes to daily and annual volumes.

The model simulates the behaviour of travelers taking into account the different costs (e.g. transit fares, auto operating costs, road tolls, parking charges,) and travel times (e.g. walking, waiting, in-vehicle) via the available modes (e.g. auto, transit or walk/cycle) for that individual’s trip. Different types of people behave differently and thus key socio-economic characteristics that affect travel and travel choices such as age, employment status, occupation type, and household structure (e.g. single, married, married with children, etc.) are reflected when determining propensities to make trips or use a given mode. The computer model covers the entire GTHA and surrounding areas that comprises the Greater Golden Horseshoe.

As part of the forecasting for the Draft RTP, the following post-run adjustments were made to model results, based on the judgement of the Metrolinx planning team and on the team’s experience with the response of travelers in other cities to substantial policy changes of the types proposed in the Draft RTP

- Average auto occupancy was increased to reflect results of preferential treatment for high occupancy vehicles, both in carpool lots and on HOV lanes. The increased auto occupancy, in turn, reduces the volume of autos required to move a given number of people, with resulting reductions in rates of increase in congestion levels and costs and in automotive emissions.
- The percentage of people anticipated to work at home is increased, reflecting information programs and corporate policies to encourage home-based work, where feasible. This, in turn, reduces the number of peak period work trips, with positive impacts on congestion, emissions, etc. as above.
- The transit mode split is increased to reflect introduction of various measures such as tax deductible transit passes and better integration with other modes, which cannot be captured explicitly by the model as currently calibrated. This, in turn, reduces auto volumes and increases the ridership and viability of transit services.
- The active transportation mode split is increased for trips 10 kilometres or less in length, to reflect the enhanced pedestrian environment and more extensive networks of bicycle lanes and bicycle/pedestrian paths which are part of the Draft RTP. This, in turn, reduces auto and other motorized trips, with positive impacts as noted above.

The GGH model directly provided the inputs associated with auto and transit use including vehicle/passenger-km, mode split ratios, travel times, speeds, trip lengths and trip purposes.

The emissions estimation inputs were based on the Draft RTP model results, processed through Transport Canada's Urban Transportation Emission Calculator. This online tool estimates annual GHG emission from fuel combustion as well as upstream emissions from fuel extraction, processing, and transportation.

Capital costs were calculated on an order-of-magnitude basis using per unit cost estimates for rapid transit expansion, estimated to be \$32 billion for the 15 Year Plan and \$49 billion for the 25 Year Plan, with a much lower level of \$5 billion for the BAU system.

Annual operating cost estimates were again prepared on an order-of-magnitude basis based on observed highway operating costs from MTO and other sources and transit operating costs from CUTA and GTHA transit system sources. Municipal and rapid transit operating costs are estimated to increase from \$1.6 billion per year in 2006 to about \$3 billion per year for the 15 Year Plan and \$3.5 billion per year for the 25 Year Plan, with a lesser increase to \$2.1 billion for the BAU system. Included in these numbers are the estimated operating costs for new rapid transit of \$800 million for the 15 Year Plan, \$1.1 billion for the 25 Year Plan and \$20 million for the BAU system.

APPENDIX 7: COMPARISON BETWEEN REGIONS

Table 44 provides a summary of the results of three separate studies concerning the cost of congestion in large North American cities. It should be noted that the results between the three regions are not directly comparable due to methodological differences in the studies and differences in certain assumptions and input values. Nevertheless, it is apparent that the costs of congestion in the three regions are of a similar order of magnitude once adjusting for the relative population size of the region.

Table 44: Comparison of HDR Cost of Congestion Studies³⁶

	NEW YORK	CHICAGO	GTHA
YEAR OF ANALYSIS (DATA)	2005	2005	2006
Study Region	10 member-counties of the New York Metropolitan Transportation Council	Chicago and six surrounding counties	Hamilton, Halton, Peel, Toronto, York, Durham
Analysis timeframe	Daily traffic, 260 days per year	Peak period traffic, 260 days per year	AM + PM peak period traffic, 260 days per year
Population	12 million	8 million	6 million
Costs included in the analysis	Time, productivity, vehicle operating costs	Time, fuel, productivity, environmental	Time (including reliability), productivity, vehicle operating costs, accidents, environmental
Total cost of congestion	\$11 billion	\$7.3 billion	\$6 billion
Annual cost to commuters	\$7 billion	\$6.2 billion	\$3.3 billion
Annual cost to the economy (productivity)	\$4 billion		\$2.7 billion
Annual cost to the freight industry	Not included	\$1 billion	Not included
Annual cost of total excess congestion, per capita	\$917	\$912	\$1,000
Increase in peak travel time as a result of congested traffic conditions	13%	22%	32%
Lost time per week for average driver	52.5 minutes/week	66 minutes/week	57.5 minutes/week
Monetary value of excess travel delay per commuter³⁷	\$1229 per year per commuter	\$1544 per year per commuter	\$1346 per year per commuter
Number of jobs region loses due to congestion	51,515	87,000	42,000

³⁶ Partnership for New York City, “The Economic Costs of Congestion in the New York City Region” (study conducted by HDR|Decision Economics). Metropolitan Planning Council “Moving at the Speed of Congestion: The True Costs of Traffic in the Chicago Metropolitan Area” (study conducted by HDR|Decision Economics)

³⁷ Assuming equal value of time across regions, where the value is that of the GTHA study