Sustainable Development Branch

Cost Benefit Framework and Model for the Evaluation of Transit and Highway Investments

Final Report

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In Association with
ICF Consulting
PBConsult

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ECONOMIC STUDY TO ESTABLISH A COST-BENEFIT FRAMEWORK FOR THE EVALUATION OF VARIOUS TYPES OF TRANSIT INVESTMENTS

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EXECUTIVE SUMMARY

This report provides a comprehensive framework for applying Cost-Benefit Analysis to a wide range of prospective transit investments (both greenfield and expansion projects) as well as rehabilitation and maintenance work. The framework is applicable to various transit modes, including stage bus systems (local and express bus service in regular street operation); bus rapid transit (buses in various types of dedicated rights-of-way); light rail; heavy rail; commuter rail; and highway investment.

The report is accompanied by a user-friendly computer analysis tool designed to facilitate ready-application of the framework. The computer tool permits Cost-Benefit Analysis to be performed with either default values or locally generated data. It is scaled to apply over the range of differently sized urban areas and over the range of variously sized projects.

The report begins by positioning transit in the context of national congestion related problems. The need for a comprehensive Cost-Benefit Analysis framework is shown to arise from the critical search for effective, sustainable solutions to a problem that is not only eroding the benefits of economic growth, but also is materially inhibiting the growth process itself. The study then demonstrates that existing mainstream methodologies used to assess transit investments are poorly suited to the meet this need. Through a survey and detailed evaluation of a representative sample of 30 actual investment appraisals, it is shown that comprehensive Cost-Benefit Analysis is extremely rare. It is shown that in the absence of comprehensive Cost-Benefit accounting for transit benefits, highway investment projects nearly always appear more effective, even where "induced demand" guarantees that the effects of highway investments are short-lived.

The details of the benefit-cost analysis framework are described including an examination the different types of benefits and costs associated with transit investment projects. Various key points of the methodology related to highway investment evaluation, net present value and risk analysis are discussed. The report also provides an overview of the computer program to be used in the evaluation of transit and highway investment projects.

The report then uses the computer model to evaluate three case studies:

- Winnipeg: Southwest Transit Corridor;
- Kelowna: New Bus Capacity;
- Toronto: Spadina Light Rail.

The results for all three case studies include benefits associated with congestion management (time savings, vehicle operating costs, criteria air contaminants emission savings, GHG emission savings and accident savings), low income mobility and liveable communities. Project costs (capital, O&M) are presented and three summary statistics are given (net present value, benefit-cost ratio, internal rate of return).

The document also describes the current Canadian federal government role in urban transport, including issues such as planning and policy, service delivery, and other support. It reviews the current federal role and then summarizes the alternate service delivery experience in the U.S. and other selected countries and presents possible options for changes to the current federal role.

Finally, the report presents summary conclusions and a set of recommendations. These include:

- The Canadian government should seriously consider establishment of a transit capital funding program *targeted* at specific types of projects and under specific sets of conditions;

- In concert with an expanded federal role in capital funding the federal government should establish more explicit transit-friendly planning and policy principles (guidelines, goals, etc.) at the national level;

- The federal government should encourage, though not require, local transit providers to seek competitive bids from private and public operators for discrete service elements such as, for example, a geographic grouping of bus routes, special or ancillary services and, possibly, select rail operations;

- The federal government should increase its investment in research, education, and direct technical assistance such as training to transit service providers and project sponsors; and

- In light of a prospectively greater federal role in urban transportation planning and funding, Transport Canada might consider employing the economic benefits model developed by HLB in one or more of several possible contexts, ranging from the evaluation of individual projects up to assessment of the entire national transportation program.

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1. INTRODUCTION

This report provides a comprehensive framework for applying Cost-Benefit Analysis to a wide range of prospective transit investments (both “Greenfield” and expansion projects) as well as rehabilitation and maintenance work. The framework is applicable to various transit modes, including stage bus systems (local and express bus service in regular street operation); bus rapid transit (buses in various types of dedicated rights-of-way); light rail; heavy rail; and commuter rail.

The report is accompanied by a computer analysis tool designed to facilitate ready-application of the framework. The computer tool permits Cost-Benefit Analysis to be performed with either “default” data values or locally generated data. The model is applicable in any sized urban area and over the range of variously sized projects.

Chapter 2 discusses the role of Cost-Benefit Analysis in urban transportation planning and in the context of matters of national policy significance such as congestion and environmental issues. The need for a comprehensive Cost-Benefit Analysis framework is shown to arise from the search for effective, sustainable alternatives to managing each of these problems, as well as concerns regarding personal mobility and land-use.

Chapter 3 examines the range of existing, mainstream methodologies in use to assess transit investments. The Chapter reports that these methods are in general poorly suited to the policy and planning challenges identified in Chapter 2. Through a survey and detailed evaluation of a representative sample of transit investment appraisals, Chapter 2 finds that comprehensive Cost-Benefit Analysis is rare in application to transit. The chapter thus sets the stage for the detailed benefit and cost accounting framework to follow in Chapter 4.

Chapter 4 presents the detailed Cost-Benfit Analysis framework. It also presents the framework in the form of a user-friendly computer model and provides hands-on guidance in its use. Chapter 5 illustrates the functionality of the model by applying it to four case studies of actual projects in Canadian cities.

Chapter 6 closes with a review of alternative transit service delivery and financing concepts.

2. TRANSIT IN THE NATIONAL CONTEXT

Unlike highway investment, for which a rigorous micro-economic analysis framework has been in place for more than 30 years, the appraisal of transit investment has been given to largely subjective evaluation methods. Highway investment alternatives are typically examined in the context of their economic benefits, economic costs, net present values and rates of return: In contrast, prospective transit projects are usually evaluated in terms of "planning balance sheets," "multi-criteria scorecards," "cost-per-trip" indices and other schemes that reveal little about transit's economic value or the benefits of transit relative to its costs.

The state of affairs outlined above presents decision makers with a dilemma when transit alternatives exist (either in lieu of or in addition to highway investment) as a means of addressing Canada's mounting congestion, environmental and mobility problems. Unless both the transit and highway alternatives are evaluated on a common basis, with a comprehensive accounting for all the costs and benefits of each, there can be no basis for rational choice. The fact that a consistent economic evaluation framework is available for the highway mode but for transit might well cause a bias toward highway investment alternatives.

Even where decisions do not involve transit-highway *comparisons*, the absence of a transit Cost-Benefit Analysis framework represents a barrier to reasoned decision making. Whether or not to extend a service, modernize a facility, replace or repair a vehicle, and so on, are all matters in which decision makers require a valid comparison of costs and benefits as a basis rational choice.

The absence of a Cost-Benefit Analysis framework suited to the evaluation of transit projects presents problems for policy makers at the federal level as well as decision makers the local level where transit systems are managed on a day-to-day basis. The economic and social costs of congestion, greenhouse gases, deteriorating air quality, limited mobility among the poor and urban sprawl have been identified as matters of national concern in a range of federal studies, reviews and commissions. Findings published in the Royal Commission on Passenger Transportation, the Canadian Transportation Act Review and various federal investigations into the management of greenhouse gases all indicate that automobile use in congested conditions costs the economy billions of dollars annually in lost productivity and the social costs associated with environmental degradation.

While each of the federal studies and reviews mentioned above point to transit as an alternative to be considered in the formulation of transportation and environmental policies, none of them conclude that transit investment is "always" to be preferred to highway investment, nor that highway investment is universally the option of choice. Instead, national policy makers are urged to consider the alternatives on their merits, on a level playing, taking all costs and benefits into account. The absence of a comprehensive Cost-Benefit Analysis framework represents a material barrier to doing so. This report seeks to eliminate that barrier.

3. TRANSIT EVALUATION PROCEDURES IN USE TODAY

This chapter presents a review and assessment of various analytical frameworks used to evaluate proposed transit investments in Canada and the United States. The review covers more than thirty transit investigations by federal and local transit agencies and focuses on the ability of the frameworks to address the principal requirements of a comprehensive economic (benefit/cost) analysis.

The Chapter also examines state-of-art assessment methodology in relation to highway projects, with special reference to approaches that facilitate direct comparisons between highway and transit investment alternatives.

3.1 Overview of Selected Transit Studies

The selected studies address bus, bus rapid transit, light rail, heavy rail, and commuter rail projects. The locations of the proposed investments range from large metropolitan areas such as Montreal and Toronto to smaller communities such as Aspen, Colorado. The study frameworks also vary, and include full benefit/cost analysis, quasi benefit/cost analysis, cost-effectiveness analysis, benefit assessment analysis, and partial system assessment. The following is an overview of the selected studies:

Table 1: Project Evaluation Studies Overview

	Study	Year	Sponsor	Type of Methodology	Mode	City	Region / City Characteristics
1	*Light Rail in Milwaukee*	1998	WI Policy Research Institute	Comparative Analysis / Cost Effectiveness	Light Rail	Milwaukee	Pop: 600,000
2	*Los Angeles East Side Corridor*	2001	USDOT/LA.MTA	Impact Study / Cost Effectiveness	Light Rail	Los Angeles East Side	Pop: 250,000
3	*Public Transit Benefits in the Victoria Region*	1996	BC Transit	Benefit Assessment	All Transit Services	Victoria Region	Pop: 304,000
4	*Westside LRT MAX Extension: User Benefit-Cost Analysis*	1988	Tri-met	Benefit-Cost Analysis	Light Rail	Portland, OR	Pop: 532,000
5	*Public Transportation Renewal as an Investment: The Economic Impacts of SEPTA on the Regional and State Economy*	1991	Delaware Valley Regional Planning Commission	Economic Forecasting and Simulation Model	All Transit Services	Philadelphia and Suburbs	Pop: 1.6 Million
6	*Options to Improve SkyTrain Passenger Safety and Security and Reduce Fare Evasion*	2000	City of Vancouver	Quasi Benefit-Cost Analysis (no social benefits)	Sky Train	Vancouver	Pop: 1.83 Million
7	*Moving Forward: The Economic and Community Benefits of Transportation Options for Greater Cincinnati*	2001	Metropolitan Mobility Alliance	Benefit-Cost Analysis / Risk Analysis	Light Rail/Bus	Cincinnati	Pop: 400,000
8	*RMOC Transportation Master Plan Mass Transit*	1996	Regional Municipality of Ottawa-Carlton	System Assessment (costs and revenues)	Mass Transit	Ottawa-Carlton	Pop: 1.01 Million
9	*RMOC Transportation Master Plan Rapid Transit*	1996	Regional Municipality of Ottawa-Carlton	System Assessment (costs and revenues)	Rapid Transit	Ottawa-Carlton	Pop: 1.01 Million

Table 1 Continued

	Study	Year	Sponsor	Type of Methodology	Mode	City	Region / City Characteristics
10	*Optimising Transit Service Decisions Based on Ridership- Good for Passengers and the Community*	1999	Toronto Transit Commission	Cost Effectiveness (Ridership maximization)	Mass Transit	Toronto	Pop: 4.3 Million
11	*The Future of Rapid Transit on Broadway: Compare the Options*	2000	City of Vancouver	Comparative Analysis / Cost Effectiveness	Rapid Transit	Vancouver	Pop: 1.83 Million
12	*Baltimore MTA Central LRT*	1996	Federal Transit Administration/MTA	Cost Analysis/Risk Analysis	Light Rail	Baltimore	Pop: 2.5 Million
13	*Going the Distance: West Coast Express*	1998	BC Rapid Transit Company	System Assessment (costs, Benefits and revenues)	Commuter Rail	British Columbia	Pop: 4.1 Million
14	*Measuring and Valuing Transit Benefits and Disbenefits*	1996	TRB/TCRP	Benefit-Cost Analysis / Description of Benefits and Costs	Mass Transit	N/A	N/A
15	*Tax Exempt Status for Employer Provided Transit Benefits*	1999	National Climate Change Process	Comparative Analysis / Cost Effectiveness	Mass Transit	N/A	N/A
16	*Low Floor Buses*	1993	TRB/TCRP	Qualitative Assessment of Service Improvement	Bus	Ann Arbor MI	Pop: 114,000
17	*Commuter Buses*	1993	TRB/TCRP	Qualitative Assessment of Service Improvement	Bus	Aspen Co/ Pitkin County	Pop: 14,800
18	*Transit Mall Shelters*	1993	TRB/TCRP	Qualitative Assessment of Service Improvement	Bus	Portland, OR	Pop: 532,000
19	*Transit Shelters*	1993	TRB/TCRP	Qualitative Assessment of Service Improvement	Bus	Rochester NY	Pop: 1.1 Million
20	*Historic Street Cras*	1993	TRB/TCRP	Qualitative Assessment of Service Improvement	Streetcars	San Francisco, CA	Pop: 800,000
21	*The Benefits and Economic Rate of Return for Alternative Light Rail Alignments and Route Segments in the Austin Region*	1999	Capital Metro	Benefit-Cost Analysis	Light Rail	Austin, TX	Pop: 1.1 Million
22	*The Edmonton LRT: An Appropriate Choice?*	1991	Canadian Public Policy	Benefit-Cost Analysis / Comparative Analysis	Light Rail/ Bus	Edmonton	Pop: 862,000
23	*Cost-Effective Alternatives to Atlanta's Rail Rapid Transit System*	*1997*	*Harvard University*	*Cost Effectiveness (Ridership maximization)*	*Heavy Rail*	Atlanta	Pop: 4.3 Million

Table 1 Continued

	Study	Year	Sponsor	Type of Methodology	Mode	City	Region / City Characteristics
24	*An Appraisal of Candidate Project Evaluation Measures*	1999	Federal Transit Administration	Quasi Benefit-Cost Analysis	Transit	N/A	N/A
25	*Commercial Property Benefits of Transit*	1999	Federal Transit Administration	Quasi Benefit-Cost Analysis	Heavy Rail	Washington DC	Pop: 4 Million
26	*Calgary Transit: Bus and C-Train Usage*	2000	The City of Calgary	System Assessment / Cost Effectiveness	Bus and Rail	Calgary	Pop: 821,000
27	*Progression or Regression: Case Study for Commuter Rail in San Francisco Bay Area*	1999	San Francisco Bay Area Rapid Transit District	Comparative Analysis / Cost Effectiveness	Commuter Rail	San Francisco, CA	Pop: 800,000
28	*A Vital Economic Player in the Greater Montreal Region*	2000	La Société de Transport de la Communauté Urbaine de Montréal	System Assessment / Qualitative Assessment of Benefits	Mass Transit	Montreal	Pop: 3.3 Million
29	*Direction to the Future*	2000	City of Winnipeg Transit System	System Assessment / Cost Effectiveness/User Benefits Assessment	Mass Transit	Winnipeg	Pop: 667,000
30	*Benefits of Transit 2000*	2000	Federal Transit Administration	Benefits Assessment	Heavy Rail/ Light Rail	Washington DC, Sacramento, St. Louis, Portland, Dallas, Chicago	N/A
31	Miami Valley Benefits of Transit	1997	Miami Valley Regional Transit Authority	Benefit-Cost Analysis/Economic Impact	Bus/Trolley	Dayton OH	Pop: 1.2 Million
32	RTA Economic Benefit Report to Western Riverside County	1996	Riverside Transit Agency	Benefit Assessment	Bus	Riverside County, CA	Pop: 1.55 Million
33	Individual and Community Benefits of Public Transit Services and Facilities	1987	Toronto Transit Commission	Benefit Assessment	Mass Transit	Toronto	Pop: 4.3 Million

3.2 Assessment Framework

The frameworks employed in the studies listed above were assessed to determine the extent to which they meet two major tests:

1. Ability to provide a comprehensive underlying vision of the project's economic and social effects – its "policy functions" – rather than a vision that is constrained by perceived measurement problems; and

2. Acknowledgement of the special significance of sustainability as a desirable policy outcome.

As stated in Chapter 1, research has confirmed the importance of recognizing all social and economic impacts when conducting a benefit/cost analysis. Focusing only on congestion and/or environmental benefits, for example, might result in a project failing a benefit/cost test where inclusion of all factors would bring the opposite result. Therefore, the inclusion of other benefit categories, such as affordable mobility and economic development benefits, is critical to drawing a comprehensive picture of the benefits of transit. Highlighting the sustainability attribute of transit is equally important, especially when assessing modal alternatives.

The 33 studies listed in Table 1 (above) were reviewed against 35 criteria designed to measure their effectiveness in providing a comprehensive benefit/cost analysis for transit investments. These criteria can be grouped under four main categories:

I. <u>Specification of Base Case and Options</u>
  1. Valid Specification of a Base Case
  2. Comprehensive Specification and Analysis of Options
  3. Comprehensive Specification and Analysis of Delivery and Management Options
  4. Comprehensive Specification and Analysis of Pricing Options

II. <u>Benefit Categories of Transit</u>
  1. Quantify Benefits over the Entire Project Life-Cycle
    a) Physical Effects
    b) Monetary Value
  2. Quantify Discounted Benefits
  3. Quantify Benefits and Costs (Partially or Quantitatively)
    a) Physical Effects
    b) Monetary Value
  4. Quantify Value of Congestion Benefits (Partially or Quantitatively)
    a) Average Time Savings
    b) Reduced Unreliability
    c) Convergence Effects
    d) Vehicle Operating Costs Savings
  5. Environmental Benefits
    a) Emissions
    b) Greenhouse Gases
    c) Noise
    d) Water
  6. Safety Benefits
    a) Fatalities Avoided
    b) Injuries Avoided
    c) Property Damage Avoided
  7. Quantify Value of Mobility Benefits (Partially or Quantitatively)

        a) Consumer Surplus
        b) Cross-sector Benefits
    8. Quantify Sprawl Related Benefits (Partially or Quantitatively)
        a) Physical Effects
        b) Monetary Value
    9. Quantify Community/Livability Benefits (Partially or Quantitatively)
        a) Residential Value
        b) Commercial Value
    10. Quantitative Analysis of Potential Double-Counting
    11. Quantitative sensitivity Analysis of Benefits Analysis

III. <u>Cost of Transit</u>
    1. Quantify Costs Comprehensively (Capital, Right-of-Way, O&M)
    2. Quantify Costs over the Entire Project Life-Cycle
    3. Quantify Discounted Costs
    4. Quantitative sensitivity or Risk Analysis

IV. <u>Evaluation Measures of Projects</u>
    1. Quantitative Cost-Effectiveness Measures (Cost per Trip, Other)
    2. Quantitative Cost-Benefit Measures (NPV, Rate of Return)
    3. Quantitative Sensitivity or Risk Analysis

3.2.1 Specification of Base Case and Options

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 can include certain transportation system management (TSM) innovations; small-scale spot infrastructure capacity improvements (such as interchange improvements); expanded bus service, and so on. Decision-makers and the general public are aware that if relatively low-cost steps can be found to diminish or delay existing transportation problems without recourse to high-cost investment, scarce capital resources can be employed more efficiently in meeting other urban and regional needs. The net benefits of an investment option are called “incremental net benefits” when they account explicitly from the likely effects of a properly conceived base case package.

Table 2 below shows that while 55 percent of the reviewed studies provided some comparative analysis of alternative investments, only 8 studies out of 33 (one fourth) provided a valid specification of a base case. Furthermore, few studies addressed delivery and management options, and even fewer (two studies) considered pricing options.

Table 2: Assessment Summary – Specification of Base Case and Options Criteria

Specification of Base Case and Options Criteria	Number of Studies	Percentage of Studies
1. Valid Specification of a Base Case (best use of existing resources rather than do-nothing)	8	24%
2. Comprehensive Specification and Analysis of Options (alternative transit modes, road capacity alternatives, alternative technologies)	18	55%
3. Comprehensive Specification and Analysis of Delivery and Management Options (public-private partnerships; commercialization etc)	11	33%
4. Comprehensive Specification and Analysis of Pricing Options (fare level alternatives; road pricing)	2	6%

3.2.2 Categories of Transit Benefit

While all relevant costs and benefits must be taken into account, the number of potential mistakes in applying the principle can be surprisingly large. In the transit domain, for example, studies often value the benefits of time savings to highway and transit users, but fail to assign economic value to mobility improvements occasioned by non-car owning transit passengers. As well, studies fail to recognize gains in economic development precipitated by station location effects.

Table 3 below shows that while the studies reviewed here attempt to quantify benefits over the project life cycle, only one third of them estimate the monetary value of the benefits, and only one fourth quantify discounted benefits. Also, when estimating benefits, most of the studies focus on ridership growth as the sole indicator of benefits. In fact, the majority of studies – about 60 percent – estimate only travel time savings and vehicle operating savings as transit benefits. Further, many studies fail to account for the value of reliability improvements on the assumption that the valuation of time savings accounts for such effects. Both micro-economic theory and actual measurement, however, prove this assumption wrong.[1] Travelers value reductions in travel time variability and unpredictability even when there is no improvement in average speed or reduction in average travel time. Moreover, the estimated value of reductions in average travel time has been found to be four times greater during congested conditions (i.e., during times of unpredictability) than during uncongested periods.

Only one third of the reviewed studies estimate emission savings as part of the environmental benefits of transit. While literature providing GHG factors, noise impact, and water pollution costs for different transportation modes are available, very few of the reviewed studies estimate these environmental benefits from transit. The review also shows that most of the studies fail to

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[1] HLB Decision Economics and University of California at Irvine, *Valuation of Travel-Time Savings and Predictability in Congested Conditions*, National Cooperative Highway Research Program Report 431, 1999

assign economic value to safety and mobility improvements occasioned by non-auto owning transit passengers.

The review also shows that benefit-cost studies of transit improvements often omit the value of community economic development, on the assumption that such impacts are the manifestation ("capitalization") of time savings and thus inadmissible on double-counting grounds. It turns out (based on the underlying micro-economic theory) that the question hinges on the propensity of station-induced increases in property value to reflect the relocation decisions of low-income, transit-dependent households (i.e., the propensity of poor people to move closer to stations to save time). The greater this propensity the more likely it is that increased property values are indeed the capitalized value of passenger time savings. Table 3 shows that only 15% of the studies attempt to quantify economic development benefits.

The table also shows that there is a lack of risk analysis applied to the benefit estimates. Despite its importance, only one study out of 33 applied risk analysis for different benefit estimates. Decision-makers and the public know one thing when it comes to benefit/cost analysis: every important forecast and assumption will almost certainly be wrong to some degree. Confidence in benefit/cost results is maximized when risk analysis is applied.

Table 3: Assessment Summary – Transit Benefits Criteria

Transit Benefits Assessment Criteria	Number of Studies	Percentage of Studies
1. Quantify Benefits over the Entire Project Life-Cycle		
a. Physical Effects	23	70%
b. Monetary Value	12	36%
2. Quantify Discounted Benefits	8	24%
3. Quantify Benefits and Costs (Partially or Quantitatively)		
a. Physical Effects	26	79%
b. Monetary Value	15	45%
4. Quantify Value of Congestion Benefits (Partially or Quantitatively)		
a. Average Time Savings	20	61%
b. Reduced Unreliability	1	3%
c. Convergence Effects	4	12%
d. Vehicle Operating Costs	19	58%
5. Environmental Benefits		
a. Emissions	12	36%
b. Greenhouse Gases	1	3%
c. Noise	1	3%
d. Water	1	3%
6. Safety Benefits		
a. Fatalities Avoided	4	12%
b. Injuries Avoided	3	9%
c. Property Damage Avoided	3	9%
7. Quantify Value of Mobility Benefits (Partially or Quantitatively)		
a. Consumer Surplus	15	45%
b. Cross-sector Benefits	3	9%
8. Quantify Sprawl Related Benefits (Partially or Quantitatively)		
a. Physical Effects	8	24%
b. Monetary Value	3	9%
9. Quantify Community/Livability Benefits (Partially or Quantitatively)		
a. Residential Value	5	15%
b. Commercial Value	5	15%
10. Quantitative Analysis of Potential Double-Counting	3	9%
11. Quantitative sensitivity Analysis of Benefits Analysis	1	3%

3.2.3 Transit Costs

Like benefit assessment, cost assessment should be comprehensive – that is, it should account for all cost components over the life cycle of a project in order to ensure that the investment's incremental benefits exceed its costs. The review shows that most of the studies considered direct project investment cost – mainly using cost data taken from engineering studies or transit agency capital and operating budgets. Only one half of the studies, however, quantified costs over the project's life cycle, and only one third quantified discounted costs.

Given the uncertainty surrounding cost estimates and the construction schedule, risk analysis of the cost components can expose the range of uncertainty. Data reported in Table 4 below reveal that only 6 percent of the studies reviewed used risk analysis to expose the range of cost uncertainty to decision-makers.

Table 4: Assessment Summary – Transit Costs Criteria

Transit Costs Assessment Criteria	Number of Studies	Percentage of Studies
1. Quantify Costs Comprehensively (Capital, Right-of-Way, O&M)	22	67%
2. Quantify Costs over the Entire Project Life-Cycle	17	52%
3. Quantify Discounted Costs	11	33%
4. Quantitative Sensitivity or Risk Analysis	2	6%

3.2.4 Evaluation Metrics

To assess the benefits of transit, two measures stand out as being most critical: (1) measures of investment worth (net present value, rate of return and B/C ratio) and (2) measures of optimal timing. Most of the reviewed studies addressed cost-effectiveness measures rather that benefit/cost measures (see Table 5, below). While cost-effectiveness measures are good performance indicators, they are not adequate for comparative analysis, especially for modal alternatives.

Most studies fail to apply risk analysis in the evaluation of transit investments. Risk analysis enables benefit/cost analysts to identify which options are more amenable to risk mitigation strategies than others. This is especially important in the assessment of corridor level projects.

Table 5: Assessment Summary – Evaluation Measures Criteria

Evaluation Measures Criteria	Number of Studies	Percentage of Studies
1. Quantitative Cost-Effectiveness Measures (Cost per Trip, Other)	19	58%
2. Quantitative Cost-Benefit Measures (NPV, Rate of Return)	8	24%
3. Quantitative Sensitivity or Risk Analysis	1	3%

3.3 Highway Project Evaluation

Whereas Cost-Benefit Analysis has only recently been introduced to transit decision makers, economic tools have been a mainstay of highway budgeting and decision making for more than 40 years. This is not to say to highway investment decisions routinely adhere to economic guidance. Nevertheless, it is the case that economic information is routinely provided in support of most major highway investment proposals.

3.3.1 Evolution of Economic Analysis in Highway Investment

The Cost-Benefit Analysis tradition in highway planning first took route in Britain. In the late 1950s, as part of the government's planning framework for construction of Britain's national motorway system, the Department of Transport developed an economic framework and supporting computer tool for use in judging the merits of alternative motorway designs and alignments. The result was a mainframe computer model called COBA (for Cost-Benefit Analysis). In addition to life-cycle costs, COBA recognized time savings, reduced vehicle operating costs and improved safety as the principal benefits of highway construction (in the micro-economic context of consumers' surplus). To quantify the economic value of time savings, COBA embodied a simple algorithm that multiplied the empirically observed value of time saved by the projected quantity of time saved. Safety benefits were estimated on the basis of an algorithm that multiplied the projected decline in fatal accidents and injuries by statistically estimated values of a life saved and of various degrees of injury avoided.

Over the 40 years since COBA was launched, other models have been developed and steadily improved. The most widely used models are those of the World Bank (HIAP[2]); the U.S. Department of Transportation (HERS[3]); and the National Cooperative Highway Research Program (MicroBENCOST[4] and StratBENCOST[5]). The basic micro-economic theory underpinning the models remains largely unchanged. Evolution has come in the form of:

- Intensive research on traffic forecasting;
- Intensive research on induced demand (traffic growth caused by the addition of new highway capacity);
- Intensive research on the relationship between highway capacity, traffic flow and traffic speed;
- Intensive research on the value of time savings, with special reference to the value of small time savings and the value of improved travel time reliability and predictability;
- Intensive research on the statistical value of life and injury savings; and
- Periodic updating of vehicle operating costs and accident rates; and
- The addition of environmental effects, including the economic value of emissions and greenhouse gases.

Today's manifestation of the models discussed above incorporate state-of-the-art aspects of each of these various line of research and data improvements.

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[2] Highway Investment Analysis Program
[3] Highway Economic Requirements Model
[4] Micro-Computer Benefit Cost Analysis Model
[5] Strategic Benefit Cost Analysis Model

3.3.2 Aggregate, Program-Level Models versus Disaggregate, Project-Level Models

Important differences exist between HERS and StratBENCOST on the one hand and COBA and MicroBENCOST on the other. Whereby HERS and StratBENCOST enable the economic analysis of highway program alternatives, COBA and MicroBENCOST apply to individual roadway investment options.

HERS operates on even broader level than StratBENCOST. In particular, HERS employs a national pavement and capacity performance database to assess the economic performance of alternative levels of service and spending at the national level. Rather than specifying projects, the model user specifies levels of pavement quality and traffic speeds for different categories of the national highway system (the Interstates, the primary system and the secondary system). The estimated infrastructure cost of achieving the specified pavement quality and traffic speeds is compared with the model's estimates of economic benefit. The model is used to provide the U.S. Congress with the estimated economic rate of return on alternative long-term aggregate spending scenarios.

StratBENCOST is an aggregate model in the sense that detailed geometric design aspects of projects are not required and projects can be grouped into "programs" for analysis. In short, the StratBENCOST user can assess either individual projects or groups of projects, but in neither case are detailed engineering details required as inputs to the model.

MicroBENCOST and HIAP are employed for exclusively single projects, and only for schemes that are developed to point at which detailed planning and engineering specifications are available (such as roadway grades, curvatures, pavement thickness and so on).

3.3.3 Choice of Model for Use in Transit-Highway Comparisons

While both MicroBENCOST and StratBENCOST enable direct comparisons of economic worth with Cost-Benefit Analyses of transit projects, MicroBENCOST is not useful at the strategic level. The strategic level is level at which project alignments and design concepts are specific enough to warrant Cost-Benefit Analysis but for which geometric and engineering details have yet to be developed. Since transit and highway projects need to be compared at the strategic level prior to the authorization of spending on design and engineering studies, StratBENCOST represents the appropriate tool for policy analysis. Importantly, StratBENCOST includes a risk analysis component that permits a wider degree of sensitivity analysis than MicroBENCOST.

3.4 Conclusion

Transit projects historically have come up short when compared with highways due to the widespread use of inappropriately narrow benefit and cost accounting frameworks – that is, frameworks that exclude numerous benefits arising from transit and a number of costs allocable to highways and the automobile. From the assessment of the reviewed studies based on the criteria described in Section 2.2, above, we see that most of the frameworks used in these studies are indeed not broad enough to account comprehensively for transit benefits. Instead, the studies focus mainly on ridership growth and congestion management.

Further, it is notable that when describing other potential benefits of transit, most studies do so through qualitative evaluation rather than quantitative analysis. While the literature on transit benefits and techniques to quantify them – such estimation of environmental benefits and economic development benefits – is extensive and widely available, most analysts still fail to account for them.

Last, transit studies traditionally fail to stress the sustainability solution that transit offers to congestion and mobility problems, and fail to apply risk analysis in order to help identify those project factors that must be controlled in order to deliver on a promise of positive net benefits. Decision-makers can be far more confident in risk-managed solutions than in mere benefit/cost findings.

4. BENEFIT-COST ANALYSIS FRAMEWORK

The Chapter is presented in nine sections. Sections 4.1 through 4.5 examine the different types of benefits and costs associated with transit investment projects. Sections 4.6 through 4.8 discuss various dimensions of the methodology related to highway investment evaluation, net present value and risk analysis. Finally, Section 4.9 provides an overview of the computer program to be used in the evaluation of transit and highway investment projects.

4.1 The Benefits and Costs of Transit Investments

This section examines the benefits and costs of transit in different categories of capital investment. It provides the quantitative data needed to estimate the investment costs and benefits of specific project proposals.

The analysis is intended to facilitate four levels of comparison:

- Alternative projects within a given category of investment (i.e., alternative light rail alignments, alternative scheduling technologies, and so on);
- Maintenance and modernization of existing capacity versus the creation of new capacity;
- Modal alternatives, such as fixed-route bus, light rail, heavy rail, and commuter rail; and
- Capital investment versus "revenue investment" (in other words, investment to improve service quality versus revenue support – subsidy – to limit increased fares).

This section explores the costs and benefits associated with two major investment types: investment in new capacity, and maintenance or modernization of existing capacity. It also considers five transit modes: conventional bus, BRT (dedicated busway), light rail, heavy rail and commuter rail. Analytical tools, data and assumptions are broken down by investment type and transit mode, whenever necessary.

4.1.1 Taxonomy of Benefits and Costs

Although the effects of capital projects can arise in many different forms, many of the effects represent different economic manifestations of a single result. Consider time savings. Travelers will often value faster journey times for their own sake. But improved travel times lead others to change their choice of residential location. This can alter the supply and demand for housing, leading to higher or lower housing prices and rents. While increased rents reflect an increase in the economic value of housing, it would be "double-counting" to add this increase to the value of the travel time savings since such rents stem from an economic "chain reaction", namely the capitalization of improved travel times. Health benefits represent another example. Population health can improve when the use of transit results in higher air quality.[6] It would be double-counting however to add the value of improved health (reduced incidence of disease) to the estimated value of improved air quality if the estimation method employed in valuing air quality

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[6] Noxon Associates Ltd., *Promoting Better Health Through Public Transit Use,* Canadian Urban Transit Association and Federation of Canadian Muncipalities, June 2001

accounts, implicitly, for health gains. In this example, double-counting arises not from a failure to recognize an economic chain reaction but rather failure to recognize overlapping measuring methods.

While double-counting can arise in various ways (economic chain reactions and overlapping measurement techniques are but two), the social Cost-Benefit Analysis framework demands a taxonomy of benefits and costs that maximizes the comprehensiveness with which costs and benefits are reflected while minimizing the risk of double-counting. The most rigorous taxonomy in this context – indeed, the only taxonomy devised specifically to meet this challenge – is that developed by the Federal Transit Administration.[7] The taxonomy has three components in relation to benefits, as follows:

- **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 transit users, highway users and to the community as a whole.

- **Low-Income Mobility Benefits**: The mobility-related benefits of transit arise in two ways: 1) the availability of affordable transportation to low-income people; and 2) the budgetary savings arising from reduced social service agency outlays on home-based health and welfare services (such as home health care or unemployment benefits); and

- **Community Economic Development Benefits**: Transit-oriented development can increase the value of commercial and residential property. 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.

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

- Capital expenditures on vehicles, facilities and equipment;

- Outlays for maintenance and repairs;

- Spending on wages, fuel and other operating costs; and

- The opportunity cost of capital employed.

Each of the categories listed above are addressed, in turn, in the following sections.

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[7] For an overview, see David Lewis *Policy and Planning as Public Choice: Mass Transit in the United States*, Ashgate, 1999

4.1.2 Economic Framework for Measuring Transit Benefits

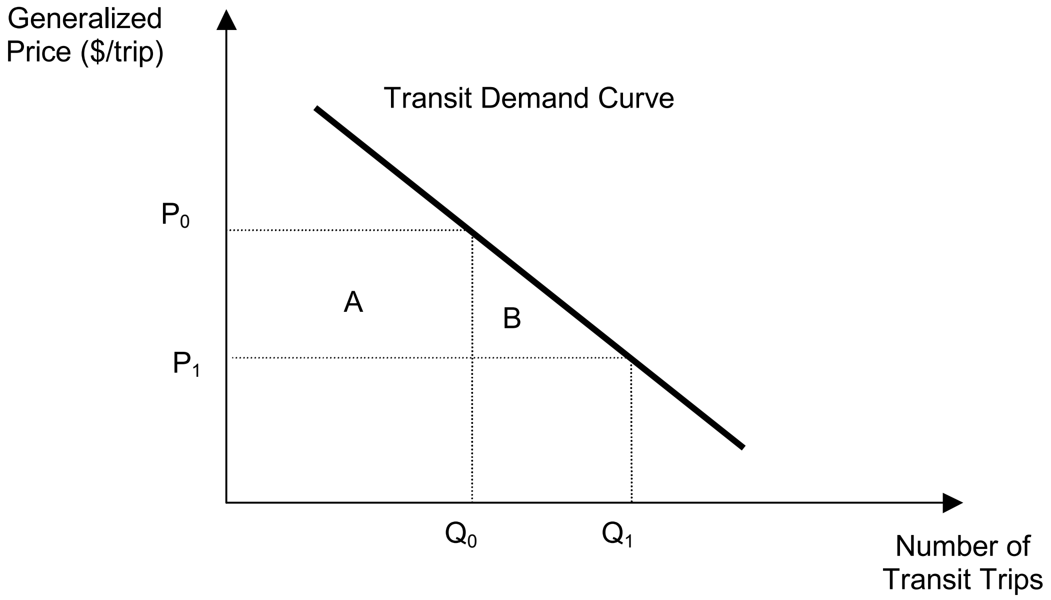
The economic benefits of transit investments can be illustrated with a simple graph relating the generalized cost of travel (including the value of travel time, and any out-of-pocket expenses such as fare for transit users, or fuel, oil and depreciation costs for auto users) to the demand for travel (measured as the number of trips in a year). This relationship, the "travel demand curve," is an inverse relationship: as the generalized cost of travel decreases, the number of trips undertaken increases. In other words, the "travel demand curve" (in a system of axes where the number of trips is represented on the horizontal axis, and the generalized cost of travel on the vertical axis) is downward sloping.

As shown below, this economic framework can be used for the estimation of benefits arising from both "modernization" investments (improvement or addition to existing transit systems), and investments in new systems.

4.1.2.1 Benefits to New and Existing Transit Users from Improvement or Addition to Existing Systems

The economic benefits of improvements or additions to existing systems, is best described by considering the demand for transit itself, a relationship between the generalized price of transit and the number of transit trips completed, as shown in Figure 1 below.

Figure 1: The Demand for Transit



The effects of a modernization investment can be illustrated as a reduction in the generalized price of transit from level P_0 to level P_1. A transit investment adding buses on an existing route will, for example, reduce average waiting time, thereby reducing the value-of-time component of the generalized price of transit. This reduction will have a dual effect: it will benefit existing transit riders, as they are now spending less time per trip; it will also induce some auto users to start using transit, to shift from auto to transit use, as transit is now less expensive than before, this is the so-called "induced demand."

These benefits, commonly referred to as changes in "consumer surplus," are represented on the above graph, by rectangle area A (benefits accruing to existing transit users) plus triangle area B (benefits accruing to new transit users). This framework can be applied to any investment types affecting the generalized price of transit: investments reducing in-vehicle time, waiting time or time spent in unsecured conditions, investments improving the safety of transit vehicles, investments reducing agency O&M costs and thereby avoiding fare increases.

4.1.2.2 Benefits to Transit Users from New Transit Systems

Similarly, investments in new transit systems or new routes can be evaluated by estimating changes in consumer surplus arising from the investments. For these investment types, the relevant analytical tool is the demand for *travel*, and the average generalized cost or price of *travel*.

Riders on the new transit facility will experience travel cost savings compared to their previous travel mode (this is precisely why they are now using the facility). These cost savings are the analytical equivalent to rectangle area A in Figure 1. In addition, some transit riders did not travel at all before the investment. These new riders have been "induced" to traveling. Cost savings to these riders are the analytical equivalent to triangle area B in Figure 1.

4.1.2.3 Benefits to Highway Users

Highway users will benefit from both investment types as trip diversion (from auto use to transit use) frees up some capacity on the highways. Again, benefits to highway users can be evaluated through a consumer surplus approach, as the reduction in highway congestion reduces the generalized cost of highway travel (reducing travel time, fuel and oil consumption, accident rates, etc.) and induces more people to use the highway. Again, the benefits of transit will be the sum of benefits to existing *and* new highway users.

It should be noted that certain benefits and benefit-determination factors vary by transit mode (“mode-dependent” variables) while others, mostly price variables (such as the value of time), do not (the latter are “mode-independent”). Table 6 on the next page provides an overview of the variables introduced in this section, by benefit category, and mode-dependence status.

Table 6: Overview of Input Variables for Transit Benefit Estimation

Variables By Benefit Category	Unit of Measurement	Mode Dependent
Congestion Management Benefits		
Value of Time in vehicle	$/hour	No
Value of Time spent walking	$/hour	No
Value of Time spent waiting	$/hour	No
Value of Time spent in crowded conditions	$/hour	No
Value of Time spent in unsecured conditions	$/hour	No
Average Annual VKT Growth 2000-2005	%	Yes
Average Annual VKT Growth 2005-2010	%	Yes
Average Annual VKT Growth 2010-2020	%	Yes
Free Flow Travel Speed	Km/hour	No
Travel Time Convergence Auto – Rail	%	Yes
Ridership Forecast	Riders	Yes
Average Annual Rail Ridership Growth	%	Yes
Percent of Trips Diverted from Cars to Transit	%	Yes
Average Trip Length	Kilometers	Yes
Average Number of Passengers per Car	Passengers	No
Volatile Organic Compounds Emission Factor	Gram/km	Yes
Carbon Monoxide Emission Factor	Gram/km	Yes
Nitrogen Oxide Emission Factor	Gram/km	Yes
Sulfur Oxides Emission Factor	Gram/km	Yes
PM10 and PM2.5 Emission Factor	Gram/km	Yes
Carbon Dioxide Emission Factor	Gram/km	Yes
Volatile Organic Compounds Emission Costs	$/tonne	No
Carbon Monoxide Emission Costs	$/tonne	No
Nitrogen Oxide Emission Costs	$/tonne	No
Sulfur Oxides Emission Costs	$/tonne	No
PM10 and PM2.5 Emission Costs	$/tonne	No
Carbon Dioxide Emission Costs	$/tonne	No
Fuel Consumption Rate	Litres	Yes
Oil Consumption Rate	Litres	Yes
Tire Consumption Rate	% wear	Yes
M&R Consumption Rate	% cost	Yes
Depreciation Rate	% depreciation	Yes
Fuel Unit Cost	$/litre	No
Oil Unit Cost	$/litre	No
Tire Unit Cost	$/tire	No
M&R Unit Cost	$	No
Depreciation Unit Cost	$	No
Average Parking Cost	$	No
Fatal Accident Rate	Acc./VKT	Yes
Injury Accident Rate	Acc./VKT	Yes
Property Damage Rate	Acc./VKT	Yes
Fatal Accident Cost,	$/accident	No
Injury Accident Cost	$/accident	No
Property Damage Cost	$/accident	No

Table 6 Continued

Variables By Benefit Category	Unit of Measurement	Mode Dependent
Low-Income Mobility Benefits		
Average Transit Fare	$	Yes
Average Fare of the Next Best Alternative	$	Yes
Elasticity of Transit Among Low-Income People	–	Yes
Percent of Trips for Medical Purposes	%	No
Percent of Trips for Work Purposes	%	No
Percent of Lost Medical Trips that Result in Home Care	%	No
Incremental Cost of Home Care	$/visit	No
Percent of Lost Work Trips Leading to Unemployment	%	No
Welfare Cost per Recipient	$/year	No
Economic Development Benefits		
Area of Impact	Km-radius	Yes
Number of Residential Properties within Impact Area	#	No
Number of Commercial Properties within Impact Area	#	No
Residential Property Premium	%	Yes
Commercial Property Premium	%	Yes
General Assumptions		
Average Consumer Price Inflation	%	No
Discount Rate	%	No

4.2 Congestion Management and Related Environmental Benefits

The availability of transit can provide travelers with time savings. Because of transit, some travelers can avoid expenses associated with vehicle ownership. In addition, transit is an effective congestion relief mechanism affecting users of the transit system and other travelers as well. Congestion results from vehicle traffic on the highway 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 transit services results in social costs savings. Moreover, transit services (1) allow for a reduction in travel time for drivers remaining on roadways, (2) lead to elimination of trips being taken by private vehicles, (3) and result in more efficient use of the roadway network. Therefore, transit can be an alternative to congestion management policies such as gasoline taxes, parking taxes, and congestion-zone taxes. The congestion management benefits are expressed as the cost savings associated with transit use versus automobile use.

4.2.1 Time and Delay Benefits

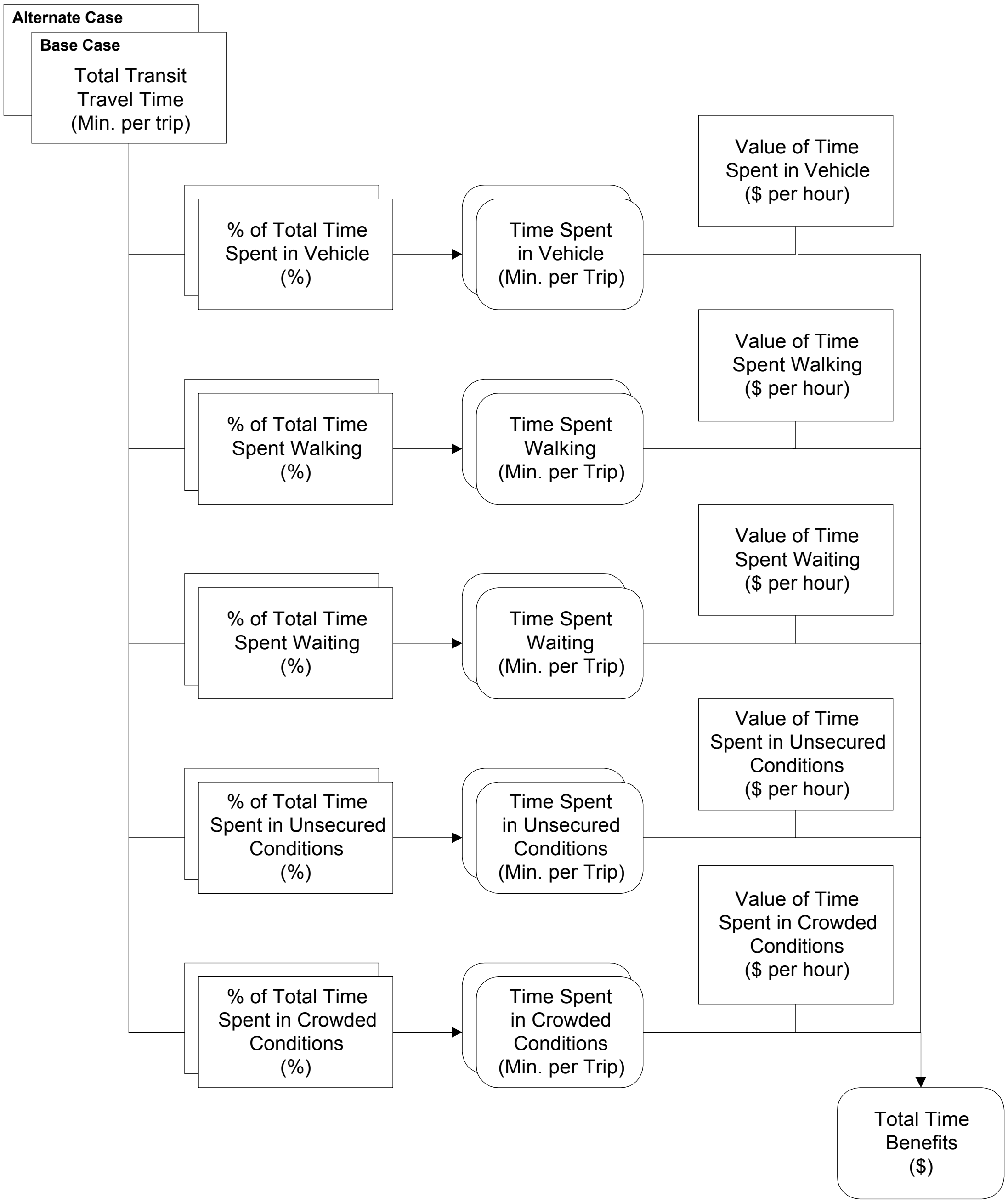
Time-related benefits occur as a result of total travel time reduction and changes in the quality or attributes of travel time.

For most transit investments, time savings are evaluated on the basis of projected reductions in highway use (vehicle kilometers traveled – VKT) that arise from mode shift. In the special case of high capacity fixed guideway transit systems (such as light rail or heavy rail) in heavily congested multi-modal travel corridors, delay savings also reflect convergence effects (discussed in Section 3.2.1.2 below).

While time savings arising from highway VKT reductions represent benefits to "new" transit users, 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. While such benefits do not represent reductions in highway congestion, they do represent the creation of economic value.

For both bus and rail modes, some investment projects (such as major maintenance or modernization) may not affect the *amount* of time spent traveling but instead the *quality*, or attributes, of time. Time benefits from such investments can be evaluated by examining the percentage of *total* travel time spent under different conditions (crowded conditions, or unsecured conditions) in the base (without investment) and alternate (with investment) cases. Estimates of distinct value of time under these specific conditions can then be applied to estimate actual dollar benefits. This is illustrated in Figure 2 below.

Figure 2: Structure and Logic Diagram for Estimating Time (Quality) Benefits



Note: % of Total Time Spent by Transportation Mode varies across projects and should be provided by transit agency.

4.2.1.1 Delay Savings from Bus Investment Projects

For conventional bus investment projects, delay savings occur principally as a result of mode shifts: car or taxi users, by shifting to transit, free up some capacity on highways, thereby improving traffic flows and average vehicle speed.

To estimate the impact of modes shifts, total trips diverted to transit are converted to Vehicle Kilometers Traveled (VKT) reduction, based on average trip length and vehicle occupancy by mode. The VKT reduction per day by mode ΔVKT_{Mode} can be estimated as follows:

$$\Delta VKT_{Mode} = ((DF * RF) / OR_{Mode}) * ATL_{Mode}$$

Where DF is the trip diversion factor,

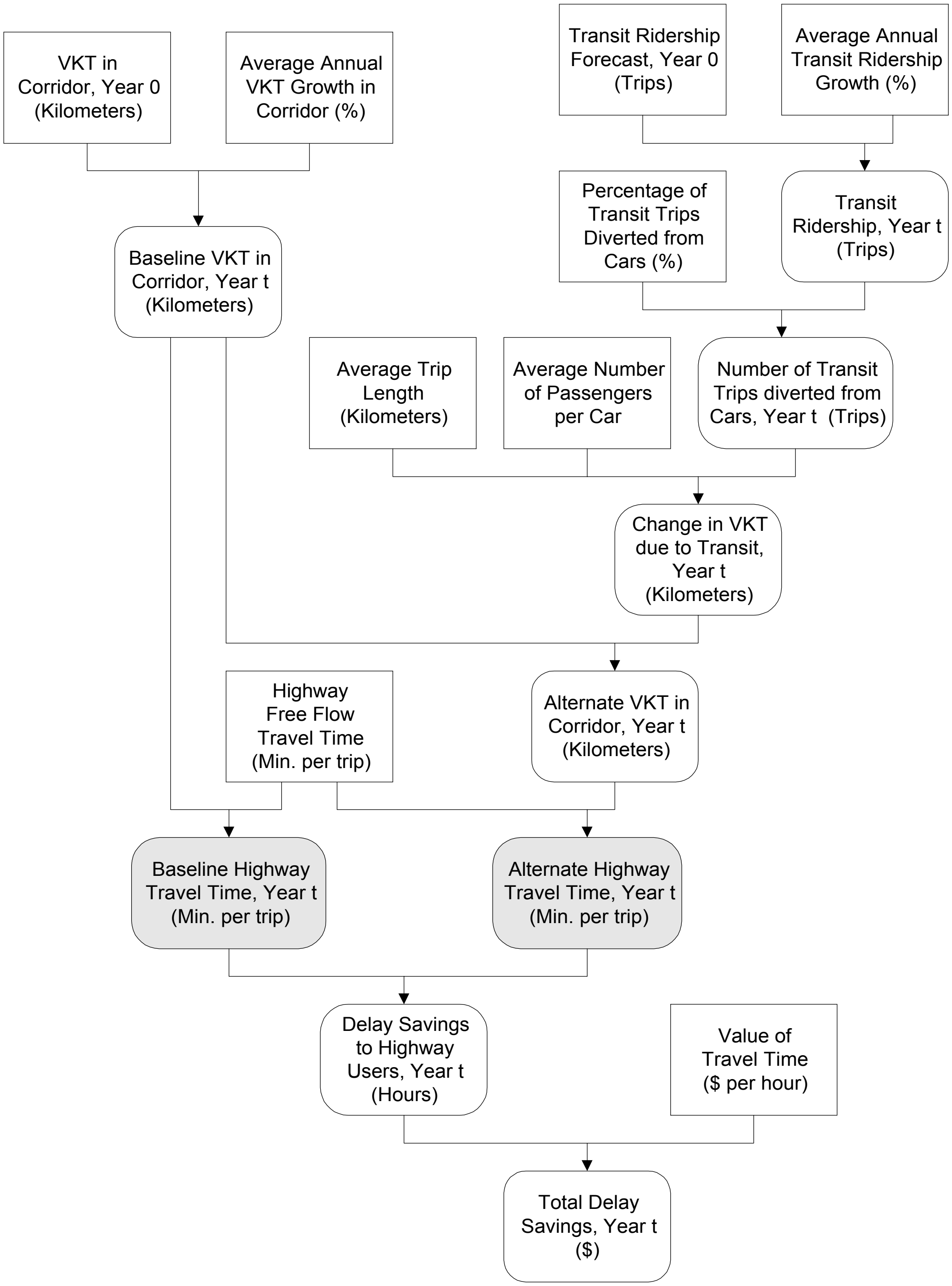
RF is the transit ridership forecast,

OR is vehicle occupancy rate by mode, and

ATL is the average trip length by mode.

Delay savings can be estimated from estimates of VKT reduction with speed-flow relationships borrowed from the StratBENCOST default database, a highway investment evaluation software, developed by HLB for the U.S. National Cooperative Highway Research Program. Alternatively, average highway travel time in the base and alternate cases can be estimated on the basis of travel time projections in the base and alternate cases, from regional traffic forecasting models.

Figure 3: Structure and Logic Diagram for Estimating Delay Savings for Bus Investment Projects



4.2.1.2 Delay Savings from Rail Investment Projects

4.2.1.2.1 Travel Time Convergence Theory[8]

For the past several years, researchers of traffic systems have observed that in congested urban corridors served by a dedicated transit mode, door-to-door journey times tend to be equal. The findings have profound implications for transportation investment strategies in congested urban corridors and favor a transit-led strategy of investment for the improvement of system performance by all modes.

In general, the amount of time it takes to make a trip during peak hours, and the number of users who decide to use roads versus transit, depend on a number of factors: the highway capacity, the costs of using a car versus taking public transit, and individual traveler's tastes. In spite of all of these variables, a travel pattern emerges in congested urban corridors: the time it takes to complete a journey, door-to-door, tends to be the same across different modes of transportation. Furthermore, it is the journey time by the transit mode that seems to determine the journey time for other modes. In fact, this pattern of converging travel times is predicted by economic theory. Current planning practice usually does not allow for the convergence of travel times and, in fact, proceeds quite differently.

The standard planning practice consists first of predicting the number of trips that will be made between two locations based on the number of inhabitants in both places, the location of jobs, etc. Then, these trips are apportioned among the different modes based on the traveler's income, personal tastes, etc. It is at this point that standard practice departs from the theoretical and empirical results set forth in this section. The standard approach does not account for travelers who move back and forth between modes, much as motorists move between lanes on a highway in their search for a faster-moving lane. It is the presence of these "explorers" that allows for the travel times to converge across modes, toward those for transit.

What explains the phenomenon of travel time convergence? One claim is that a dynamic relationship exists which parallels that of a multi-lane highway. Speeds across lanes tend to be equal because some drivers are "explorers" who seek out the faster-moving lane thus driving the system to an equilibrium speed shared by all lanes. By the same token, in congested urban corridors some travelers and commuters are explorers who value travel time improvements highly. They are not committed through circumstance or strong preference to either mode and they behave as occasional mode switchers.

If the transit mode has a high-speed, non-stop segment, then the door-to-door journey time by this mode will be relatively stable and small shifts in ridership will not significantly impact the journey time by the transit mode. On the other hand, under congested conditions even a one-half percent increase in highway traffic volume in the peak period can have a major impact on journey times. In two studies[9] sponsored by the Federal Transit Administration (FTA), HLB estimated intermodal door-to-door travel time for 21 corridors in the United States. The

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[8] Also known as the Mogridge-Lewis Convergence (MLC) theory

[9] HLB (1997) "The Benefits of Modern Transit" sponsored by the Office of Budget and Policy" and HLB (1999) "Method for Streamlined Strategic Corridor Travel Time Management", sponsored by the Office of Budget and Policy

difference between auto mode time and transit mode time was small in all corridors, rarely exceeding 8 minutes, for trips averaging 40 minutes to 1 hour and a half.

Because the journey time by transit is stable and determined by the speed of the high-capacity mode, transit "paces" the performance of the urban transportation system in the congested corridor. The modal explorers, like exploring drivers on the multi-lane highway, serve to bring about an equilibrium speed across modes as they seek travel time advantages across modes.

4.2.1.2.2 Travel Time Equilibrium and Modal Choice

While travel time represents a dominant component in the cost of trips, the generally accepted models of modal choice and the assignment of trips to networks would not predict travel times to be equal. Rather, the theory behind current practice is that individuals choose a mode based on income, car ownership, price differentials and modal preferences which account for non-money factors like convenience, uninterrupted travel, etc. The persistence of equal, or near equal, travel times across modes in congested corridors suggests that current theory fails to correctly capture modal interrelationships in a multi-modal system.

Appendix A presents the economic theory for consumer behavior under congestion and develops the conditions under which door-to-door trip time by highway converges to the trip time by the high-capacity transit mode. It further demonstrates how congestion promotes the modal explorer behavior.

4.2.1.2.3 Methodology for Estimating Delay Savings

This section describes the methodology to estimate delay savings to be brought by a transit system. The methodology is based on the Mogridge-Lewis Convergence (MLC) theory exposed in the previous section. The methodology consists of four steps:

1. Estimating the Corridor Performance Baseline;
2. Estimating the Corridor Performance in the Presence of transit;
3. Extrapolating Delay Savings Due to Transit; and
4. Estimating Travel Cost Savings.

4.2.1.2.3.1 Corridor Performance Baseline

This model represents the baseline that quantifies the role of transit in congestion management. In the absence of transit, the travel time T_1 is estimated as:

$$T_1 = T_{ff} \; * \; (1 + A\,(V)^{\beta}) \qquad \text{Equation 1}$$

Where T_1 is the door-to-door travel time;

T_{ff} is the trip travel time at free-flow speed;

V is the volume of person trips by auto; and

A is a scalar, and β is a parameter.

Equation 1 implies that the door-to-door travel time in the absence of high-capacity transit depends on the travel time at free-flow speed and the level of congestion on the road.

4.2.1.2.3.2 Corridor Performance in the Presence of Transit

This model establishes a functional relationship between the person highway trip volume and the average door-to-door travel time by auto in the corridor. The door-to-door travel time by auto can be determined using a logistic function that calculates the travel time in terms of travel time at free flow speed, trip time by high capacity rail mode, and the volume of trips in the corridor for all modes. The door-to-door travel time can be estimated as follows:

$$T_2 = (T_c - T_{ff}) / (1 + e^{-(\delta + \varepsilon V)}) + T_{ff} \qquad \textit{Equation 2}$$

Where T_2 is the door-to-door travel time;

T_c is trip time by high-capacity transit mode;

T_{ff} is auto trip time at free-flow speed;

V is person auto trip volume in the corridor; and

δ, ε are model parameters.

Equation 2 implies that the door-to-door auto trip time is equal to the trip time at free-flow speed plus a delay that depends on transit travel time and the person trip volume in the corridor.

In other words, when the highway volume is close to zero, travel time is equal to travel time at free flow speed: $T_2 = T_{ff}$. As the volume increases, the travel time is equal to T_{ff} plus a delay due to the high volume, but adjusted to the travel time by high capacity transit. That is the high capacity transit alleviates some of the highway trip delay as some trips shift to transit.

Equation 2 is transformed into a linear functional form before the parameters δ and ε can be estimated, the transformed equation is:

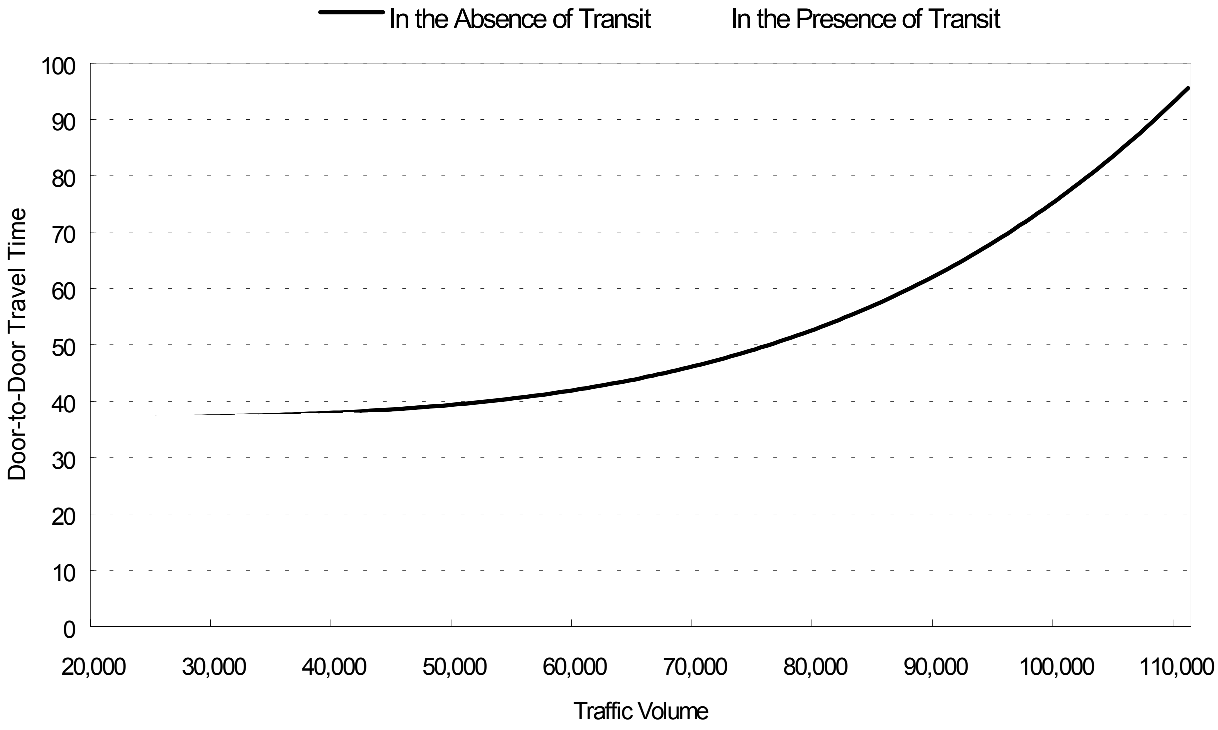
$$U = \delta + \varepsilon V_1 \qquad \textit{Equation 3}$$

Where $U = \ln [(T_c - T_{ff}) / (T - T_{ff}) - 1]$

The parameters δ and ε do not have to be re-estimated each year. They are both specific to the corridor and are relatively stable over the years. Therefore, the person trips volume forecast can be inserted into Equation 2 to estimate the door-to-door travel time by auto.

The model shows that in the absence of transit and high degree of convergence, the person trip volume is very high, which translates into excessive delay. The relationship between trip time and person trip volume can be expressed as a convex curve (as the volume increases, travel time increases at an increasing rate). The figure below illustrates the relationship between volume and travel time, both in the presence and in the absence of transit.

Figure 4: Travel Time in the Presence and Absence of Transit



4.2.1.2.3.3 Network Delay Savings

The methodology employs the MLC hypothesis to measure the savings in network delay brought by transit and its equilibrating effect on the level of service in the corridor. The MLC hypothesis, again, predicts that in congested urban corridors the time it takes to complete a journey door-to-door tends to be the same across different modes of transportation. Furthermore, it is the journey time by the transit mode that seems to determine the journey time for other modes. Therefore, the introduction of high-capacity transit services leads to lower congestion and reduced trip time. This relationship implies that in the presence of transit in the corridor, the congestion will improve as trip time and trip volume on the highway decrease.

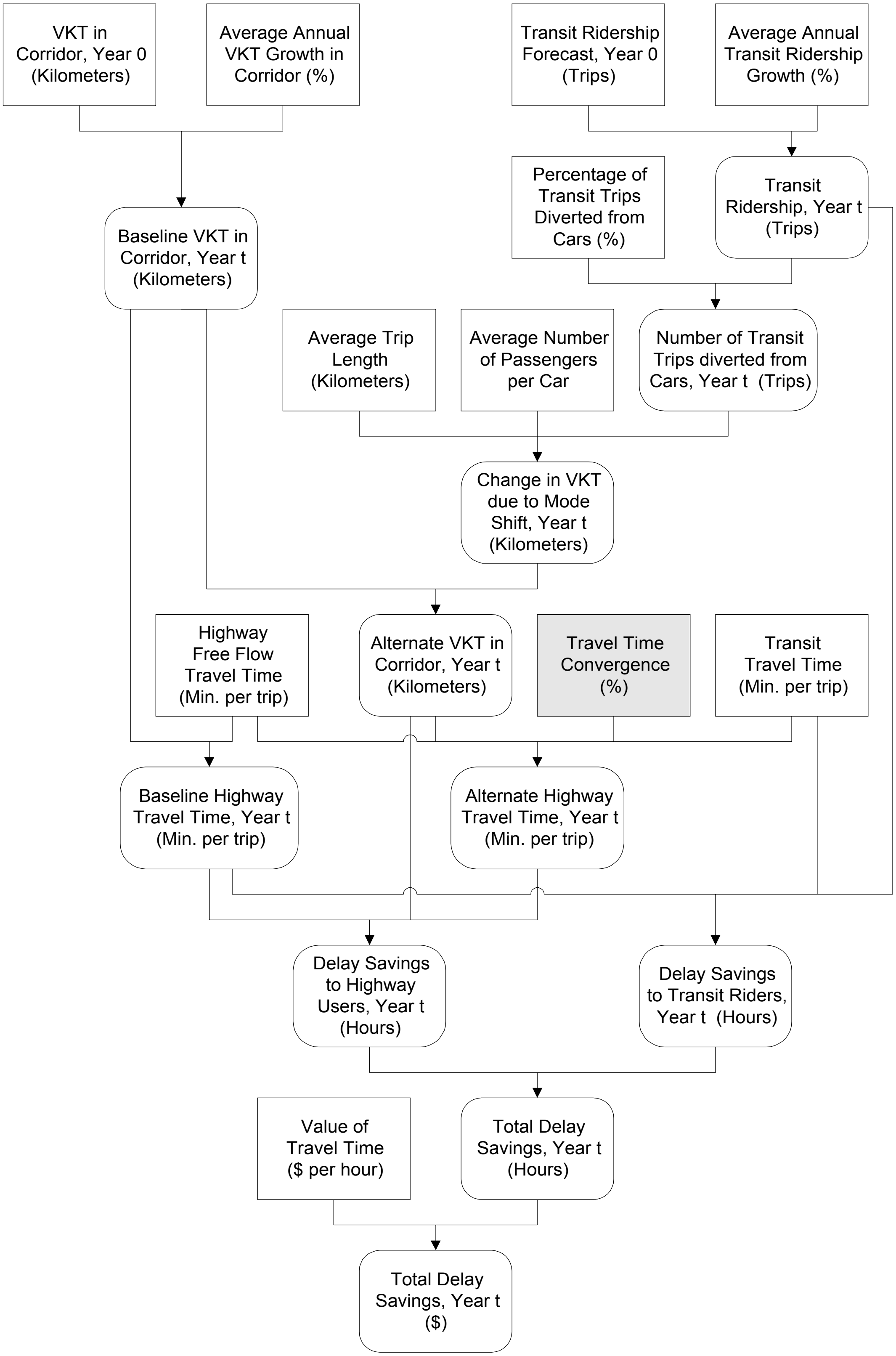
The methodology uses the functional relationship between travel time and person trip volume. The model is populated by door-to-door auto travel time, door-to-door travel time by transit, and historical travel volume data. The coefficients of the model are estimated using non-linear regression. Delay savings are estimated as the vertical difference between the “In the presence of Transit” curve and the “In the absence of Transit” curve. That is, at a specific person trip volume, the difference in travel times between the two cases can be defined as “the hours of delay saved due to transit”.

Total benefits are calculated as the sum of market benefits (benefits to transit riders), club benefits (benefits to users of highways next to the transit alignment), and spillover benefits (benefits to the rest of the network users):

- The market benefits are estimated based on delay saved (which depends on the distance traveled) for each rider within the corridor;
- The club benefits are estimated based on the volume on the common segment using an origin-destination table and the daily trip distribution. These savings are the results of faster roadway travel on the corridor due to the shift of motorists to transit; and
- The spillover benefits are estimated based on the savings per kilometer, traffic volume, and the distance traveled on the overall network including segments parallel to the common segment that will directly benefit from the improvement to the travel speed due to transit service. The spillover benefits are calculated by multiplying the traffic volume with a percentage of the delay savings. This percentage decreases as the distance between the corridor segment and the parallel highway increases.

Figure 5 on the next page shows the structure and logic diagram for estimating delay savings for rail (and other high capacity fixed guideway transit) investment projects.

Figure 5: Structure and Logic Diagram for Estimating Delay Savings for Rail Investment Projects



4.2.1.3 Assumptions For Estimating Time/Delay Benefits

The assumptions necessary for estimating time/delay benefits are described below.

Table 7: Value of Time

Description:
This variable describes the average value of travel time for commuter trips. The variable is expressed as dollars per hour.

How the Variable Affects the Model:
The model uses the average value of travel time to translate minutes saved (or improved) due to a transit investment project to dollar benefits.

Assumptions:

Variable	Median Estimate	10% Lower Limit	10% Upper Limit
Value of time in vehicle ($)	$10.5	$9.0	$12.8
Value of time spent walking ($)	$13.1	$11.2	$15.9
Value of time spent waiting ($)	$21.0	$18.0	$25.5
Value of time spent in crowded conditions ($)	$31.5	$27.0	$38.3
Value of time spent in unsecured conditions ($)	$15.8	$13.5	$19.1

Sources:
Transport Canada's 1999 Study "Final Report Highway Infrastructure and Opportunities for Reductions of GHG Emissions"

Values based on A. Horowitz and N. Thomas, "Evaluation of Intermodal Passenger Transfer Facilities," 1994

Table 8: Average Annual Vehicle Kilometers Traveled (VKT) Growth

Description:
This variable represents the expected traffic volume growth between Year 2000 and Year 2020. The traffic volume here is expressed as the annual vehicle kilometers traveled in the corridor.

How the Variable Affects the Model:
The model uses the growth to estimate the door-to-door travel time in the corridor, thus the delay savings to be brought by transit. A faster VKT growth leads to a higher travel time savings due to transit.

Assumptions:

Variable	Median Estimate	10% Lower Limit	10% Upper Limit
Average Annual VKT Growth 2000-2005, %	5.0%	2.5%	7.5%
Average Annual VKT Growth 2005-2010, %	3.0%	2.0%	5.0%
Average Annual VKT Growth 2010-2020, %	3.0%	2.0%	5.0%

Sources:
Based on Data from the study "An Economic Model of Inter-Urban Traffic on the Canadian Highway Network"

Actual, area or corridor-specific projections should be used instead if available.

Table 9: Transit Ridership Forecasts

Description*:*
This variable describes the expected transit ridership in the opening year. The ridership is expressed as average daily boarding.

How the Variable Affects the Model:
The model uses the ridership forecasts to estimate the delay savings by transit riders and the number of diverted trips from cars. A high level of ridership translates into high overall delay savings and high shift from cars to transit. The ridership depends mainly on demographic and employment growth, the congestion level on highway, and the transit level of service.

Assumptions:

Variable	Median Estimate	10% Lower Limit	10% Upper Limit
Ridership forecast (riders)	N/A	N/A	N/A

Sources:
Specific to project and corridor.

Table 10: Average Annual Ridership Growth

***Description**:*
This variable is the expected annual growth of average daily boarding.

How the Variable Affects the Model:
The model uses the expected growth to estimate the delay savings to transit users and the number of trips diverted from cars. The ridership growth is affected by the same variables listed under the ridership forecast.

Assumptions:

Variable	Median Estimate	10% Lower Limit	10% Upper Limit
Bus	2.00%	1.00%	3.75%
BRT	3.00%	2.50%	5.00%
Light Rail	2.50%	2.00%	5.00%
Heavy Rail	2.50%	2.00%	5.00%
Commuter Rail	2.50%	2.00%	5.00%

Sources:
Average growth is based on data from the American Public Transportation Association, 2000. Actual, project or corridor-specific projections should be used instead if available.

Table 11: Highway Free-Flow Travel Speed

Description:
This variable is the average free flow travel speed in the study area or corridor.

How the Variable Affects the Model:
The model uses the free flow travel speed, in combination with traffic level and speed-flow relationships, to estimate travel time in the base and alternate cases.

Assumptions:

Variable	Median Estimate	10% Lower Limit	10% Upper Limit
Free Flow Travel Speed (Km/hour)	N/A	N/A	N/A

Sources:
Specific to project and corridor.

Table 12: Travel Time Convergence, Auto - Rail

Description:
This variable describes the expected percentage *difference* of door-to-door travel time between auto and rail transit. A 10% value implies that on average, door-to-door travel time by car is 10% faster than travel time by transit.

How the Variable Affects the Model:
The model uses the convergence percentage to estimate door-to-door travel time in the presence of transit. A high convergence percentage means a high door-to-door transit travel time, thus low level of delay savings.

Assumptions:

Variable	Median Estimate	10% Lower Limit	10% Upper Limit
Auto - Light Rail	20%	10%	30%
Auto - Heavy Rail	15%	10%	20%
Auto - Commuter Rail	15%	10%	20%

Sources:
HLB estimates.

Table 13: Trip Diversion Factors

Description:
This variable describes the expected percentage of trips to be diverted from cars to transit as a result of the transit investment.

How the Variable Affects the Model:
The model uses this variable to estimate the change in VKT due to transit investment. The percentage of trips diverted to transit is affected by travel time, travel time reliability, and level of service (safety, comfort, etc.)

Assumptions:

Variable	Median Estimate	10% Lower Limit	10% Upper Limit
Bus	10.0%	5.0%	15.0%
BRT	30.0%	25%	40%
Light Rail	48.0%	35%	60%
Heavy Rail	54.0%	40%	60%
Commuter Rail	54.0%	40%	60%

Sources:
HLB study of 21 corridors, for the U.S. Federal Transit Administration

Table 14: Average Trip Length

Description:
This variable describes the average trip length in the corridor. The variable is expressed in kilometers.

How the Variable Affects the Model:
The model uses the average trip length in the corridor to estimate the annual delay saved by highway users due to transit. A high average trip length in the corridor leads to high delay savings.

Assumptions:

Variable	Median Estimate	10% Lower Limit	10% Upper Limit
Bus	6.1	4.0	7.0
BRT	6.5	4.0	8.0
Light Rail	6.6	5.0	10.0
Heavy Rail	8.2	6.0	12.0
Commuter Rail	22.0	15.0	35.0

Sources:
Canadian Urban Transit Association, "Canadian Transit Fact Book: Operating Data", 1999
American Public Transportation Association, 1999

Table 15: Average Number of Passengers per Car

Description:
This variable describes the average occupancy rate per car for work-based trips in the corridor. The variable is expressed as the average number of individuals per car.

How the Variable Affects the Model:
The model uses the average occupancy rate to estimate the change in VKT due to transit. A high occupancy rate reduces the change in VKT due to transit, therefore reducing travel cost savings.

Assumptions:

Variable	Median Estimate	10% Lower Limit	10% Upper Limit
Passenger per Car	1.60	1.20	1.75

Sources:
Consumer Policy Institute, "Passenger Travel by Motorized Modes, Canada 1970-1995"

4.2.2 Travel Cost Savings

Estimating travel cost savings requires three steps. The first step determines the number of trips diverted from other modes (primarily cars) to transit person trips. The estimate is based on the availability of cars to commuters, the price of alternative modes, and the income level of commuters. The second step consists of translating the number of trips into Vehicle Kilometers Traveled (VKT), based on average trip length for each mode. The third step computes the cost savings resulting from changes in VKT and speed improvements throughout the network. The cost categories considered in the model are:

1. <u>Vehicle operating costs</u>: fuel consumption, oil consumption, maintenance and repairs, tire wear, insurance, license, registration, taxes, and roadway related vehicle depreciation;

2. <u>Accident costs</u>: monetary cost of fatal accidents, injuries, and Property Damage Only (PDO) accidents; and

3. Environmental costs: social costs associated with vehicular emissions that are leading factors in air pollution: Volatile Organic Compounds, Carbon Monoxide, Nitrogen Oxide, Sulfur Oxides, Ambient Particulate Matter (PM10 and PM2.5), and Carbon Dioxide.

Again, travel cost savings - other than travel time savings - are estimated based on the VKT reduction and the cost factor estimated for each travel cost category: vehicle operating costs, accident costs, and environmental costs.

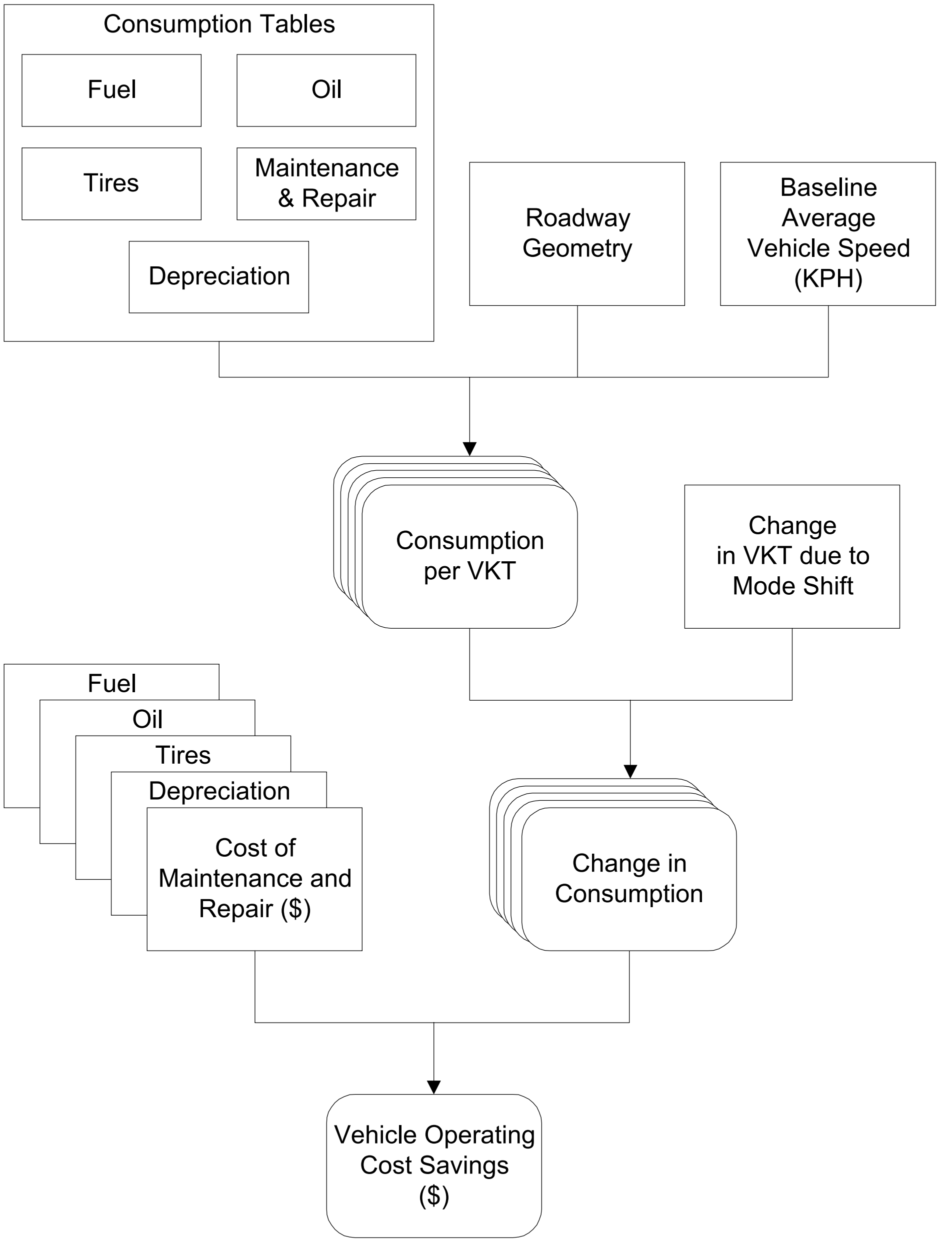
4.2.2.1 Vehicle Operating Cost Savings

Vehicle operating costs (VOC) 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 VOC can vary significantly between different facility types, geographic areas, and traffic patterns. In the model, vehicle operating costs in the base and alternate cases are estimated based upon parameters and relationships developed by the Texas Transportation Institute for the National Cooperative Highway Research Program, and adjusted by HLB for Canadian conditions.

Table 16: Measurement Units for Consumption and Price Components of VOC

Component	Unit Measurement	Price Measurement
Fuel	Litres	$ per Litre
Oil	Litres	$ per Litre
Tire	% of wear	$ per Tire
Maintenance and Repair	% of cost	$ (Average M&R Cost)
Depreciation	% depreciation	$ (Average Vehicle DepreciableValue)

Figure 6: Structure and Logic Diagram for Vehicle Operating Cost Savings



The Vehicle Operating Cost (VOC) consumption rates presented in the tables below are drawn from the "*Technical Memorandum for National Cooperative Highway Research Program (NCHRP) Project 7-12* ", Texas Transportation Institute, The Texas A&M University System, College Station, Texas, January 1990.

Table 17: Vehicle Operating Cost Consumption Rate, per 1,000 VKT

Speed	Fuel	Oil	Tires	Maintenance & Repair	Depreciation
	Autos				
8	174.124	2.245	0.039	29.605	0.991
16	133.828	1.390	0.042	29.192	0.833
24	106.540	1.093	0.049	30.158	0.741
32	87.815	0.948	0.060	31.689	0.679
40	74.971	0.867	0.073	33.530	0.631
48	66.267	0.820	0.090	35.566	0.593
56	60.692	0.795	0.112	37.738	0.561
64	57.540	0.783	0.141	40.009	0.535
72	56.504	0.782	0.178	42.354	0.512
80	57.445	0.789	0.224	44.760	0.492
88	60.504	0.803	0.284	47.214	0.475
97	66.008	0.822	0.360	49.707	0.459
105	74.547	0.847	0.457	52.234	0.445
113	87.203	0.877	0.581	54.790	0.433
	Buses				
8	833.664	4.951	0.068	28.988	0.462
16	609.176	3.942	0.068	29.250	0.364
24	511.998	3.235	0.076	29.779	0.310
32	457.305	2.735	0.088	30.572	0.275
40	423.454	2.384	0.104	31.630	0.249
48	402.047	2.140	0.125	32.953	0.230
56	389.086	1.980	0.150	34.541	0.214
64	382.476	1.888	0.180	36.395	0.203
72	380.994	1.854	0.213	38.513	0.193
80	384.028	1.877	0.250	40.897	0.186
88	391.250	1.958	0.292	43.546	0.180
97	402.565	2.105	0.338	46.459	0.175
105	418.044	2.332	0.388	49.638	0.172
113	437.945	2.661	0.442	53.082	0.169
	Trucks				
8	987.864	10.336	0.079	32.347	0.155
16	721.832	8.171	0.076	33.920	0.119
24	606.682	6.638	0.078	36.215	0.099
32	541.897	5.539	0.086	38.952	0.086
40	501.789	4.749	0.098	42.064	0.076
48	476.407	4.182	0.112	45.542	0.070
56	461.045	3.785	0.131	49.394	0.064
64	453.212	3.518	0.152	53.641	0.060
72	451.471	3.361	0.177	58.311	0.057
80	455.070	3.297	0.206	63.438	0.055
88	463.633	3.324	0.237	69.057	0.053
97	477.018	3.442	0.272	75.214	0.052
105	495.367	3.663	0.310	81.956	0.051
113	518.938	4.004	0.351	89.335	0.050

The following table provides vehicle operating cost component estimates.

Table 18: Vehicle Operating Cost Component Estimates, 1997 Dollars per Unit

Vehicle Class	Median Estimate	Lower Estimate	Upper Estimate
Automobiles			
Fuel	$0.35	$0.30	$0.43
Oil	$2.82	$2.40	$3.38
Tire	$102.56	$87.18	$123.08
Maintenance and Repair	$62.89	$53.46	$75.47
Depreciable Value	$16.70	$14.20	$20.04
Buses			
Fuel	$0.32	$0.27	$0.38
Oil	$2.38	$2.02	$2.85
Tire	$669.15	$568.78	$802.98
Maintenance and Repair	$196.46	$166.99	$235.75
Depreciable Value	$295.53	$251.20	$354.64
Trucks			
Fuel	$0.30	$0.25	$0.35
Oil	$2.88	$2.44	$3.45
Tire	$669.16	$568.79	$802.99
Maintenance and Repair	$110.61	$94.01	$132.73
Depreciable Value	$128.58	$109.29	$154.3

Source: HLB estimates based upon data from Transport Canada.

Table 19: Average Downtown Parking Cost

***Description*:**
This variable describes the average daily parking cost in the study area.

How the Variable Affects the Model:
The model uses the parking cost to estimate the net reduction in total vehicle operating costs due to transit presence. A high parking cost leads to higher transit benefits.

Assumptions:
Variable
Median Estimate
10% Lower Limit
10% Upper Limit

Parking Rate
$7.00
$5.00

$12.00

Sources:
Estimate based on Driving Costs 2000 published by the Canadian Automobile Association.

4.2.2.2 Safety Benefits

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. The accident cost model component is based on incident rate tables developed for the FHWA. Incident rates, expressed as number of fatalities, injuries and Property Damage Only (PDO) accidents per 100,000,000 VKT are combined with estimated VKT reduction to come up with total accident cost savings.

Figure 7: Structure and Logic Diagram for Safety Benefits

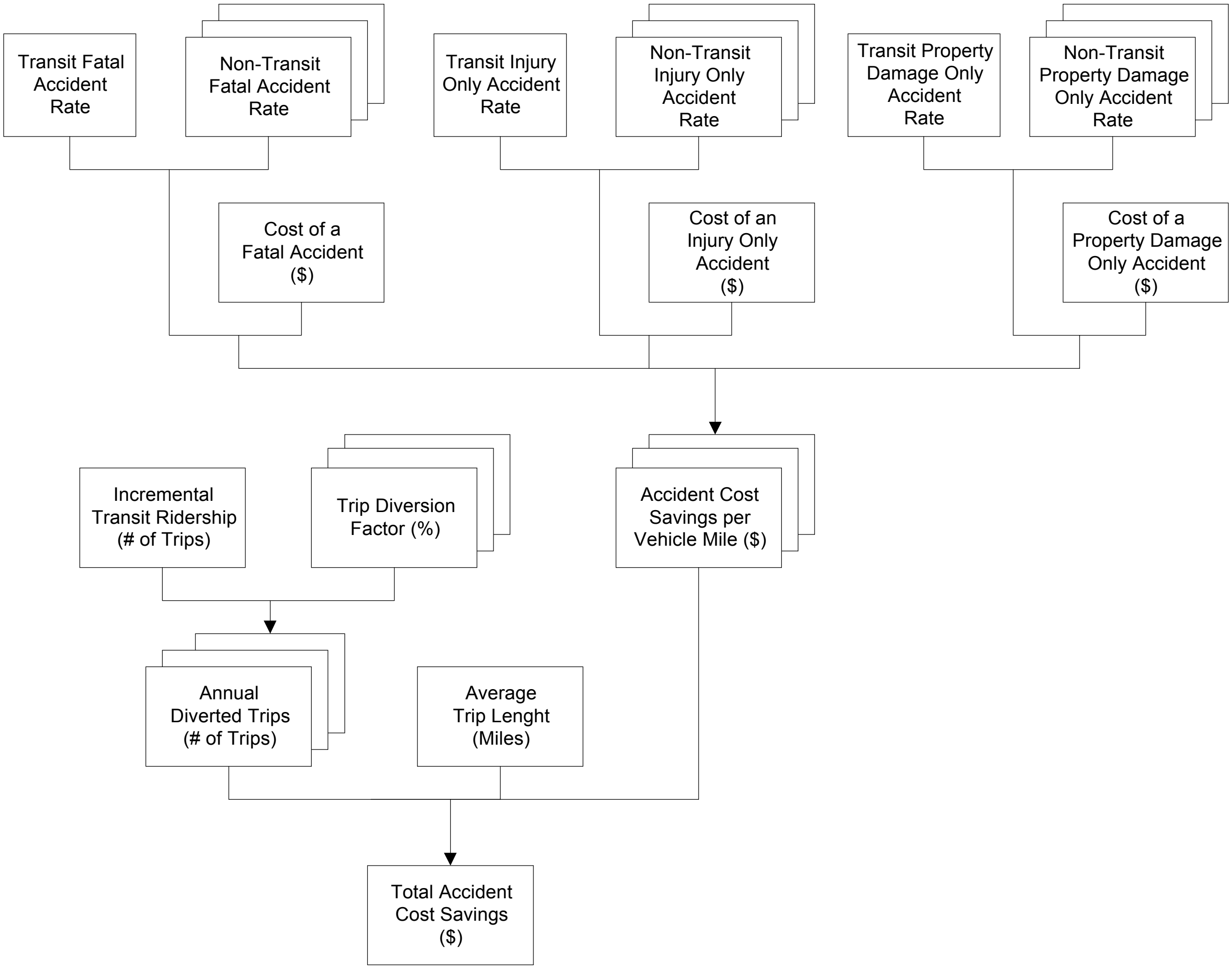


Table 20: Accident Costs

Description:
This variable describes the average cost per fatal, property damage only, and injury only accident. The variable is expressed in 1997 dollars per accident.

How the Variable Affects the Model:
The model uses the accident cost by type to estimate the net reduction in accident costs as car commuters shift to transit, which leads to higher savings due to transit.

Assumptions:

Variable	Median Estimate	10% Lower Limit	10% Upper Limit
Accident Costs ($/accident)			
Fatal Accident	$3,590,000	$1,500,000	$6,300,000
Injury Only Accident	$49,340	$13,400	$175,000
Property Damage Only Accident	$5,084	$2,700	$6,700

Sources:
Adjusted Estimate based on Motor Vehicle Accident Costs, Technical Advisory T 7570.2, US Department of Transportation, Federal Highway Administration, October 1994

Accident rates are expressed as: number of accidents per 100 million vehicle kilometers traveled. The accident rate depends on the roadway type and the average annual daily traffic (AADT).

Table 21: Accident Rates

AADT	Under 1,000	1,000-2,999	3,000-5,999	6,000-11,999	12,000-19,999	20,000-29,999	30,000-46,999	47,000-66,999	67,000-87,999	Above 88,000
Fatal Accidents Per 100 Million VKT										
Urban 4 Lanes Full Access Control	1.2	1.2	1.2	1.2	1.2	0.9	0.6	0.6	0.6	0.6
Urban 6+ Lanes Full Access Control	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
Urban 4 Lanes Partial Access Control	1.9	1.9	1.9	1.9	1.6	1.2	1.2	1.2	1.2	1.2
Urban 6+ Lanes Partial Access Control	1.6	1.6	1.6	1.6	1.6	1.6	1.2	1.2	1.2	1.2
Urban 2 or 3 Lanes	1.6	1.6	2.5	1.9	1.6	1.2	1.2	1.2	1.2	1.2
Urban Multilane Undivided	4.0	4.0	4.0	2.5	2.2	1.6	1.2	1.2	1.2	1.2
Urban Multilane Divided	2.5	2.5	2.5	2.2	1.9	1.6	1.2	1.2	1.2	1.2
Injury Accidents Per 100 Million VKT										
Urban 4 Lanes Full Access Control	25	25	25	22	22	22	25	37	37	37
Urban 6+ Lanes Full Access Control	40	40	40	40	40	44	25	28	34	44
Urban 4 Lanes Partial Access Control	115	115	115	115	124	137	137	137	137	137
Urban 6+ Lanes Partial Access Control	227	227	227	227	227	227	140	140	140	140
Urban 2 or 3 Lanes	121	121	121	168	205	245	245	245	245	245
Urban Multilane Undivided	360	360	360	227	227	227	208	208	208	208
Urban Multilane Divided	171	171	171	171	202	208	208	208	208	208
PDO Accidents Per 100 Million VKT										
Urban 4 Lanes Full Access Control	44	44	44	40	40	40	50	75	87	87
Urban 6+ Lanes Full Access Control	87	87	87	87	87	78	56	56	62	75
Urban 4 Lanes Partial Access Control	171	171	171	171	186	218	233	233	233	233
Urban 6+ Lanes Partial Access Control	320	320	320	320	320	320	233	233	233	233
Urban 2 or 3 Lanes	214	214	214	305	367	410	410	410	410	410
Urban Multilane Undivided	488	488	488	426	426	426	367	367	367	367
Urban Multilane Divided	258	258	258	258	305	367	367	367	367	367

Sources:

- Based on relationships and data put forth in "Highway Economic Requirements System Technical Report", Federal Highway Administration, U.S. Department of Transportation, Jack Faucett Associates, Bethesda, MD, July 1991.

4.2.2.3 Environmental Benefits

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. As with other travel costs savings, environmental cost savings are calculated based on the vehicle kilometers traveled reduction and the speed improvement throughout the network.

The analysis covers the major pollutants for which reasonably 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)
- Carbon Monoxide (CO)

Greenhouse Gases:

- Carbon Dioxide (CO_2)

For all transit investment types producing modal shifts (commuters shifting from auto to bus, or rail), changes in emission volumes are estimated on the basis of changes in highway VKT and emission factors. These volume changes are then combined with unit emission costs (unit damage values) to arrive at total emission cost savings. This is illustrated in Figure 8 below.

Other investment types (such as the replacement of a bus fleet with newer, more fuel efficient vehicles) may not produce any mode shift and yet, generate significant emission savings. In these cases, emission savings can be estimated by calculating emissions in the base case (with emission factors for the current fleet and current engine types) and in the alternate case (with emission factors for the new fleet).

4.2.2.3.1 Emission Factors

Emission factors for Criteria Air Contaminants (CAC) are in emissions per unit of travel and vary over time as fleet technologies evolve. Emission factors for greenhouse gases are in emissions per unit of fuel and remain constant over time, depending purely on the carbon content of the fuels consumed.

Emission factors for light-duty rail (assumed to operate exclusively on electricity) reflect the average emissions per kWh resulting from power generation. Since power sources vary considerably across provinces, so do emission factors. This means that the estimated emission impacts of light-duty rail projects will differ depending on the location of the project.

Where multiple emission factors are provided for different fuel or vehicle technologies, assumptions about future fleet composition will be developed and used to estimate a single emission factor for each vehicle type (on-road passenger vehicles, transit bus, etc.).

4.2.2.3.2 Emission Unit Costs

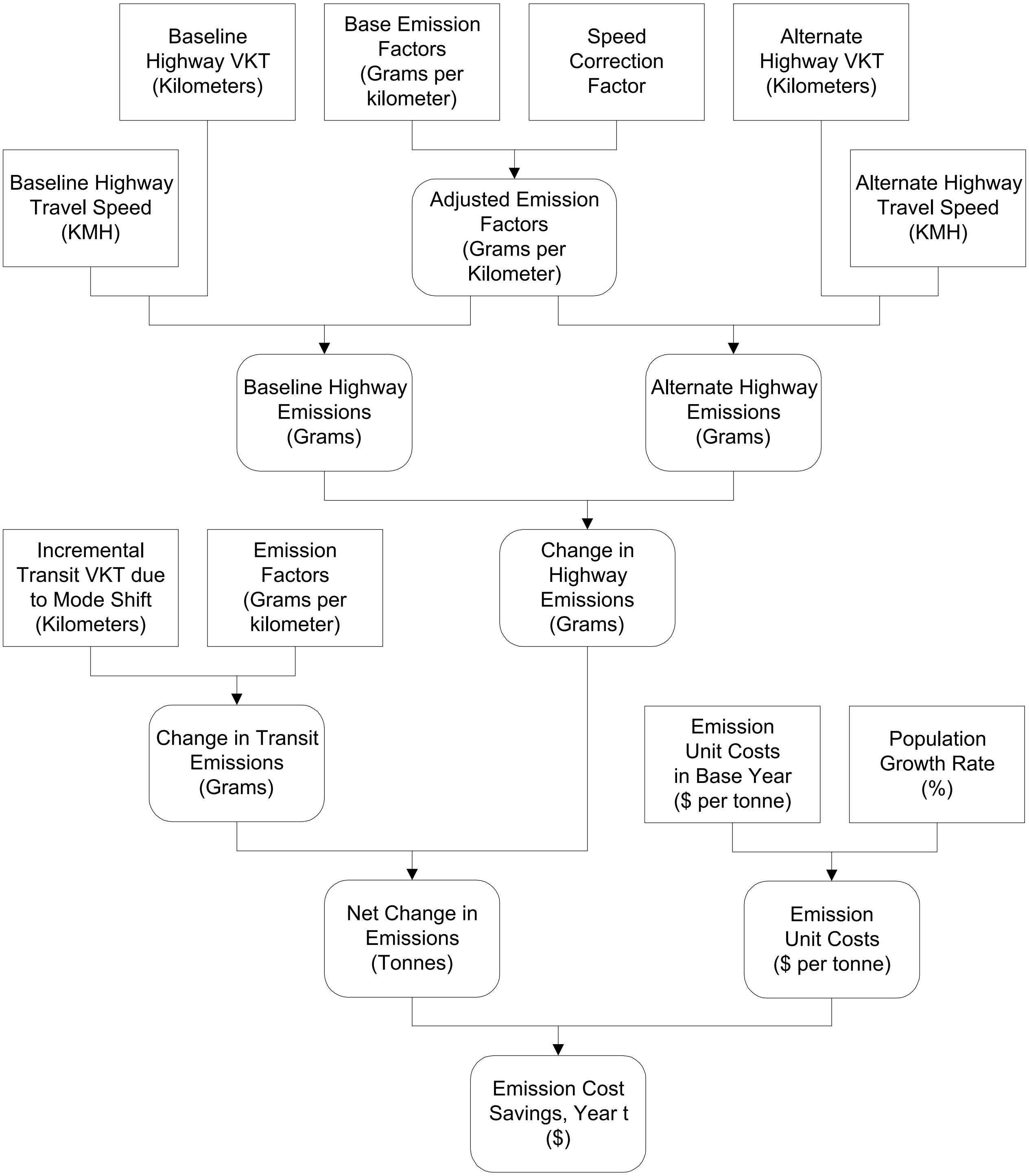
For Criteria Air Contaminants, unit values represent the average monetary value of a tonne of each pollutant estimated using the damage function approach. The damage function approach estimates the value of pollutants based on a three-step modeling process:

> Step 1: Dispersion modeling to determine the change in ambient air quality resulting from emissions;
>
> Step 2: Dose-response relationships to determine the change in human health or environmental amenities resulting from changes in ambient air quality;
>
> Step 3: Economic studies of the cost of damage resulting from, or willingness-to-pay to avoid, changes in human health or environmental amenities.

To generate unit damage cost estimates, we surveyed the literature for existing estimates of the unit damage costs per tonne of air pollutants, assessed their credibility and applicability to Canada, and made judgments as to the "best" estimates to incorporate into the transit benefit model. For each time period, three unit values for each pollutant are provided, reflecting the range of estimates found in a review of 42 studies. Estimates vary in part due to differences in analytical techniques and data availability, as well as the characteristics of the study site. Estimates also increase over time, reflecting population increases. As population increases, so too will incidences of illnesses.

For Greenhouse Gases, damages from climate change are too uncertain, and the associated literature insufficiently robust, to base unit values on the damage function approach. Therefore, the estimated unit values reflect the expected market value of carbon. In other words, the unit values reflect the economy-wide marginal cost of achieving an equivalent GHG emission reduction through other means. The values were derived from ICF Consulting's *Carbon Emissions Outlook* (Winter 2000/2001). The *Outlook* uses the proprietary IPM™ model to estimate carbon values under a range of international and domestic frameworks that are shaping climate change negotiations. Given the lack of a clear regulatory framework, the carbon values represent varying levels of flexibility regarding international emissions trading and the availability of non-carbon GHG offsets.

Figure 8: Structure and Logic Diagrams for Environmental Benefits



Highway emissions are estimated for seven types of vehicles, listed in Table 22 below. The EPA default distribution of vehicles across vehicle types is also shown in the table.

Table 22: Vehicle Types

Vehicle Type	Description	EPA "Default"
LDGV	Gasoline fueled cars	78.20%
LDGT	Pick-ups and commercial vans	13.00%
HDGV	Gasoline-fueled trucks	4.20%
LDDV	Diesel fueled cars	0.20%
LDDT	Diesel-fueled trucks < 8500 lb.	0.00%
HDDV	Diesel-fueled trucks >8500 lb.	3.50%
MC	Motorcycles	0.90%

Transit emissions are estimated for 8 engine types (for the bus and BRT modes) and 10 Provinces (for the light-rail mode).

Table 23: Transit Modes, Engine Types and Regions

Transit Mode	Engine Type / Region
Bus	500 ppm S Diesel
	300 ppm S Diesel Hybrid
	CNG
	Biodiesel
	DME
	M100 Fuel Cell
	H2 (Natural Gas) Fuel Cell
Light Rail	Alberta
	B.C. and Territories
	Manitoba
	New Brunswick
	Newfoundland
	Nova Scotia
	Ontario
	Prince Edward Island
	Quebec
	Saskatchewan
Heavy Rail	

Highway base emission factors, in grams per kilometer, for years 2005, 2010 and 2020, are shown in Table 24 below.

Table 24: Highway Base Emission Factors, Grams per Kilometer

	LDGV	LDGT	HDGV	LDDV	LDDT	HDDV
Year = 2005						
VOC	0.54748	0.70316	1.15316	0.25208	0.31802	0.40498
CO	5.13711	5.57498	11.62512	0.67593	0.71343	4.54890
NOx	0.62086	0.73239	3.74106	0.65099	0.70747	6.02128
SOx	0.00356	0.00188	0.00786	0.04352	0.05524	0.02930
PM10	0.00304	0.00346	0.02788	0.06907	0.07250	0.19919
PM2.5	0.00280	0.00313	0.02135	0.06354	0.06670	0.18325
CO2	0.23364	0.31388	0.47200	0.27300	0.35490	1.08927
Year = 2010						
VOC	0.35366	0.43227	1.00371	0.25931	0.33266	0.26965
CO	3.71323	3.77966	10.04808	0.68471	0.72674	4.53414
NOx	0.36392	0.46748	3.43897	0.64720	0.71599	5.19319
SOx	0.00357	0.02837	0.00767	0.04185	0.05414	0.02837
PM10	0.00303	0.00337	0.02226	0.06240	0.06775	0.14822
PM2.5	0.00280	0.00305	0.01758	0.05741	0.06249	0.13636
CO2	0.21476	0.30444	0.47200	0.27300	0.35490	1.05378
Year = 2020						
VOC	0.27579	0.30479	0.95665	0.26907	0.34841	0.24394
CO	2.91717	2.89251	10.08710	0.69669	0.74129	4.53138
NOx	0.20294	0.29177	3.29241	0.65844	0.72977	4.90344
SOx	0.00358	0.02756	0.00759	0.04078	0.05329	0.02756
PM10	0.00303	0.13389	0.02025	0.06214	0.06773	0.13389
PM2.5	0.00280	0.12318	0.01623	0.05717	0.06231	0.12318
CO2	0.19588	0.28792	0.472	0.273	0.3549	1.0101

Sources:

- CAC Emissions Factors - Christian Vzina, Pollution Data Branch, Environment Canada, August 2001. Contact: (819) 994-2975
- GHG Emissions Factors - Canada's Greenhouse Gas Inventory: 1990-1998, Final Submission to the UNFCCC Secretariat, October 2000, Volume 1 of 2
- Environment Canada confirming the test procedures (speed) at which the CAC emission factors were calculated.
- Grams per litre to grams per kilometer conversion based on fuel efficiency figures estimated by Joycelyn Exeter, Analysis Modelling Division, Natural Resources Canada, July 2001

Table 25: Bus Emission Factors, Grams per Kilometer, Year 2005

	500 ppm S Diesel	300 ppm S Diesel Hybrid	CNG	Bio Diesel	DME	M100 Fuel Cell	H2 Fuel Cell
Year = 2005							
VOC	1.15257	0.66927	2.52719	0.20588	1.70926	0.12129	0.00000
CO	12.43751	7.22266	24.87751	3.73138	16.17013	0.00000	0.00000
NOx	16.75419	9.72808	8.37710	21.78057	8.37710	0.00000	0.00000
SOx	0.34583	0.31473	0.05287	0.21459	0.10263	0.00000	0.00000
PM10	0.50239	0.29172	0.01990	0.25129	0.10014	0.00000	0.00000
PM2.5	NA	NA	NA	NA	NA	NA	NA
CO2	1,315.29	842.18	1,249.59	1,339.78	1,184.28	1,071.70	0.00000
Year = 2010							
VOC	1.09907	0.61889	2.43886	0.19842	1.65079	0.11880	0.00000
CO	11.96666	6.66224	23.93394	3.59018	15.55684	0.00000	0.00000
NOx	13.30893	7.40926	6.65416	17.30155	6.65416	0.00000	0.00000
SOx	0.34708	0.30167	0.05287	0.21459	0.10263	0.00000	0.00000
PM10	0.35205	0.19593	0.01679	0.17603	0.07029	0.00000	0.00000
PM2.5	NA	NA	NA	NA	NA	NA	NA
CO2	1,316.57	784.96	1,221.60	1,341.03	1,186.77	919.93	0.00000
Year = 2020							
VOC	1.03003	0.53865	2.27714	0.18473	1.54007	0.11196	0.00000
CO	11.10083	5.77029	22.20167	3.33019	14.43102	0.00000	0.00000
NOx	8.39762	4.36520	4.19912	10.91734	4.19912	0.00000	0.00000
SOx	0.34770	0.28114	0.05287	0.21459	0.10263	0.00000	0.00000
PM10	0.18971	0.09828	0.01368	0.09454	0.03794	0.00000	0.00000
PM2.5	NA	NA	NA	NA	NA	NA	NA
CO2	1,318.94	751.37	1,199.21	1,341.65	1,188.64	832.85	0.00000

Sources:

- CAC Emissions Factors - Vernel Staniciulescu, Transportation and Energy Use, Natural Resources Canada, September 2001, Contact: (613) 995-2100
- GHG Emissions Factors - Alternative and Future Fuels and Energy Sources for Road Vehicles, Transportation Issue Table, National Climate Change Process, December 1999

Table 26: Light Rail Emission Factors, Grams per kWh, Year 2005

	Alberta	B.C. and Territories	Manitoba	New Brunswick	NFL	Nova Scotia	Ontario	PEI	Quebec	Saskatchewan
Year = 2005										
VOC	0.000017	0.000008	0.000001	0.000008	0.000001	0.000011	0.000002	0.000003	0.000000	0.000019
CO	0.000122	0.000091	0.000005	0.000051	0.000009	0.000080	0.000019	0.000025	0.000002	0.000154
NOx	0.001383	0.000056	0.000029	0.000757	0.000085	0.002060	0.000373	0.000142	0.000007	0.002481
SOx	0.001989	0.000005	0.000043	0.003079	0.000361	0.011421	0.000470	0.000295	0.000002	0.005668
PM10	0.000137	0.000006	0.000013	0.000008	0.000021	0.000039	0.000011	0.000015	0.000000	0.001132
PM2.5	0.000134	0.000006	0.000007	0.000005	0.000015	0.000024	0.000005	0.000012	0.000000	0.000382
CO2	0.692242	0.055958	0.095761	0.278921	0.059839	0.660457	0.102411	0.100402	0.003193	0.673700
Year = 2010										
VOC	0.000017	0.000008	0.000001	0.000008	0.000001	0.000011	0.000002	0.000003	0.000000	0.000019
CO	0.000122	0.000091	0.000005	0.000051	0.000009	0.000080	0.000019	0.000025	0.000002	0.000154
NOx	0.001383	0.000056	0.000029	0.000757	0.000085	0.002060	0.000373	0.000142	0.000007	0.002481
SOx	0.001989	0.000005	0.000043	0.003079	0.000361	0.011421	0.000470	0.000295	0.000002	0.005668
PM10	0.000137	0.000006	0.000013	0.000008	0.000021	0.000039	0.000011	0.000015	0.000000	0.001132
PM2.5	0.000134	0.000006	0.000007	0.000005	0.000015	0.000024	0.000005	0.000012	0.000000	0.000382
CO2	0.637905	0.063920	0.000000	0.340045	0.048077	0.694327	0.152368	0.096712	0.003193	0.683796
Year = 2020										
VOC	0.000017	0.000008	0.000001	0.000008	0.000001	0.000011	0.000002	0.000003	0.000000	0.000019
CO	0.000122	0.000091	0.000005	0.000051	0.000009	0.000080	0.000019	0.000025	0.000002	0.000154
NOx	0.001383	0.000056	0.000029	0.000757	0.000085	0.002060	0.000373	0.000142	0.000007	0.002481
SOx	0.001989	0.000005	0.000043	0.003079	0.000361	0.011421	0.000470	0.000295	0.000002	0.005668
PM10	0.000137	0.000006	0.000013	0.000008	0.000021	0.000039	0.000011	0.000015	0.000000	0.001132
PM2.5	0.000134	0.000006	0.000007	0.000005	0.000015	0.000024	0.000005	0.000012	0.000000	0.000382
CO2	0.548849	0.061867	0.086911	0.371661	0.044466	0.652999	0.293024	0.092507	0.002967	0.689090

Sources:

- GHG Emissions Factors - Calculated based on the CO2 emissions and electricity generation figures from Canada's Energy Outlook 1996-2020, Energy Policy Branch, Natural Resources Canada, April 1997

- CAC Emissions Factors - Calculated based on the CAC emissions from CAC Emission Summaries, Pollution Data Branch. Environment Canada. March 2001, http://www.ec.gc.ca/pdb/ape/cape_home_e.cfm and electricity generation figures from Canada's Energy Outlook 1996-2020, Energy Policy Branch. Natural Resources Canada, April 1997

Table 27: Heavy Rail Emission Factors, Grams per Litre

	2005	2010	2020
VOC	0.00267	0.00267	0.00267
CO	0.01053	0.01053	0.01053
NOx	0.05468	0.05468	0.05468
SOx	0.00251	0.00251	0.00251
PM10	0.00126	0.00126	0.00126
PM2.5	NA	NA	NA
CO2	2.70568	2.70568	2.70568

Sources:

- Locomotive Emissions, Monitoring Program 1998, Transportation Systems Branch, Air Pollution Prevention Directorate, Environment Canada, October 2000

Speed correction factors are used to adjust highway base emission factors, presented in the tables above, for changes in vehicle speed. As shown in Figure 9, below, emission rates for VOC, CO and NOx are *typically* very high at low speed, fall to a minimum and then rise again at higher speed levels. Emissions of particulate matter are invariant with speed.

Figure 9: Speed Correction Factors, for Gasoline Fueled Cars

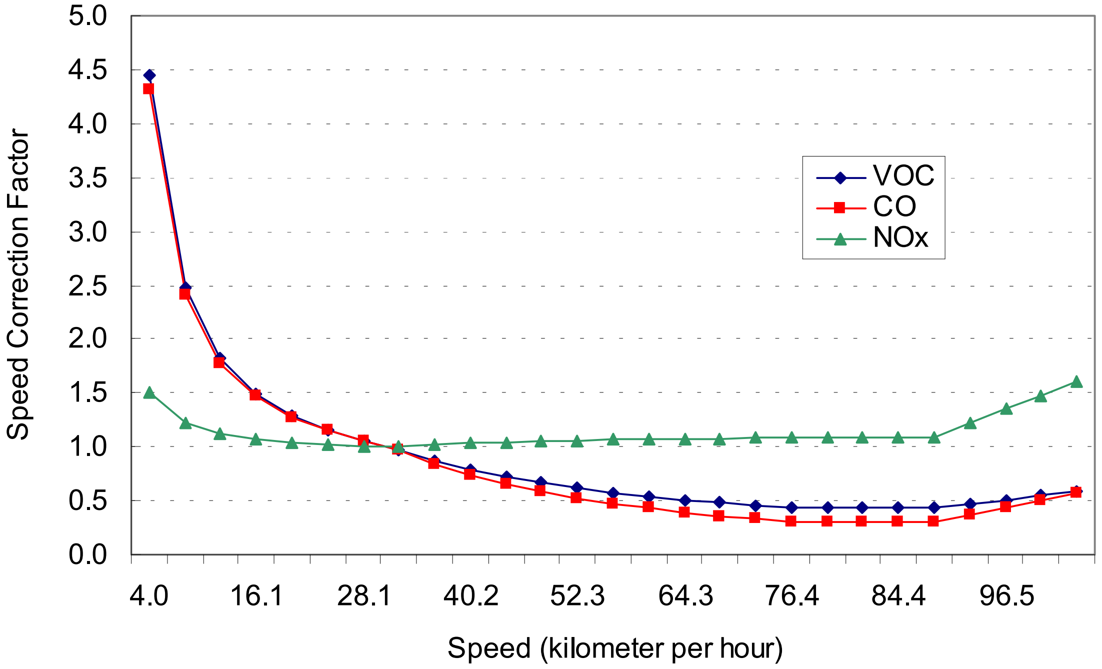


Table 28: Speed Correction Factors, LDGV, LDGT, LDDV and LDDT

Speed	LDGV			LDGT			LDDV			LDDT		
	VOC	CO	NOx	VOC	CO	NOx	VOC	CO	NOx	VOC	CO	NOx
4	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
8	4.454	4.310	1.508	4.743	4.029	1.508	2.161	3.176	1.734	2.161	3.176	1.734
12	2.475	2.413	1.217	2.598	2.293	1.217	1.899	2.593	1.559	1.899	2.593	1.559
16	1.815	1.781	1.120	1.883	1.714	1.120	1.678	2.141	1.413	1.678	2.141	1.413
20	1.485	1.465	1.071	1.525	1.425	1.071	1.491	1.788	1.293	1.491	1.788	1.293
24	1.287	1.275	1.042	1.311	1.252	1.042	1.332	1.510	1.194	1.332	1.510	1.194
28	1.155	1.148	1.023	1.168	1.136	1.023	1.196	1.290	1.112	1.196	1.290	1.112
32	1.061	1.058	1.009	1.066	1.053	1.009	1.081	1.115	1.044	1.081	1.115	1.044
36	0.975	0.972	1.005	0.977	0.975	0.996	0.981	0.974	0.990	0.981	0.974	0.990
40	0.871	0.843	1.020	0.883	0.855	0.998	0.896	0.861	0.947	0.896	0.861	0.947
44	0.788	0.740	1.032	0.808	0.758	1.001	0.823	0.770	0.914	0.823	0.770	0.914
48	0.720	0.655	1.042	0.746	0.679	1.002	0.760	0.696	0.890	0.760	0.696	0.890
52	0.663	0.585	1.050	0.695	0.614	1.004	0.706	0.637	0.874	0.706	0.637	0.874
56	0.615	0.525	1.057	0.652	0.558	1.005	0.659	0.589	0.866	0.659	0.589	0.866
60	0.574	0.474	1.063	0.614	0.510	1.006	0.618	0.551	0.866	0.618	0.551	0.866
64	0.539	0.430	1.068	0.582	0.469	1.007	0.584	0.522	0.873	0.584	0.522	0.873
68	0.507	0.391	1.072	0.554	0.433	1.008	0.554	0.500	0.889	0.554	0.500	0.889
72	0.480	0.357	1.076	0.529	0.401	1.008	0.529	0.484	0.913	0.529	0.484	0.913
76	0.456	0.327	1.080	0.507	0.372	1.009	0.507	0.474	0.945	0.507	0.474	0.945
77	0.434	0.299	1.083	0.487	0.347	1.010	0.489	0.469	0.988	0.489	0.469	0.988
80	0.430	0.294	1.083	0.483	0.342	1.010	0.475	0.470	1.042	0.475	0.470	1.042
84	0.430	0.294	1.083	0.483	0.342	1.010	0.463	0.476	1.108	0.463	0.476	1.108
88	0.430	0.294	1.083	0.483	0.342	1.010	0.454	0.488	1.190	0.454	0.488	1.190
92	0.468	0.362	1.215	0.517	0.411	1.169	0.448	0.506	1.288	0.448	0.506	1.288
96	0.507	0.429	1.347	0.550	0.481	1.328	0.444	0.530	1.408	0.444	0.530	1.408
100	0.546	0.497	1.479	0.583	0.550	1.487	0.443	0.563	1.552	0.443	0.563	1.552
105	0.584	0.564	1.611	0.617	0.619	1.646	0.444	0.603	1.726	0.444	0.603	1.726

Sources:

- Compilation of Air Pollutant Emission Factors, Volume II: Mobile Sources (AP-42), Appendix H, Office of Transportation and Air Quality, US EPA, November 2000

Table 29: Speed Correction Factors, HDGV and HDDV

Speed	HDGV			HDDV		
	VOC	CO	NOx	VOC	CO	NOx
4	3.938	3.603	0.846	2.202	3.260	1.751
8	3.139	2.879	0.868	1.935	2.661	1.574
12	2.527	2.332	0.890	1.710	2.197	1.428
16	2.056	1.916	0.912	1.519	1.835	1.306
20	1.691	1.595	0.934	1.357	1.550	1.206
24	1.405	1.346	0.956	1.219	1.324	1.123
28	1.179	1.152	0.978	1.101	1.144	1.055
32	1.000	1.000	1.000	1.000	1.000	1.000
36	0.857	0.880	1.022	0.913	0.884	0.956
40	0.742	0.785	1.044	0.839	0.790	0.923
44	0.649	0.710	1.066	0.774	0.715	0.898
48	0.574	0.651	1.088	0.719	0.654	0.882
52	0.513	0.605	1.110	0.671	0.605	0.875
56	0.463	0.570	1.132	0.630	0.566	0.874
60	0.422	0.544	1.154	0.595	0.536	0.882
64	0.389	0.527	1.176	0.564	0.513	0.898
68	0.362	0.518	1.198	0.539	0.496	0.922
72	0.341	0.516	1.220	0.517	0.486	0.955
76	0.324	0.520	1.242	0.499	0.482	0.998
77	0.311	0.533	1.264	0.484	0.482	1.052
80	0.302	0.553	1.286	0.472	0.489	1.120
84	0.296	0.581	1.308	0.463	0.501	1.202
88	0.294	0.620	1.330	0.457	0.519	1.301
92	0.294	0.670	1.352	0.453	0.544	1.422
96	0.298	0.735	1.374	0.452	0.577	1.567
100	0.304	0.817	1.396	0.453	0.619	1.743

Sources:

- Compilation of Air Pollutant Emission Factors, Volume II: Mobile Sources (AP-42), Appendix H, Office of Transportation and Air Quality, US EPA, November 2000

Table 30: Speed Correction Factor for CO2 Emissions, LDGV and LDGT

Speed	LDGV	LDGT
24	0.875	0.875
32	1.000	1.000
40	1.093	1.093
48	1.136	1.136
56	1.118	1.118
64	1.111	1.111
72	1.133	1.133
80	1.161	1.161
88	1.161	1.161
96	1.125	1.125
105	1.047	1.047
113	0.961	0.961
121	0.889	0.889

Sources:

- Calculated from speed and fuel efficiency estimates, Transportation Energy Data Book: Edition 20-2000, ORNL, U.S. Department of Energy

Finally, fuel efficiency parameters are used to convert emission factors expressed in tonne per litre, to factors expressed in tonne per kilometer.

Table 31: On-Road and Heavy Rail Fuel Efficiency

	LDGV	LDGT	HDDV	HDGV	LDDV	LDDT	Heavy Rail (*)
2000	0.099	0.133	0.399	0.200	0.100	0.130	5.45599
2010	0.091	0.129	0.386	0.200	0.100	0.130	5.18859
2020	0.083	0.122	0.370	0.200	0.100	0.130	4.69247

All parameters in litres per kilometer, except (*) in litres per 1000 net tonne-km

Source:

- On-Road: Estimated by Joycelyn Exeter, Analysis Modeling Division, Natural Resources Canada, July 2001.
- Heavy Rail: Locomotive Emissions, Monitoring Program 1998, Transportation Systems Branch, Air Pollution Prevention Directorate, Environment Canada, October 2000, page 8

Table 32: Emission Unit Costs

Description:
This variable describes the estimated average emission cost by pollutant (Unit Damage Values). The variable is expressed in Canadian dollars per metric ton of pollutant.

How the Variable Affects the Model:
The model uses the emission cost to estimate the net reduction in emission cost due to transit.

Assumptions:
1996 Dollars per Metric Tonne
Median Estimate
10% Lower Limit
10% Upper Limit

Year = 2005

VOC
$1,000
$500
$2,000

CO
$100
$50
$150

NOx
$1,000
$500
$5,000

SOx
$500
$250
$2,000

PM10
$1,000
$500

$5,000

CO2

$25

$10

$100

Sources:

See Section 3.2.2.3.2

Table 33: Population Growth

***Description**:* This variable is the total Canadian population count.

How the Variable Affects the Model: Population growth is used to adjust the dollar cost of emissions. A larger population implies that more people are being affected by each tonne of pollutant emitted, hence higher emission costs.

Assumptions:

Canadian Population

	Median Estimate	10% Lower Limit	10% Upper Limit
2001	31,002,000	N/A	N/A
2006	32,228,000	N/A	N/A
2011	33,361,000	N/A	N/A
2021	35,381,000	N/A	N/A

Sources:

Provided by ICF, from Statistics Canada, Population Forecast, http://www.statcan.ca/english/Pgdb/People/Population/demo23a.htm

4.3 Low-Income Mobility

The mobility-related benefits of transit arise in two distinct ways. The first 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 second 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.

As shown below, low-income mobility benefits vary greatly across transit investment types. In particular, the mobility benefits from a bus project, in areas or corridors where taxi is the "next best alternative" for low-income residents, can be significantly *larger* than the mobility benefits from a rail project where a well functioning bus system is already in place.

4.3.1 Affordable Mobility Benefits

The value of transit trip benefits can be estimated for transit systems based on national experience. In estimating the affordable mobility benefits of transit, we develop a model incorporating corridor trip characteristics by car, taxi, and bus. The forecast to be developed from these variables permits calculation of the value of consumer surplus for transit service. For the base case (absence of transit), we derive the number of low-income individuals (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.

4.3.1.1 Methodological Framework

Three important analytical tools are used to estimate low-cost mobility benefits: the generalized price, the transit demand curve and the consumer surplus.

4.3.1.1.1 Generalized Price

The generalized price is composed of cost elements reflecting the major contributors to the full cost of each transportation mode. The cost elements first thought of are the fare paid for public transportation, the taxi fare and the average cost per trip based on the annual expenditure on privately owned vehicles (POV) and parking.

The other relevant cost elements that make it a generalized price are the safety value and the time value. The time value is a function of the time spent by an individual who normally uses a certain mode to travel and the unit value of that time spent by that individual. The cost in terms of time of one mode over another will be lower for the faster mode, assuming time has value for that individual. As a consequence, all costs other than travel time being held constant, the choice of one mode over another will be for the faster trip.

4.3.1.1.2 Transit Demand Curve

The demand function serves as the basis on which the economic value of low-cost mobility is estimated. From this demand curve, the relationship between the generalized price and the number of passenger-trips can be evaluated. Once this relationship is established, total consumer surplus can be measured.

As transit fares rise and the money cost of travel increases in importance relative to the time and effort components of travel cost, the theory of generalized cost predicts that the market fare elasticity will rise accordingly. Simply stated, when fares are already "high," a one percent increase will precipitate a larger proportional effect on demand than a one percent increase when fares are "low."

$$\eta = \frac{dT}{df}\frac{f}{T} = a + bf \qquad \textit{Equation 1}$$

In words, the elasticity (denoted by the Greek letter *eta*) of trips (T) with respect to fare (f) is a function of fare.

There are strong empirical as well as theoretical foundations for the expectation that the marginal impact of fares on demand increases as fare levels rise. Research indicates that people from low-income households increase their use of transit when their incomes rise by a much larger amount (proportionally) than higher-income people. It is well known that the marginal utility of an extra dollar is much higher for the poor. One can take the evidence regarding income elasticity as empirical confirmation that low-income people are more responsive than high-income people to any transit-related change in their financial circumstances, including change induced by fare increases or reductions. The differential Equation 1 implies the general demand function:

$$\ln T = k + a \ln f - bf \qquad \textit{Equation 2}$$

A special case of which is:

$$lnT = k - bf \qquad \textit{Equation 3}$$

Equation 3 implies that fare elasticity is directly proportional (inversely) to fare level, that is, dT/df (f/T) = bf. Equation 2 is more general than Equation 3, indicating that fare elasticity may in fact be indirectly proportional to fare level and it is in this sense that Equation 3 is a special case of Equation 2. Since the empirical data available are too limited to test the more complex possibilities of Equation 2 the analysis here adopts the assumption of proportionality between fare elasticity and fare level given by Equation 3. Given the current demand for transit, the current fare level and the current fare elasticity, Equation 3 will give the estimated aggregate demand curve for transit.

4.3.1.1.3 Consumer Surplus

Economists call the difference between the amount people actually pay for something and the amount they would pay for the next most costly alternative, “consumer surplus.” Consumer surplus is a monetary quantity that equates to the economic value (EV) of the mobility afforded to people by the availability of a transit system. Formally, it can be expressed in the following way:

$$EV = (P^f_1 - P^f_0) * Q^f_1 + \tfrac{1}{2} [(P^f_1 - P^f_0) * (Q^f_0 - Q^f_1)] \qquad \text{Equation 4}$$

Where: P^f_0 is the expected fare to be paid by passengers;

Q^f_0 is the expected number of passenger-trips;

P^f_1 is the fare that passengers pay to use other travel modes (auto, taxi, etc.); and

Q^f_1 is the number of passenger-trips using other modes.

The level of demand for transit and the price difference between transit and other travel mode measure the consumer surplus, or low-cost mobility benefits of transit.

This is illustrated in Figure 10, below. The figure implies that, for the taxi example[10], if P1 is the initial price, (aP1) is a perfectly elastic supply of taxi services, and (bP2) is a perfectly elastic supply of transit services. With the opening of transit services, the price falls to P2, and the change in consumer surplus is *P1abP2*. However, the rectangle *P1acP2* is the change in revenue to the taxi industry, and so this component of value is just a transfer from the taxi industry to consumers. Assuming that displaced taxi employees will not be unemployed, but will be employed elsewhere with a value of marginal product as least as great as this rectangle (probably safe in today’s labor market), we can focus on area *abQ2Q1*, which is the change in low-income mobility benefits from the expansion of the transit services. Area *cbQ2Q1* is the increased cost to serve this group, and is accounted for elsewhere. Triangle *abc* is the change in consumer surplus to this group.

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[10] Thanks due to Dr. Haynes Goddard for this expression of the model.

Figure 10: Consumer Surplus Benefits of Transit Investments

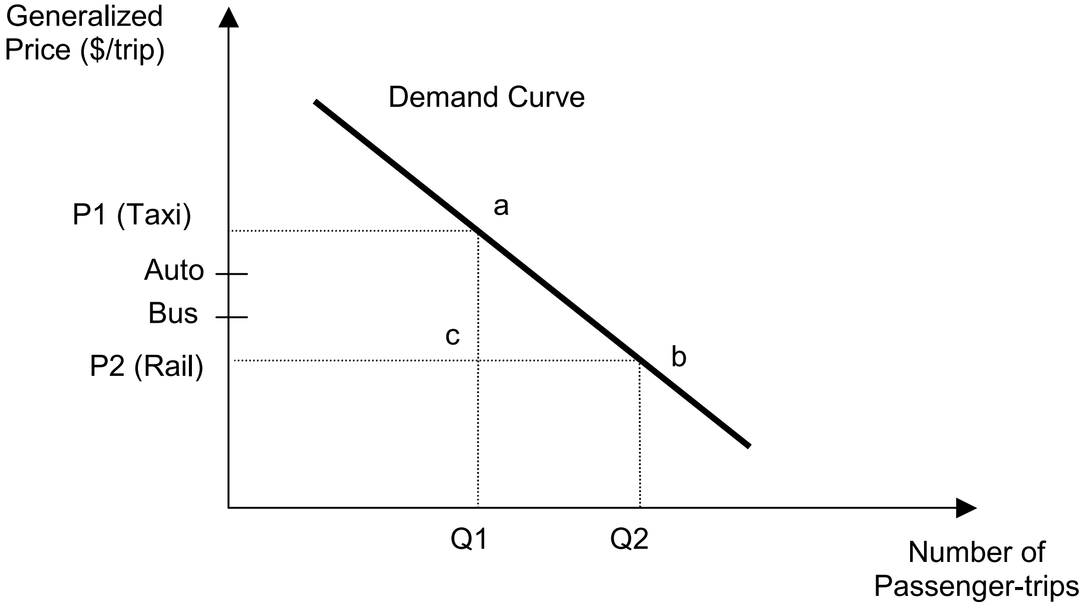
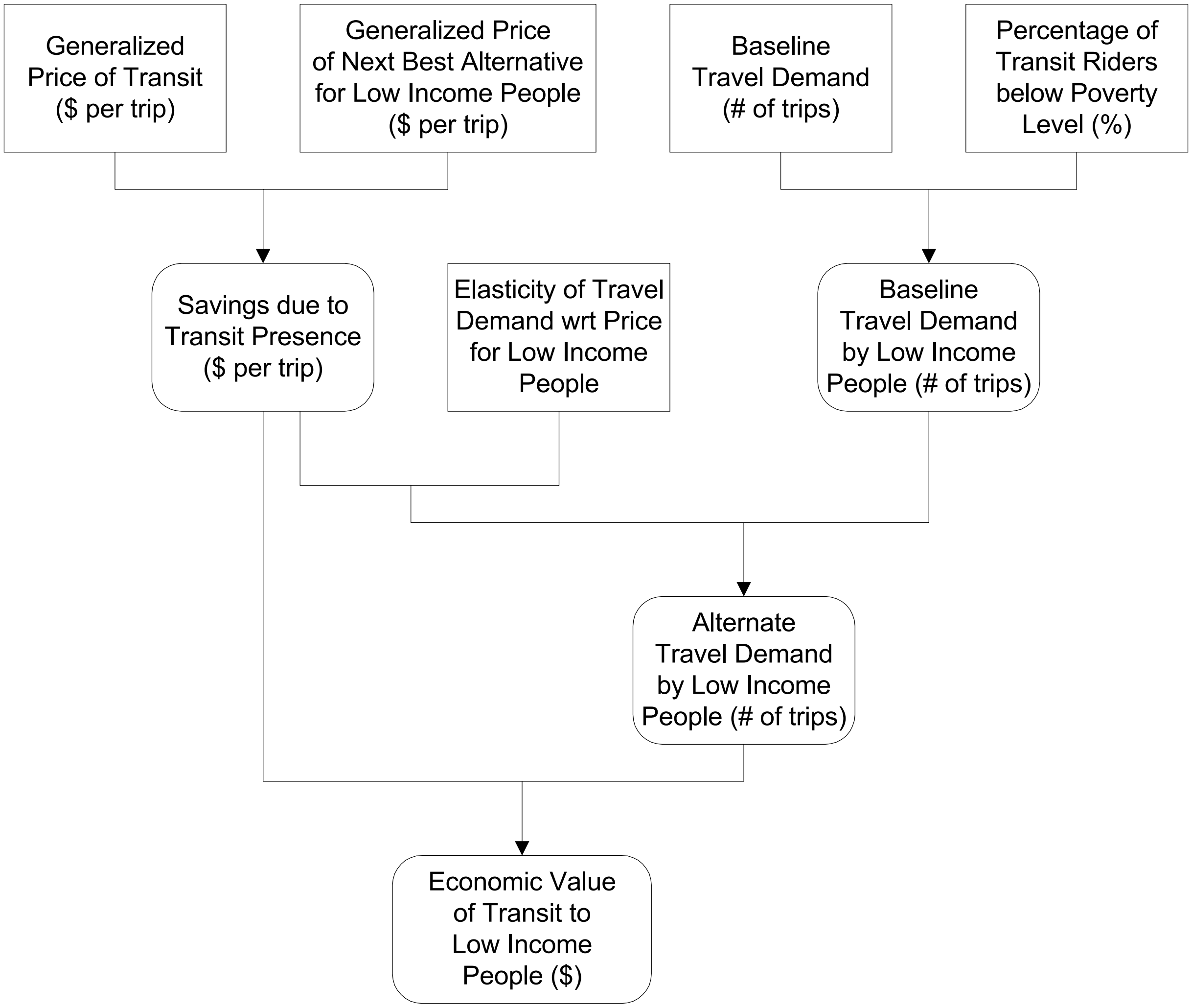


Figure 11 below presents a structure and logic diagram illustrating the methodology to derive the net economic value from affordable mobility.

Figure 11: Structure and Logic Diagram for Low-Income Mobility



4.3.1.2 Assumptions For Estimating Affordable Mobility Benefits

The assumptions necessary for estimating affordable mobility benefits are described below.

Table 34: Average Transit Fare

Description:
The average fare to be charged per trip. The variable is expressed in Year 2000 dollars.

How the Variable Affects the Model:
The model uses the average fare to estimate the saving in user cost due to transit for low-income travelers. A higher fare reduces the savings due to transit for these individuals.

Assumptions:

Variable	Median Estimate	10% Lower Limit	10% Upper Limit
Average bus fare ($)	$1.75	$1.60	$1.85
Average BRT fare ($)	$1.80	$1.65	$1.90
Average light rail fare ($)	$1.90	$1.80	$1.95
Average heavy rail fare ($)	$2.25	$2.15	$2.40
Average commuter rail fare ($)	$5.50	$5.00	$6.50

Sources:
Median fares are based on average regular fares in different cities including Toronto, Calgary, Ottawa, Edmonton, and Vancouver.

Table 35: Average Fare of Next Best Alternative

***Description**:*
The average fare to be charged per taxi trip. The variable is expressed in Year 2000 dollars

How the Variable Affects the Model:
The model uses the average taxi fare to estimate the saving in user cost due to transit for low-income travelers. A higher taxi fare increases the savings due to transit for these individuals.

Assumptions:
Variable
Median Estimate
10% Lower Limit
10% Upper Limit

Average taxi fare ($)
$8.00
$6.00
$12.00

Sources:
Median estimate, based on average trip of 8 Km in Ottawa, Toronto, and Vancouver.

Table 36: Percentage of Transit Riders Below Poverty Level

***Description**:*
The percentage of transit riders receiving an annual income inferior to the poverty level set by Statistics Canada (about $8,200 for a lone-mother family)

How the Variable Affects the Model:
The model uses this variable to estimate the size of the low-income population "benefiting" from the transit investment.

Assumptions:
Variable
Median Estimate
10% Lower Limit

	10% Upper Limit
Bus	
	50%
	40%
	75%
BRT	
	45%
	35%
	60%
Light Rail	
	30%
	25%
	50%
Heavy Rail	
	30%
	25%
	45%
Commuter Rail	
	35%
	30%
	55%

Sources:
HLB estimates

4.3.2 Cross-Sector Benefits

Studies[11] 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.[12] The FTA model of cross sector benefits used by HLB 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.

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[11] Hickling Lewis Brod. *"The Benefits of Modern Transit"* Prepared for the Federal Transit Administration, p 2-28

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

4.3.2.1 Methodological Framework

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 12 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.[13] 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. To calculate the cross-sector benefits due to the incremental effect of the transit system, benefits per trip are estimated by dividing the overall cross-sector benefits due to transit by the total number of trips. Then, the cross-sector benefits due to transit are calculated by multiplying this benefit-per-trip estimate by the number of new trips generated by the transit investment project.

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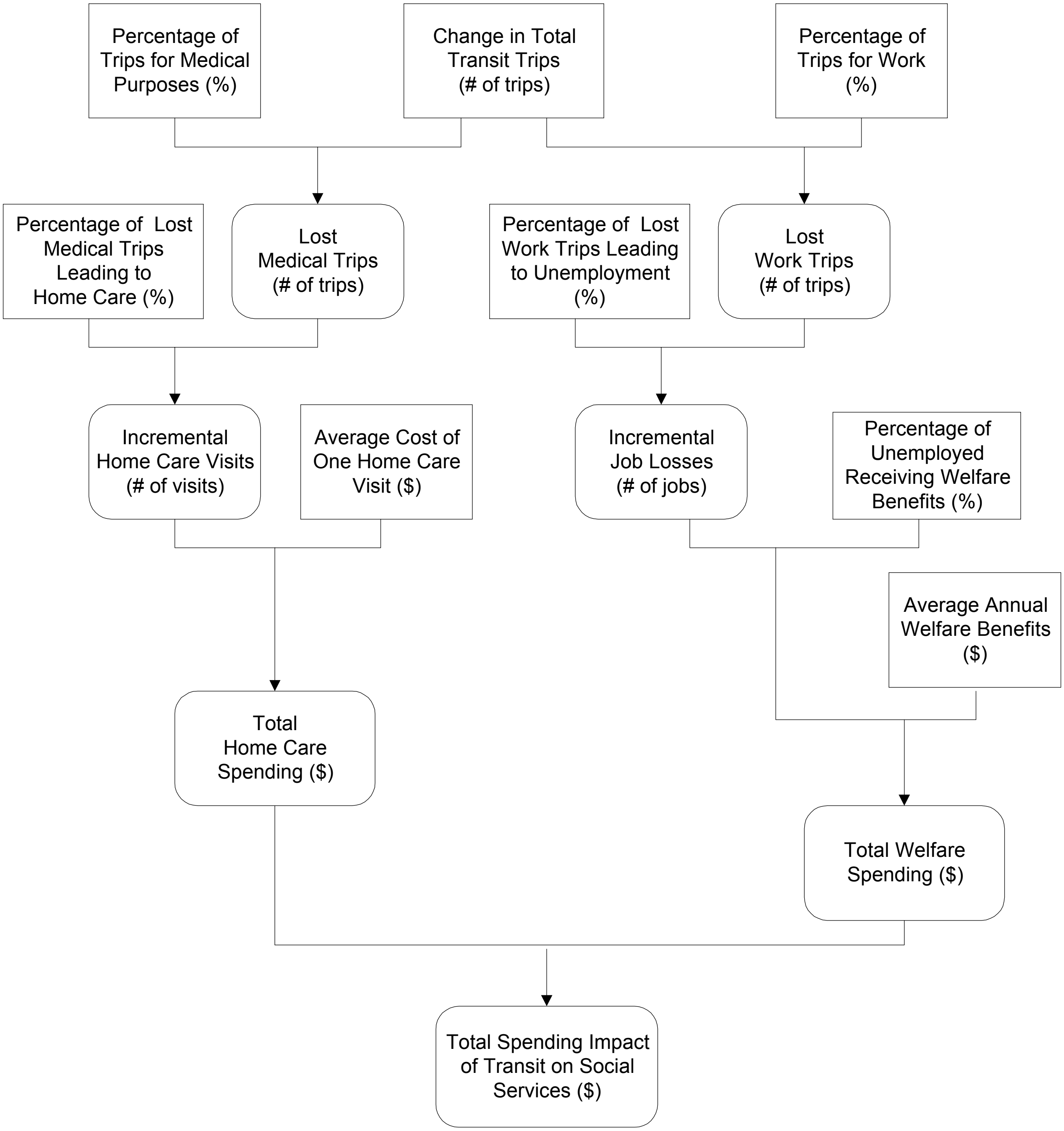
[13] In converting passenger trips into the number of medical visits, we account for the fact that ridership data report one-way trips. Dividing the total number of trips made for medical purposes by a factor of 2 gives the number of medical visits.

Figure 12: Structure and Logic Diagram for Cross Sector Benefits



4.3.2.2 Assumptions For Estimating Cross-Sector Benefits

The assumptions necessary for estimating cross-sector benefits are described below.

Table 37: Percentage of Trips for Medical Purposes

Description:
The percentage of trips for medical purposes as part of all transit trips. The variable is expressed in percent.

How the Variable Affects the Model:
Affects the potential for cross-sector savings.

Assumptions:

Variable	Median Estimate	10% Lower Limit	10% Upper Limit
Percentage of bus trips	10%	8%	15%
Percentage of BRT trips	10%	8%	20%
Percentage of light rail trips	15%	10%	25%
Percentage of heavy rail trips	18%	10%	25%
Percentage of commuter rail trips	18%	10%	25%

Sources:
HLB estimates from corridors studied as part of "The Benefits of Modern Transit" prepared for the FTA. Statistics provided by the Office of the Actuary, Health Care Financing Administration and the National Home and Hospice Care Survey.

Table 38: Percentage of Trips for Work Purposes

Description:
The percentage of trips for work purposes as part of all transit trips. The variable is expressed in percentages.

How the Variable Affects the Model:
Affects the potential for cross-sector savings.

Assumption:

Variable	Median Estimate	10% Lower Limit	10% Upper Limit
Percentage of bus trips	28%	20%	40%
Percentage of BRT trips	28%	20%	40%
Percentage of light rail trips	35%	25%	50%
Percentage of heavy rail trips	50%	35%	75%
Percentage of commuter rail trips	65%	50%	75%

Sources:
HLB estimates from corridors studied as part of “The Benefits of Modern Transit” prepared for the

FTA. Statistics provided by the Office of the Actuary, Health Care Financing Administration and the National Home and Hospice Care Survey.

Table 39: Percentage of Lost Medical Trips Resulting in Home Care

Description:
The percentage of lost medical trips resulting in home care. The variable is expressed in percentage.

How the Variable Affects the Model:
The model uses the percentage of lost medical trips resulting in home care to estimate the number of home care visits avoided by transit.

Assumptions:

Variable	Median Estimate	10% Lower Limit	10% Upper Limit
Percentage of lost medical trips resulting in home care (%)	10%	5%	15%

Sources:
HLB estimates from corridors studied as part of "The Benefits of Modern Transit" prepared for the FTA. Statistics provided by the Office of the Actuary, Health Care Financing Administration and the National Home and Hospice Care Survey.

Table 40: Cost of Home Care Visits

Description:
The cost of one home care visit. The variable is expressed in Year 2000 dollars.

How the Variable Affects the Model:
The model uses the cost of home care to estimate the total increase in homecare spending. A higher incremental cost means a higher cost for each additional homecare recipient, and therefore a greater increase in total spending.

Assumptions:

Variable	Median Estimate	10% Lower Limit	10% Upper Limit
Cost of one home care visit ($)	$50	$40	$70

Sources:
HLB estimates from corridors studied as part of "The Benefits of Modern Transit" prepared for the FTA. Statistics provided by the Office of the Actuary, Health Care Financing Administration and the National Home and Hospice Care Survey.

Table 41: Percentage of Lost Work Trips Leading to Unemployment

***Description*:**
The percentage of lost work trips due to the lack of access that leads to unemployment. The variable is expressed in percentage.

How the Variable Affects the Model:
The model uses the percent of lost work trips leading to unemployment to estimate the total number of jobs lost due to lack of access. A higher percentage means a greater number of jobs lost due to lack of access, i.e. more transit benefits.

Assumptions:
Variable
Median Estimate
10% Lower Limit
10% Upper Limit

Percentage of lost trips leading to unemployment (%)
30%
10%
45%

Sources:
HLB estimates from corridors studied as part of "The Benefits of Modern Transit" prepared for the FTA. Statistics provided by the Office of the Actuary, Health Care Financing Administration and the National Home and Hospice Care Survey.

Table 42: Welfare Cost per Recipient

***Description*:**
The average welfare cost per recipient. The variable is expressed in Year 2000 dollars.

How the Variable Affects the Model:
The model uses the welfare cost per recipient to estimate the total additional welfare program expenditures. A higher average cost per recipient leads to a higher total program expenditure.

Assumptions:

Variable	Median Estimate	10% Lower Limit	10% Upper Limit
Cost per recipient per year ($)	$856	$800	$1,050

Sources:
Average Monthly Benefit based on data from the Ministry of Community and Social Services.

4.4 Community Economic Development

4.4.1 Introduction

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.[14]

Recent case studies illustrating the impact of transit access on *residential* property value are summarized below. These case studies focus on rail technology but can be generalized to busways and conventional bus transit providing *comparable* services (in terms of accessibility, comfort, speed, and reliability).

- San Francisco: Within the study area (vicinity of the Pleasant Hill BART station, along the yellow line), single-family homeowners are willing to pay nearly $16 in home price for each foot closer to BART. The value of an average single family home in the Pleasant Hill Station Area is $22,800 greater (about 10 percent) due to its proximity to transit (HLB/FTA).

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

- New York City, Queens: Within the study areas (three NYMTA subway stations along the E, F, and R lines), home prices fall by about $23 for every foot away from the stations. Alternatively, the value of an average home within the station areas is about $37,000 greater than similar homes, without transit access (HLB/FTA).

- Philadelphia: A 1987 study by the Rice Center suggests a 7.0 percent premium (or $4,500 per house) along the Lindenwold, a 15-mile rail line, running to Philadelphia through the New Jersey suburbs.[15]

- Portland, Oregon: The analysis of three MAX light rail station areas revealed no benefits for properties located within a 2,500 feet radius of MAX. On the other hand, for properties between 2,500 and 5,280 feet to transit, prices increase by about $0.76 for every foot closer to a station (HLB/FTA).

- Washington DC: In the early nineties, the average price of a townhouse within 1,000 feet of a transit station was $12,300 higher than comparable units just few blocks away (Gatzlaff and Smith, 1993).

- Boston: A 1994 study undertaken by R.J. Armstrong examines the Fitchburg/Gardner Line in Boston to quantify the neighborhood value created by commuter rail station location, captured in single-family residential property values. He found that property values in proximity of existing rail stations experience a 6.7 percent premium compared to property without rail access.[16]

Case studies illustrating the impact of transit on *commercial* property value are summarized below.

- Atlanta: In 1989, rents at a major development located near a transit station were $3 to $5 higher per square foot than those at other office of comparable quality a block away (Cervero et al., 1994).[17]

- Los Angeles: Commercial property values near *planned* transit corridors appreciated faster than similar properties away from the corridors during the 1980's, when the transit system was being planned and developed: property values near transit appreciated by more than 78 percent, properties away from transit gained only 38 percent (Fejarang, 1994).[18]

- New York City: On average, commercial property values increase by $2.7 per square foot, for every *meter* closer to a transit station (Anas, 1993).

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[15] Rice Center, Joint Center for Urban Mobility Research, 1987. “Assessment of Changes in Property Values in Transit Areas.” Prepared for the Urban Mass Transit Administration.

[16] Armstrong, R.J., Jr. “Impacts of Commuter Rail Service as Reflected in Single-Family Residential Property Values.” Paper presented at the 73rd Annual Meeting of the Transportation Research Board, Washington DC (1994).

[17] Reported in TCRP Report 16, Transit and Urban Form

[18] Reported in TCRP Report 16, Transit and Urban Form

- Washington DC Area: In the district, interviews with real estate brokers and appraisers revealed that commercial land prices near transit stations increased by around 100 percent several years after services began and by as much as 400 percent in some locales (Damm et al., 1980; Rice Center, 1987). At transit stations, in Bethesda and Ballston, projects immediately adjacent to station entrances commanded a $2 to $4 per square foot rent premium, relative to similar projects just a few blocks away. In 1999, HLB estimated that, on average, downtown properties located 1,000 feet closer to a Metro Rail station enjoy a $2.3 per square foot - or 2.1 percent - premium.[19]

The impacts of busways and conventional bus transit have generally been *weaker* than those of rail systems. A number of case studies, such as Ottawa-Carleton and Curitiba (Brazil), however, suggest that bus systems providing service *comparable* to rail systems (in terms of accessibility, comfort, speed, and reliability) can influence the intensity of development, just as well.

- Ottawa-Carleton: Several suburban stations along the city's dedicated busway are surrounded by mid-rise apartments and offices. Interviews with developers suggest that the busway accelerated the *timing* of development.

- Curitiba: During the 1970's, city planners encouraged urban growth along five "structural" axes using various zoning tools and other land-use incentives. As part of the plan, restricted bus lanes were created along each axis. The plan fostered significant commercial development and high-density residential development in the vicinity of the transit stops. Today, the city has over thirty miles of exclusive bus lanes; the system averages 1.2 million passengers per day, or around 430 transit trips per capita annually, one of the highest rate in the world.[20]

4.4.2 Methodological Framework

A model based on the research approach outlined above has been developed by HLB. The model combines data collected from real estate transactions, socio-economic data, and Geographical Information System (G.I.S.) data for a representative sample of residential and commercial properties located within the area of study. Again, the hypothesis of this research is that transit improves the livability of transit-oriented neighborhoods, 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 neighborhood benefit apart from transit use.

The property attribute that must be measured in a transit access study is the actual walking distance to the transit station, holding all other property attributes constant. The typical solution to generating data on walking distance to transit is to use point-to-point, straight-line distance from each property parcel to the transit station. This is never an exact estimate of walking distance because streets do not always lead directly from one point to another: some streets curve, meander, or dead-end while other streets are cul-de-sacs. Studies that use geographical distance to approximate walking distance to transit miss some significant variations between

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[19] HLB Decision Economics Inc. and KPMG Peat Marwick, LLP, “Commercial Property Benefits of Transit.” Prepared for the Federal Transit Administration, February 1999.

[20] Reported in TCRP Research Results Digest, June 1995, Number 7, pages 14 and 15.

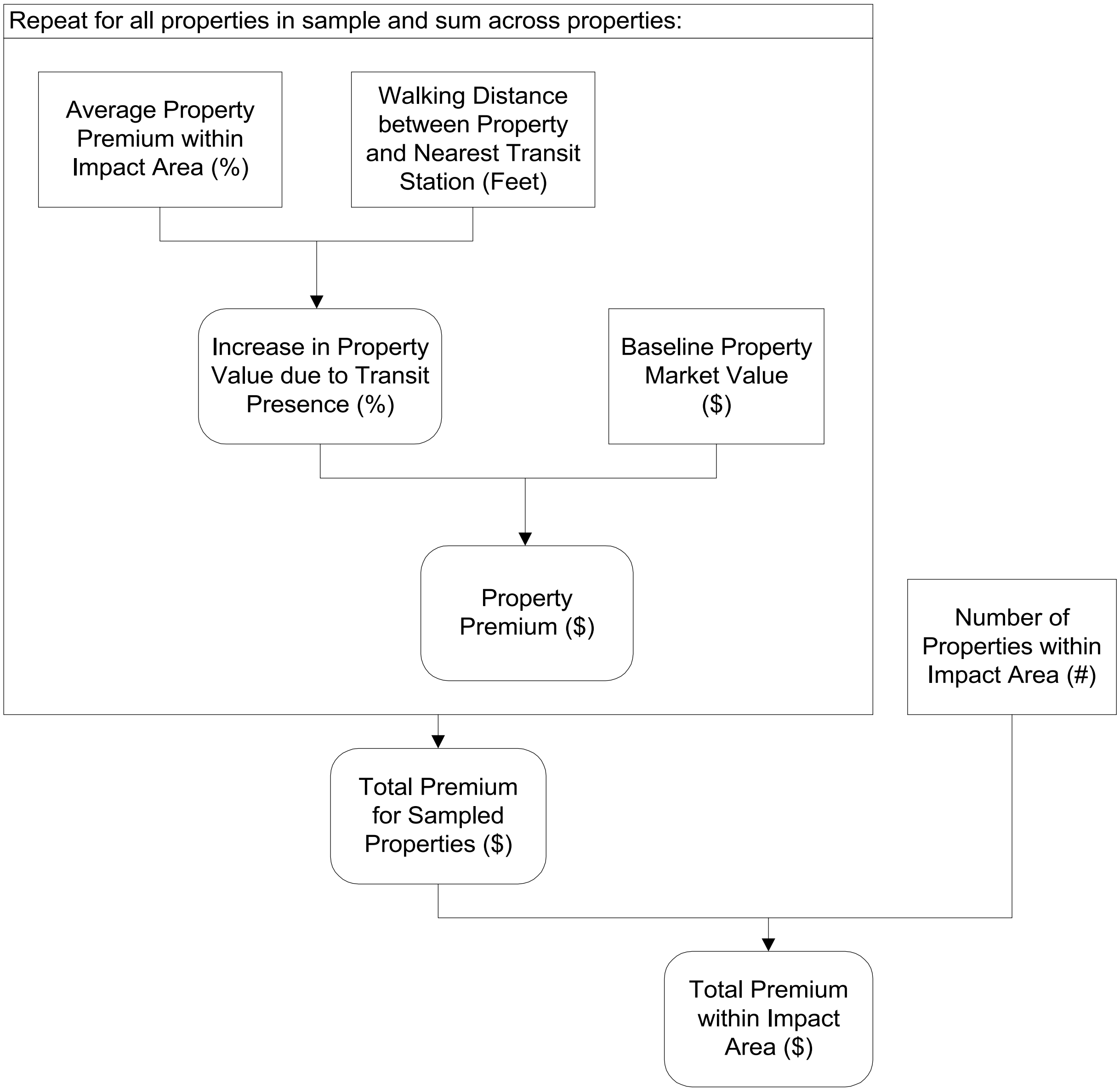
properties. The use of a G.I.S. is a major innovation over the typical straight-line methodology applied to transit station areas, both in accuracy and in cost. The G.I.S. contains detailed information regarding the street grid in a given area and specifies each property parcel within the area in question. By calculating the shortest street distance from each parcel to the transit station, detailed data regarding the true variable of interest, walking distance to transit, is accurately specified.

Advanced statistical techniques are applied to the real estate, G.I.S. and socio-economic data to estimate the impact of transit access on property values. These techniques allow isolating the effect of transit proximity from other property attributes, on observed differences in property values. The estimated impact is expressed as a dollar value increment in property value per foot of proximity to transit. Alternatively, it is sometimes expressed as a percentage increase in property value per foot of proximity to transit.

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, HLB uses findings from other cities or corridors to derive the *likely* impact of transit on residential and commercial development. 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 13 below illustrates the methodology developed by HLB.

Figure 13: Structure and Logic Diagrams for Economic Development Benefits



The assumptions necessary for estimating community economic development benefits are described below.

Table 43: Impact Area for Residential and Commercial Development

***Description**:*
This variable describes the size of the area within which residential and commercial property values will be impacted by transit, that is, over which transit-oriented development benefits will be generated (kilometer radius from a transit station).

How the Variable Affects the Model:
The model uses the area of impact to estimate the residential and commercial development benefits of transit. A large area of impact leads to large benefits.

Assumptions:
Area of Impact (kilometer radius)
Median Estimate
10% Lower Limit
10% Upper Limit

Bus
0.0
0.0
0.0

BRT
0.4
0.3
0.6

Light Rail
0.4
0.3
0.8

Heavy Rail
0.8
0.4
1.6

Commuter Rail
1.6
0.8
2.4

Sources:
Based on literature survey of transit impact area, for example, Cervero, Robert, "Light Rail Transit and Urban Development." Journal of the American Planning Association, Spring 1984.

Table 44: Number of Residential Properties within Impact Area

Description:
This variable describes the actual number of residential properties, including apartments and single-family homes, located within the impact area.

How the Variable Affects the Model:
The model uses the number of residential properties to estimate the total residential development benefits of transit. A large number of residential properties leads to large development benefits.

Assumptions:
Variable
Median Estimate
10% Lower Limit
10% Upper Limit

Number of Residential Properties (#)
N/A
N/A
N/A

Sources:
Station/Corridor Specific

Table 45: Number of Commercial Properties within Impact Area

Description:
This variable describes the actual number of commercial properties, including shops, offices, and restaurants, located within the impact area.

How the Variable Affects the Model:
The model uses the number of commercial properties to estimate the total commercial development benefits of transit. A large number of residential properties leads to large development benefits.

Assumptions:
Variable
Median Estimate
10% Lower Limit
10% Upper Limit

Number of Commercial Properties (#)
N/A
N/A

N/A

Sources:
Station/Corridor Specific

Table 46: Residential Property Premium

***Description**:*
This variable describes the average percentage increase in residential property value due to the presence of transit.

How the Variable Affects the Model:
The model uses the percentage increase in residential property value due to transit based on findings from other research to estimate the potential residential development benefits in the study area.

Assumptions:

Variable	Median Estimate	10% Lower Limit	10% Upper Limit
Residential Property Premium (%)	2.75%	1.00%	7.00%

Sources:
Estimate based on literature review of transit impact, such as Voith, R. "Changing Capitalization of CBD-Oriented Transportation Systems: Evidence from Philadelphia, 1970-1988." Journal of Urban Economics, Vol. 33 (1993)

Table 47: Commercial Property Premium

***Description**:*
This variable describes the average percentage increase in commercial property value due to the presence of transit. This variable is expressed in percentages.

How the Variable Affects the Model:
The model uses percentage increases of commercial property due to transit based on findings from other research to estimate the potential residential development benefits in the study area due to transit.

Assumption:

Variable	Median Estimate	10% Lower Limit	10% Upper Limit

Commercial Property Premium (%)

4.0%
2.0%
8.0%

Sources:
Estimate based on literature review of transit impact, such as "Commercial Transit Benefit", HLB Decision Economics Inc, prepared for the Federal Transit Administration, 1999, found a premium of 4% due transit in Washington DC.

4.4.3 The Risk of Double-Counting Community Economic Development Benefits and Congestion Management Benefits

As explained in the introduction to this section, the commercial and residential property value impacts reflect a wide array of benefits from transit access. Some of the premium paid for proximity to transit compensates, in particular, for reduced auto-related costs, including travel-time savings. Therefore, there is a risk of double counting these savings when adding up the community benefits derived from the study of property values with the congestion management time savings derived from implementing the convergence theory. Previous studies indicate, however, that most of the increase in property value due to transit arises independently of the volume of transit ridership. The economic value of transit in communities appears to be more a reflection of amenity and diversity value than the value of access to one's main mode of travel per se. The risk of double counting in is thus considered small.

4.5 Transit Costs

Project costs should be broken down into as many components as possible to improve accuracy and transparency. HLB recommends the use of eight capital cost components for large capital investment projects:

- Guideway costs;
- Station costs;
- System costs;
- Special condition costs;
- Right-of-way costs;
- Yards and shops costs;
- Vehicle costs;
- Add-on costs;

- Costs caused by construction delays; and
- Incremental operating and maintenance costs.

To account for the uncertainty surrounding the estimation of these costs, a probability distribution should be determined for each of them. These distributions can be thought of as a listing of all possible cost outcomes together with the probability that these outcomes materialize. The distributions are defined with three values or parameters: the median estimate, the 10% upper limit and the 10% lower limit.

Table 48: Guideway Costs

Description: The guideway is defined to encompass all of the civil elements directly associated with the construction of the proposed alignment. Examples of guideway elements include retaining walls, tunnels, structures, grading, drainage, sub-grade, ballast, track work, pavement, curb and gutter, traffic barriers, fences, lighting, and landscaping.
Assumptions: Variable Median Estimate 10% Lower Limit 10% Upper Limit Guideway Costs ($ 000) N/A N/A N/A ***Sources:***

Table 49: Station Costs

***Description**:*

Station costs are estimated using typical transit station designs and unit costs. For each proposed station location, an appropriate typical station design is selected, and the corresponding unit cost is applied. The typical station costs include platforms, shelters, mezzanines, stairways, elevators, and other furnishings. Additional cost elements are estimated for each proposed station individually, including site preparation, driveways, bus loading areas, parking lots, and storm water retention.

Assumptions:

Variable

Median Estimate
10% Lower Limit
10% Upper Limit

Stations Cost ($ 000)

N/A
N/A
N/A

Sources:

Table 50: System Costs

Description:
System costs include traction electrification, train control signaling, communications, and fare collection.

Assumptions:

Variable	
	Median Estimate 10% Lower Limit 10% Upper Limit
Systems Cost ($ 000)	
	N/A N/A N/A

Sources:

Table 51: Special Conditions Costs

Description:
Special conditions costs include construction activity that is not accounted for in the guideway component, including roadway restoration, non-guideway structures, traffic signals, grade crossings, and traffic controls.

Assumptions:

Variable	
	Median Estimate 10% Lower Limit 10% Upper Limit
Special Conditions Cost ($ 000)	
	N/A N/A N/A

Sources:

Table 52: Right-of-Way Costs

Description:
This component includes all of the costs associated with right-of-way acquisition and relocation of existing land uses.

Assumptions:

Variable	
	Median Estimate 10% Lower Limit 10% Upper Limit
Right-of-Way Cost ($ 000)	N/A N/A N/A

Sources:

Table 53: Yards and Shops Cost

Description:
This cost component includes all of the costs associated with any necessary centralized facilities.

Assumptions:

Variable	
	Median Estimate 10% Lower Limit 10% Upper Limit
Yards and Shops Cost ($ 000)	N/A N/A N/A

Sources:

Table 54: Vehicle Costs

***Description**:*
Vehicle costs are estimated using fleet sizes indicated in the proposed operating plan, plus a spare ratio. Unit cost estimates can be based upon experience in other systems with similar characteristics.

Assumptions:

Variable	Median Estimate	10% Lower Limit	10% Upper Limit
Vehicle Costs ($ 000)	N/A	N/A	N/A

Sources:

Table 55: Add-On (Soft) Costs

***Description**:*
Add-on costs are non-construction costs that can be anticipated during the construction process. These include engineering, construction management, project management, project administration, insurance, and start-up.

Assumptions:

Variable	Median Estimate	10% Lower Limit	10% Upper Limit
Add-On Costs ($ 000)	N/A	N/A	N/A

Sources:

Table 56: Incremental Operating and Maintenance Costs

Description:
Operating and maintenance costs are the average annual *incremental* costs associated with the proposed transit investment project or system.

Assumptions:

Variable	Median Estimate	10% Lower Limit	10% Upper Limit
Annual O&M Costs ($ 000)	N/A	N/A	N/A

Source:

4.6 Evaluation of Highway Investment Projects

4.6.1 Methodological Framework

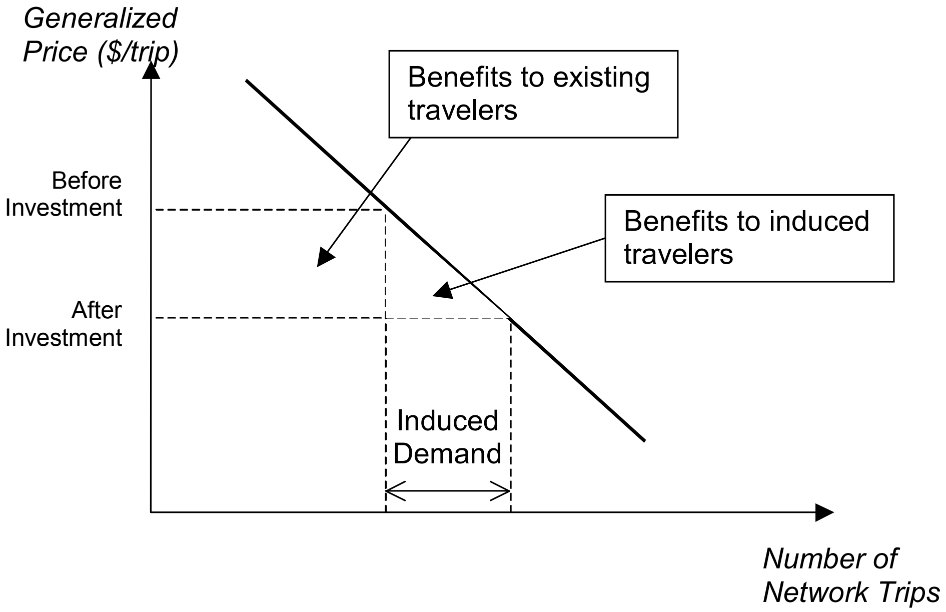
The proposed methodology for highway investment evaluation and comparison is based on StratBENCOST, a decision-support computer model for highway planning and budgeting, developed by HLB for the U.S. National Cooperative Highway Research Program. StratBENCOST has two important characteristics:

- User-Costs: highway investments are evaluated through the estimation of highway user costs in a baseline (no-investment) case and an alternate (with investment) case. The user costs considered in the model include travel time, accident costs, vehicle operating costs and emission costs;

- Induced Demand: the model accounts explicitly for induced demand, the change in traffic volume associated with changes in travel behavior triggered by the investment itself.

The methodology for measuring the economic benefits of highway improvements is illustrated in the figure below. The figure shows that when the highway is improved (through the addition of a lane, for example), the generalized price of using the highway decreases because of speed improvements. The figure shows that as a result of the decrease in generalized price, the number of trips increase, mainly due to the induced demand.

Figure 14: Methodology for Measuring the Benefits of Highway Investments



4.6.2 Highway Investment Types

The StratBENCOST default database allows for the evaluation and comparison of a number of highway investment projects, listed as " Types of Work" in Table 57, on the next page.

Table 57: StratBENCOST Types of Work

Project Type	Project Description
Resurfacing/Rehabilitation vs. Complete Reconstruction	Comparison of two surface improvement options yielding the same or a new facility configuration.
New Location vs. Upgrade	Comparison of costs involved with relocating a facility versus adding lanes to a existing facility
Freeway vs. Expressway	Comparison between upgrading a road to a freeway standard or an expressway standard.
Asphalt vs. Concrete	Comparison between resurfacing with asphalt versus concrete.
Expedient Resurface vs. Full Resurface	Comparison between an expedient (thin) resurfacing versus a full depth resurfacing.
Rural Facility Widening	Comparison between adding capacity (new lanes) to a minor rural facility versus no configuration change.
Bridge Rehabilitation vs. Replacement	Comparison between rehabilitating and repairing a bridge versus replacing a bridge.
Lane Addition	Comparison between adding a lane to any facility type versus no configuration change.
Facility Upgrade	Comparison between a major upgrade of any facility (i.e., adding a divider to an undivided arterial) versus no upgrade.
Pavement Resurfacing/ Preservation Strategy	Comparison between resurfacing and rehabilitation on any facility type.
Increased Capacity	Comparison between increasing capacity through new technologies such as, improved signage, signaling and/or ITS technologies versus no improvements.
Network Analysis	Comparison between two alternative investment options in a dense urban setting, taking into account the effects the improvements will have on travel patterns across the entire network.
Combination Project	Combination of several types of projects into a single comprehensive project.

4.6.3 Highway Investment Benefits

The StratBENCOST model estimates a number of user and agency benefits, including:

- Travel Time Savings;
- Accident Cost Savings;
- Vehicle Operating Cost Savings;
- Emission Cost Savings; and
- Highway Maintenance Cost Savings.

4.6.4 Highway Investment Life Cycle Costs

Highway investment costs are estimated over the entire economic life of the project; they include:

- Right-of-Way Costs;
- Construction Costs;
- Maintenance Costs;
- Other Life-Cycle Costs (other costs associated with maintaining and running a roadway, i.e., bridge replacement); and
- Other Costs (performance bond costs, legal fees not related to right-of-way acquisition, engineering costs, etc.).

4.7 Net Benefits and Rate of Return

This section explains how benefit and cost estimates introduced earlier in the report are combined together to arrive at standard indicators borrowed from the Social Cost-Benefit Analysis framework, and to draw conclusions about the relative economic merits of the investments under review.

4.7.1 Definitions

4.7.1.1 Project Worth

Project worth is assessed with the Net Present Value: 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, affordable mobility benefits and community development benefits) *minus* total costs in that year. The streams of costs and benefits are discounted with an annual real discount rate, typically ranging from 4.0% to 7.0% (see Table 58 below).

4.7.1.2 Project Risk

The risk analysis framework to be used in the study (see Section 3.8 for details) indicates how likely it is that the project under review will fall beneath a predetermined hurdle rate of return, given the uncertainty associated with relevant input variables. It also allows for an explicit comparison of the level of risk between two projects.

4.7.1.3 Project Timing

A project that shows strong returns over its economic life but fails to begin delivering reasonable annual returns until late in the life cycle should usually be delayed. A common rule of thumb in the private sector is that a major capital investment may be considered “well timed” (that is, neither premature nor overdue) if it begins to earn at least the hurdle rate of return (typically 4 percent) in its first full year of operation.

4.7.2 Additional Assumptions for Present Valuation and Rate of Return Estimation

Table 58: Real Discount Rate

Description:
The interest rate that can be gained from a risk free investment (opportunity cost). The variable is expressed in percentages.

How the Variable Affects the Model:
The model uses the discount rate to estimate the net present value of expected yearly benefits and costs. Therefore, selecting a low discount rate, other things being equal, will raise the present value of future benefits.

Assumptions:

Variable	Median Estimate	10% Lower Limit	10% Upper Limit
Discount Rate (%)	6.00%	4.00%	8.00%

Sources:
Estimate based on the “1998 Discount Rates for the Office of Management and Budget, OMB” Circular No.-94, White House, Washington DC 1998.

1977 AASHTO Manual: recommends 4% to 5%, based on the real cost of capital for low risk investments.

NCHRP Report 133: recommends 6% to 10%, based on the opportunity cost of capital for transportation projects of average risk.

Range Used by U.S. Department of Transportation: between 5% and 7%.

Table 59: Consumer Price Inflation

Description:
This variable describes the average annual growth of the consumer price index, CPI. The variable is expressed in percentage.

How the Variable Affects the Model:
The average annual CPI growth is used to adjust base year travel costs and project costs for future expected inflation.

Assumptions:

Variable	Median Estimate 10% Lower Limit 10% Upper Limit
Consumer Price Inflation 2000-2010, %	1.60% 1.00% 3.00%
Consumer Price Inflation 2010-2020, %	1.50% 1.00% 2.50%
Consumer Price Inflation 2020 and After, %	1.50% 1.00% 2.50%

Sources:
Based on historical data from CANSIM2, Statistics Canada.

4.8 What is Risk Analysis?

The result of a Risk Analysis is a forecast of future events and the probability, or odds, of their occurrence. Not unlike modern weather forecasting, in which the likelihood of rain is projected with a statement of probability ("there is a 20 percent chance of rain tomorrow"), Risk Analysis is intended to provide the client with a sense of perspective on the likelihood of future events. Risk Analysis is an easily understandable, but technically robust method that allows planners and decision-makers to select the level of risk within which they are willing to plan and make commitments.

4.8.1 Forecasting and the Analysis of Risk

The further into the future projections are made, the more uncertainty there is and the greater the risk is of producing forecasts that deviate from actual outcomes. Projections need to be made with a range of input values to allow for this uncertainty and for the probability that alternative economic, demographic, and technological conditions may prevail. The difficulty lies in choosing which combinations of input values to use in computing forecasts, and how to use those forecasts to produce a final estimate.

Forecasts traditionally take one of two forms: first, a single "expected outcome", or second, one in which the expected outcome is supplemented by alternative scenarios, often termed "high" and "low" cases. Both approaches fail to provide adequate perspective with regard to probable versus improbable outcomes.

The limitation of a forecast with a single expected outcome is clear – while it may provide the single best guess, it offers no information about the range of probable outcomes. The problem becomes acute when uncertainty surrounding the underlying assumptions of the forecast is especially high.

The high case-low case approach can actually exacerbate this problem because it gives no indication of how likely it is that the high and low cases will actually materialize. Indeed, the high case usually assumes that most underlying assumptions deviate in the same direction from their expected value; and likewise for the low case. In reality, the likelihood that all underlying factors shift in the same direction simultaneously is just as remote as everything turning out as expected.

A common approach to providing added perspective on reality is through "sensitivity analysis", whereby key forecast assumptions are varied, one at a time, in order to assess their relative impact on the expected outcome. A problem here is that the assumptions are often varied by arbitrary amounts. But a more serious flaw in this approach is that in the real world, assumptions do not veer from actual outcomes one at a time; it is the impact of simultaneous differences between assumptions and actual outcomes that would provide true perspective on a forecast.

The result of a risk analysis is both a forecast and a quantification of the probability that the forecast will be achieved.

Risk Analysis provides a way around the problems outlined above. It helps avoid the lack of perspective in "high" and "low" cases by measuring the probability or "odds" that an outcome will actually materialize. This is accomplished by attaching ranges (*probability distributions*) to the forecasts of each input variable. The approach allows all inputs to be varied simultaneously within their distributions, thus avoiding the problems inherent in conventional sensitivity analysis. The approach also recognizes interrelationships between variables and their associated probability distributions.

4.8.2 Application of the Risk Analysis Process to Project Evaluation

The Risk Analysis Process, as applied to project evaluation, involves four steps:

> Step 1. Adaptation of the steps evaluation and procedures into the Risk Analysis framework;
>
> Step 2. Assignment of estimates and ranges (probability distributions) to each variable and assumption in the forecasting process;
>
> Step 3. Expert evaluation, including revision of estimates and ranges developed in Step 2; and
>
> Step 4. Risk Analysis.

Step 1: Structure and Logic Models

A Structure-and-Logic Model depicts the methodology non-mathematically, indicating how all variables and assumptions combine to yield a forecast. The models provide detailed documentation of how the methodologies are characterized for risk analysis. They also provide a clear and uncomplicated means of the steps and procedures categories to outside experts, stakeholders and others in an expert panel session. The use of Structure-and-Logic Diagrams allows all stakeholders, regardless of their familiarity with mathematical modeling techniques, to understand and critique the models. Once the structure-and-logic of the model is properly represented, it is programmed into the Risk Analysis software.

Step 2: Central Estimates and Probability Distributions

Each variable is assigned a central estimate and a range (a probability distribution) to represent the degree of uncertainty.

Special data sheets are used (see Table 61 below) to record the estimates. In this case, the first column provides space for an initial median estimate, and the second and third columns define a range, which represents "an 80 percent confidence interval" – the range within which we can be 80 percent confident of finding the actual outcome. Thus the greater the uncertainty associated with a forecast variable, the wider the range will be (and vice versa). This process ensures that all risks are properly reflected in the forecasting process and that all stakeholders' views are reflected in the probability ranges.

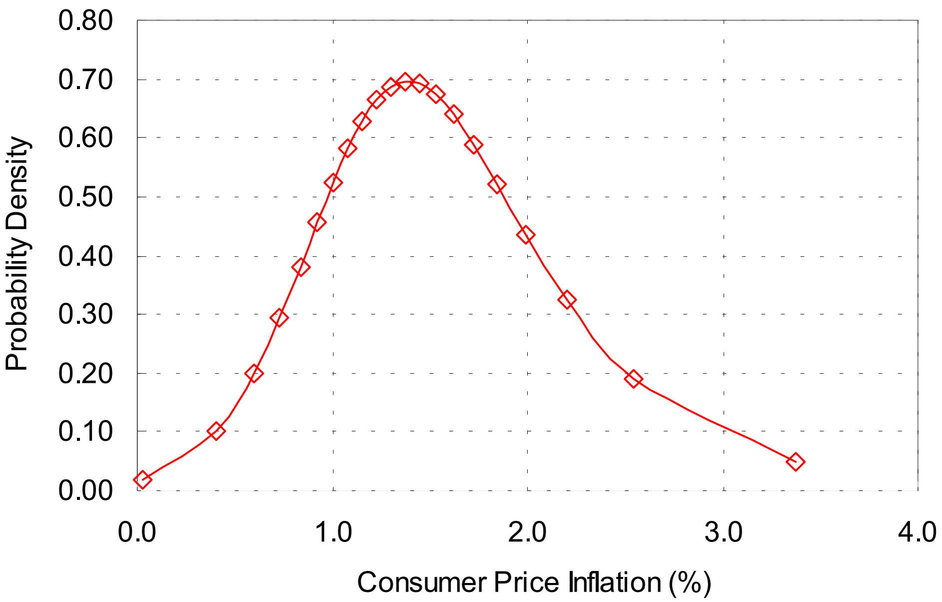
Table 60: Data Sheet Example

Variable	Median Estimate	10% Lower Limit	10% Upper Limit
Consumer Price Inflation 2000-2010, %	1.60%	1.00%	2.50%

Probability ranges for the variable in-question are established on the basis of both statistical analysis and subjective probability. Ranges need not be normal or symmetrical – that is, there is no need to assume the bell shaped normal probability curve. The bell curve assumes an equal likelihood of being too low and being too high in forecasting a particular value. It might well be, for example, that if projected inflation rates deviate from expectations, they are more likely to be higher rather than lower. The RAP process places no restrictions on the degree of "skew" in the specified ranges and thus maximizes the extent to which the Risk Analysis reflects reality.

Although the computer program will transform all ranges into formal "probability density functions", they do not have to be determined or presented in either mathematical or graphical form. All that is required is the entry of upper and lower limits of an 80 percent confidence interval in the Data Sheets. The RAP software will then use numerical analysis to translate these entries into a uniquely defined statistical probability distribution automatically. This liberates the non-statistician from the need to appreciate the abstract statistical depiction of probability and thus enables administrators, stakeholders and decision-makers to understand and participate in the process whether or not they possess statistical training.

Figure 15: Example of Risk Analysis Input Distribution



Step 3: Expert Evaluation and Consensus Building

Facilitated by the HLB team, a Risk Analysis Process session is conducted as a structured workshop that incorporates the views of various stakeholders. Participants receive a briefing book and during the session they review the model (via the Structure-and-Logic Models) and review each Data Sheet. This approach facilitates consensus building in the underlying assumptions and associated probabilities. During the panel session, each variable is discussed in-turn. Participants are asked to record their views on the median forecast – either quantitatively, qualitatively or both – in the accompanying Risk Analysis Workbook.

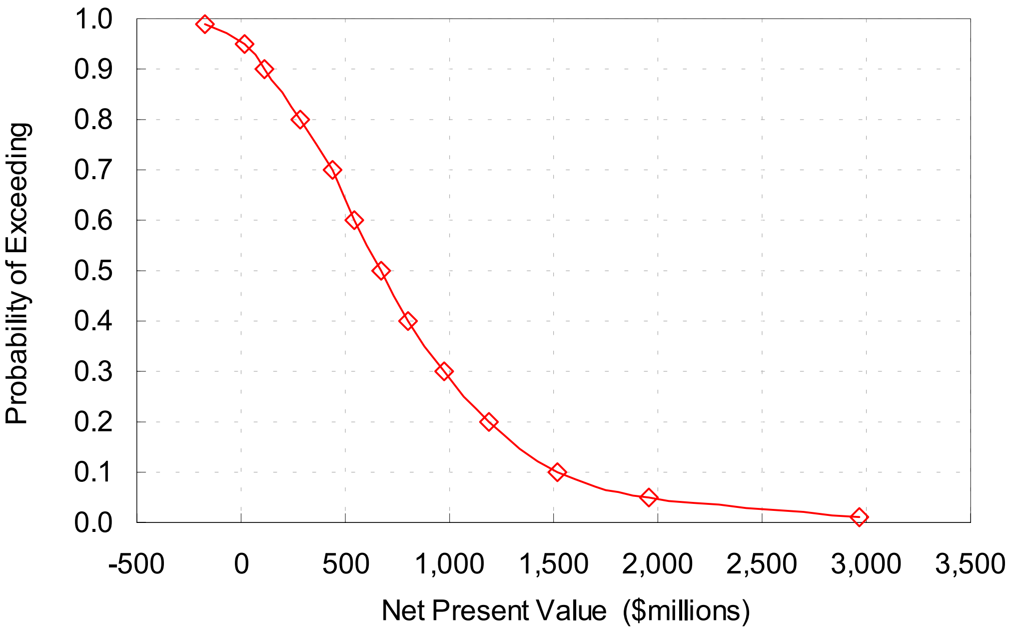
Where necessary, changes are made, often consisting of adding variables to the models in order to ensure that they reflect all the factors affecting the outcome. The purpose is to ensure that prior to the transformation of the Structure and Logic models into RAP forecasting software, the models truly reflect the reality and that the collective vision of the relevant stakeholders is reflected in the modeling and risk analysis results.

Step 4: Risk Analysis

Once the data sheets are finalized, the RAP software transforms ranges given in the data sheets into statistical probability distributions. These distributions are combined using simulation techniques that allow all variables to vary simultaneously from their expected values.

The result is *the expected net present value of the investment* together with estimates of the probability of obtaining different figures given the uncertainty in the underlying assumptions.

Figure 16: Example of Risk Analysis Output Distribution



4.9 Software Overview and Brief User Guide

This section provides an overview of the computer program to be used in the evaluation of transit and highway investment projects. The overall structure of the program is presented in Section 3.9.1 while Sections 3.9.2 through 3.9.6 provide instructions as to how to use each component of the software.

4.9.1 Software Overview

The software includes four distinct models or algorithms:

- Model 1: New Transit Systems, Grade Separated Systems;
- Model 2: New Transit Systems, Transit in Mixed Traffic;
- Model 3: Transit Modernization, Maintenance and Repair; and
- Model 4: Highway Investments (Single Segment Analysis), based upon the StratBENCOST model customized for Canadian conditions.

The software also allows for a total of twenty (20) scenarios per model. These scenarios are used to store values and assumptions for specific investment types within the broader model categories. For example, a highway capacity investment would be evaluated with the scenario "Increased Capacity" of Model 4, the highway investment model. The replacement of a bus fleet would be evaluated with the scenario "Fleet Replacement" of Model 3, Transit Modernization, Maintenance and Repair. Scenarios can also be used to store values and assumptions for specific regions, cities or corridors; a "Fleet Replacement - Toronto" could be created, for example.

Table 61: List of Models and Pre-Specified Scenarios

Model	Scenario	Description/Comments
New Transit Systems, Grade Separated	1. BRT	Investment in new busway system/capacity
	2. Light Rail	Investment in LRT system/capacity
	3. Heavy Rail	Investment in heavy rail system/capacity
	4. Commuter Rail	Investment in commuter rail system/capacity
New Transit Systems, In Mixed Traffic	1. Bus	Investment in new busway system/capacity
	2. Light Rail / Tramway	Investment in LRT / tramway system/capacity

Table 62 Continued

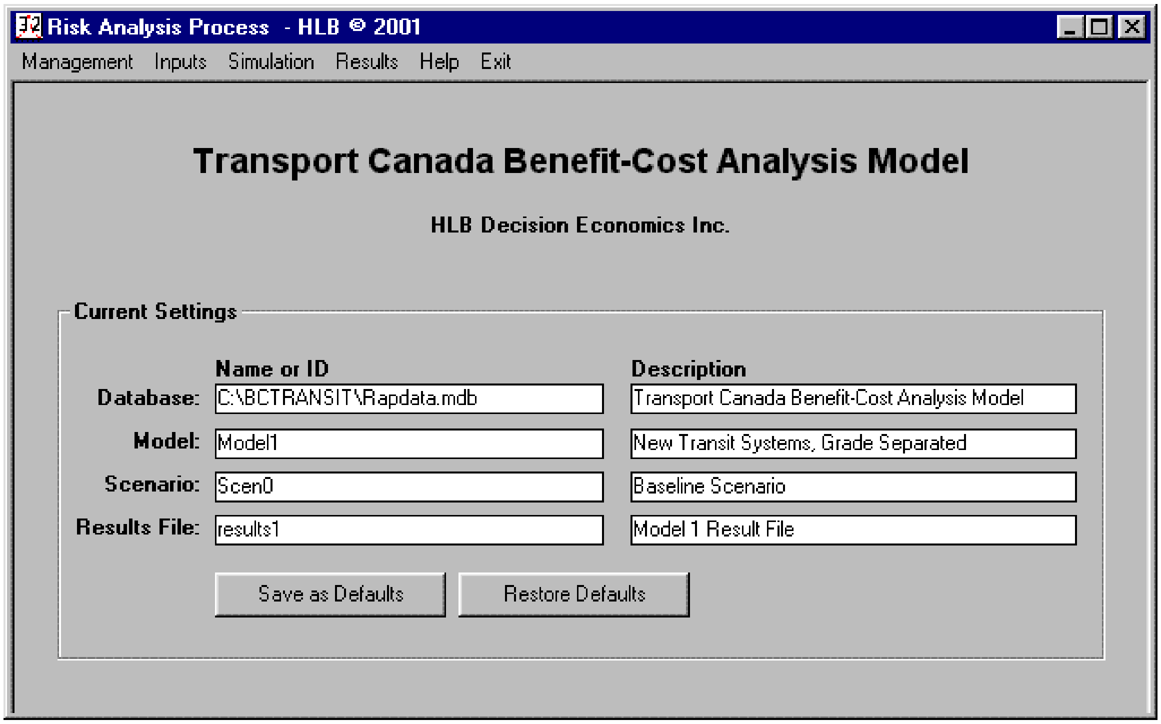
Model	Scenario	Description/Comments
Transit Modernization, Maintenance and Repair	1. Fleet Replacement / Rehabilitation	Investment in fleet replacement / rehabilitation
	2. Security Equipment and Systems Upgrade	Investment in security equipment and systems upgrade
	3. Passenger Stations and Terminals Rehabilitation	Investment in passenger stations and terminals rehabilitation
	4. Maintenance Facilities and Equipment Upgrade	Investment in maintenance facilities and equipment upgrade
	5. Signaling and Communications	Investment in signaling and communications
Highway Investments, Single Segment Analysis	1. Asphalt vs. Concrete	Comparison of asphalt investment with concrete investment
	2. Bridge Rehabilitation vs. Replacement	Comparison of bridge rehabilitation investment with bridge replacement investment
	3. Combination Project	Combination project investment
	4. Expedient vs. Full Resurfacing	Comparison of expedient resurfacing investment with full resurfacing investment
	5. Facility Upgrade	Facility upgrade investment
	6. Freeway vs. Expressway	Comparison of freeway investment with expressway investment
	7. Increased Capacity	Investment in increased capacity
	8. Lane Addition	Investment in additional lane
	9. New Location vs. Upgrade	Comparison of new location investment with upgrade investment
	10. Pavement Resurfacing vs. Preservation	Comparison of pavement resurfacing investment with preservation investment
	11. Rehabilitation vs. Reconstruction	Comparison of rehabilitation investment with reconstruction investment
	12. Rural Facility Widening	Investment in rural facility widening

Each of these models (and scenarios) can be run within a unique interface, the RAP32 interface (RAP stands for Risk Analysis Process). The interface includes a number of windows and dialog boxes allowing the user to navigate among models and scenarios, edit the models' inputs, run Monte Carlo simulations and visualize, store and export simulation results. These windows are described in the sections below:

- The Master Window (Section 3.9.2);
- Project Management (Section 3.9.3);
- Inputs or Data Entry (Section 3.9.4);
- Running a Simulation (Section 3.9.5); and
- Simulation Results (Section 3.9.6).

4.9.2 The Master Window

The Master Window, pictured below, is the first screen that appears when the program is invoked by double clicking on the program icon, , in Microsoft Windows. It includes two parts: a menu bar and a set of text-boxes describing the "current settings".



Transport Canada Benefit-Cost Analysis Model

HLB Decision Economics Inc.

Current Settings

	Name or ID	Description
Database:	C:\BCTRANSIT\Rapdata.mdb	Transport Canada Benefit-Cost Analysis Model
Model:	Model1	New Transit Systems, Grade Separated
Scenario:	Scen0	Baseline Scenario
Results File:	results1	Model 1 Result File

4.9.2.1 Main Menu Bar

The menu bar includes seven items: Management, Inputs, Simulation, Results, Data-Tables, Help and Exit.

- Select **Management** to change the current settings, i.e., select a new database, a new model, a new scenario, a new result file, or change the period of analysis (starting year and number of years).

- Select **Inputs** to edit an existing scenario or add some data to a new scenario. The Inputs window also allows visualizing the distribution of the input variables.

- Select **Simulation** to specify the number of trials, choose a "random seed" and run a simulation.

- Select **Results** to visualize the results of the simulation for the current result file, i.e., as specified in the current settings. The result window also allows exporting the simulation results into a Microsoft Excel spreadsheet.

- Select **Help** to access the user manual.

- Select **Exit** to close the application.

4.9.2.2 Current Settings

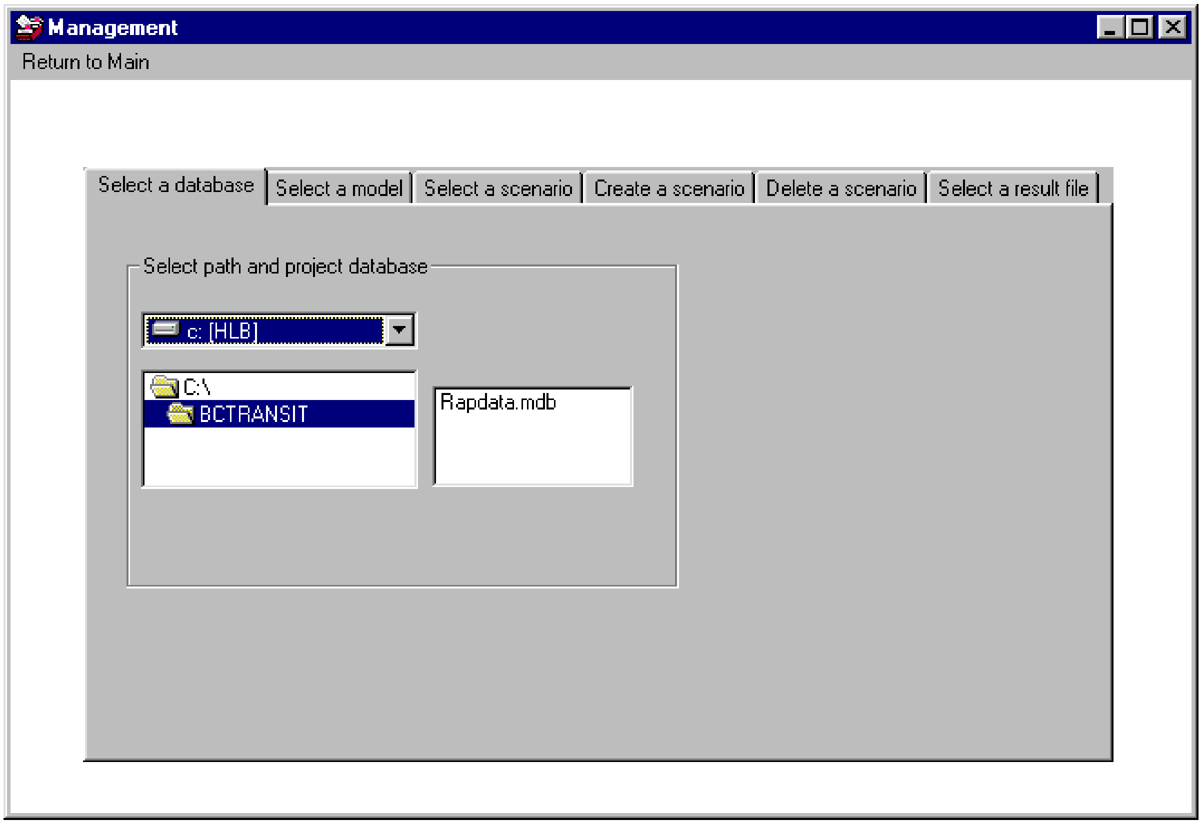
The current settings are read from, and stored into, a small text file located in the C:\WINDOWS directory: RAP32.INI. These settings can be modified only through the Project Management window.

The settings comprise six items: the full name of the database where the scenarios and input variables are stored (file name and directory), the current model, the current scenario, and the current result file. The name (or value) of these items is defined in the left-hand side of the screen under "Name or ID." The items are described in the right-hand side of the screen, under "Description."

4.9.3 Project Management

The Project Management window allows selecting a database, selecting a model and a scenario, creating a new scenario, deleting a scenario and selecting an existing result file. The main component of the screen, depicted below, is a form with six tabs (or pages). Each tab corresponds to a specific task.

Figure 17: Project Management Window



Select path and project database

c: [HLB]

C:\
BCTRANSIT

Rapdata.mdb

4.9.3.1 Select a Database

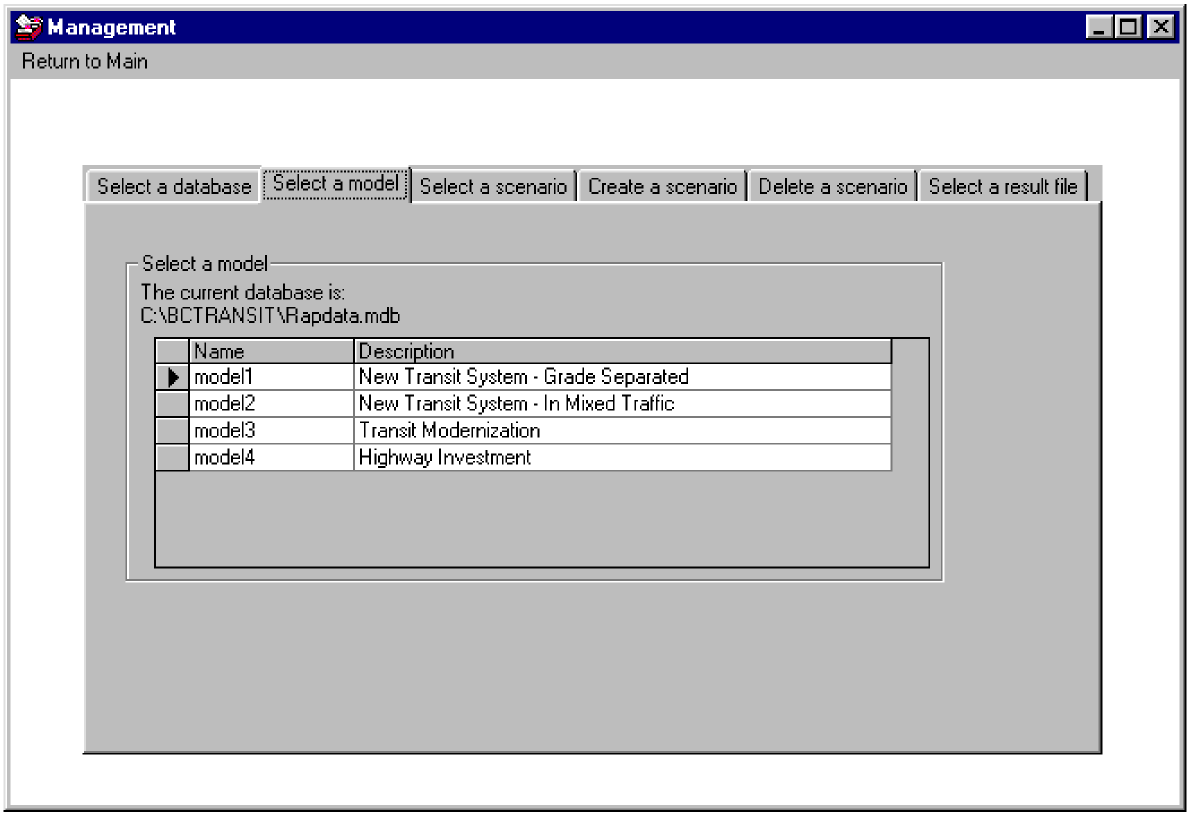
This is the page that appears when the Management Window is invoked. It allows selecting the Microsoft Access file where the input data is stored. Note that the database name must begin with “RA” to appear in the list box located in the center of the screen. In the screen presented on the previous page, the database is RAPDATA.MDB. It is located in the C:\BCTRANSIT directory.

To select a new directory and database, proceed as you would do in any Microsoft Windows application. Attention: the program will not let you select a directory where no database can be found. If you fail to specify an appropriate directory and/or database, the program will automatically select the database located in the application directory, i.e. in the directory where the software was installed.

4.9.3.2 Select a Model

This tab allows selecting one of the four models available in the application: New Transit Systems - Grade Separated; New Transit Systems - In Mixed Traffic; Transit Modernization, Maintenance and Repair; and Highway Investments. Select the model of your choice by clicking the appropriate row in the grid. The current model is identified by a small triangle in the header of the row. In the screen below, Model1 is the current model.

Figure 18: Model Selection Window



The current database is:
C:\BCTRANSIT\Rapdata.mdb

	Name	Description
▶	model1	New Transit System - Grade Separated
	model2	New Transit System - In Mixed Traffic
	model3	Transit Modernization
	model4	Highway Investment

4.9.3.3 Select a Scenario

This tab allows selecting a scenario among the existing scenarios, checking an existing scenario and accessing the Data Entry window. The list of available scenarios is presented in a grid or table with two columns: Scenario Name and Scenario Description. Select the desired scenario with a mouse click in the corresponding row. The list includes only the scenarios defined for the *current* model.

The **Name** field contains the name of the scenario. The program provides this name automatically when a new scenario is created. DO NOT edit this field. The program might not work properly if the user changes the name of one of the scenarios. The **Description** field provides a detailed description of the scenario. This description appears on all reports and graphs generated by the program. To enter data in this field either click on the field with the mouse or strike the arrow keys until the field is highlighted.

Check Scenario

Click the Check Scenario button to verify whether the current scenario is fully specified (i.e. whether all variables have been defined adequately). After few seconds, a message box indicating the outcome of the procedure will show up on the screen.

Edit Data

Click the Edit button to access the Data Entry window for the currently selected scenario. This feature allows you to visualize and/or edit the input data for any of the scenarios in the list (See Section 3.9.4: "Data Entry").

4.9.3.4 Create a Scenario

The "Create a Scenario" tab allows adding a scenario to the scenario list. To create a scenario for the currently selected model, you need to specify a scenario description and a source for the input data (again, the name of the scenario is generated by the computer). You can either set all input data to zero or create a scenario based upon an existing scenario (recommended). If you choose the later option, you will have to select an existing scenario to copy the data from.

No more than twenty scenarios for a given model can be stored in a database. If you need to have more than twenty, you will have to create a new database. In this case, use the Select a Database tab to switch from one set of scenarios to another.

After typing in the scenario description and selecting a source for the data, click the "Create" button to create the scenario and save the data. A dialog box with "Scenario Successfully Created" should appear after few seconds.

4.9.3.5 Delete a Scenario

This tab offers you the possibility to remove a scenario from the scenario list. Be aware though that you must keep at least one scenario in the list: the default scenario "scen0" cannot be deleted.

To remove a scenario, proceed in two steps. First, select the scenario you wish to delete from the drop-down list. Second, click the "Delete" button to permanently delete the currently selected scenario. Again, only those scenarios that are defined for the current model are included in the dropdown list.

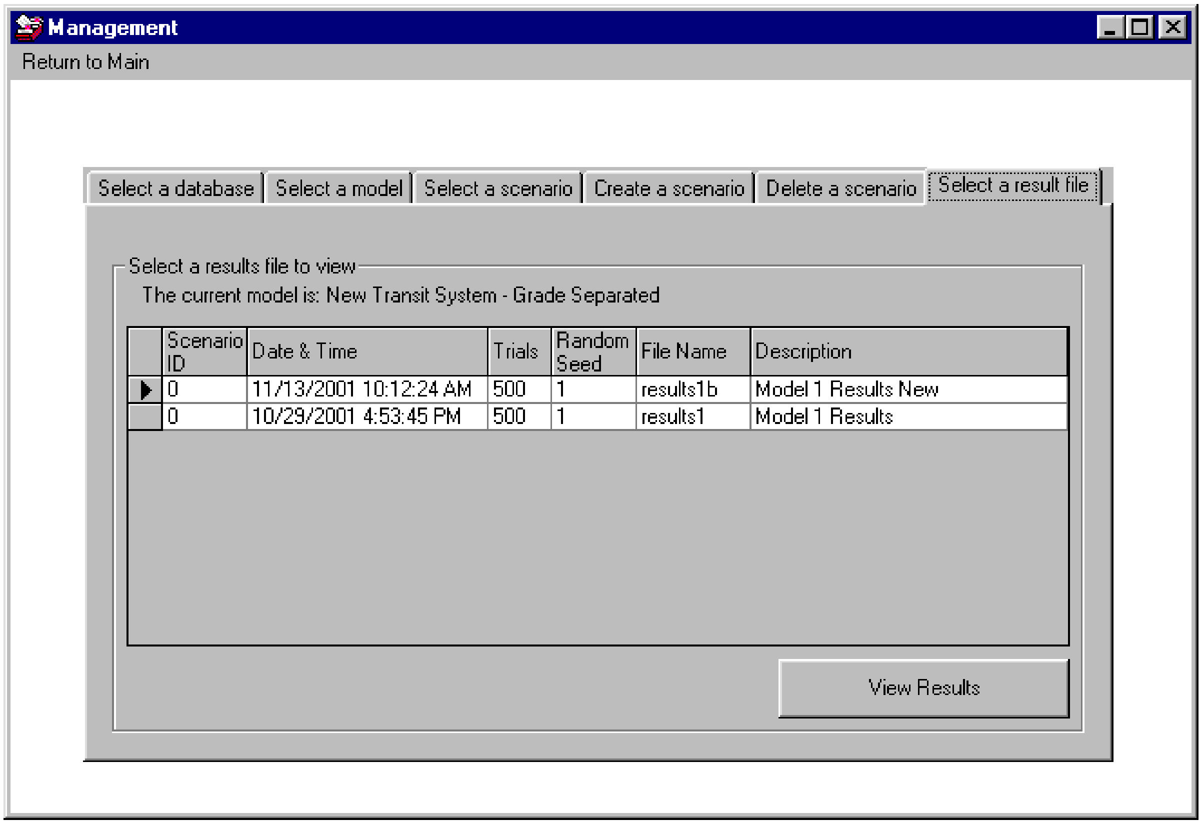
4.9.3.6 Select a Results File

Use this tab to view the content of a results file and/or select an existing file where the results of the next simulation will be stored. Note that you cannot create a new results file at this stage (see "Running a Simulation" to create additional result files). Note also that you must select a results file before exiting the management window. The name of the file you select will be part of the current settings.

Again, the purpose of this page is twofold:

- Select a results file before running a simulation: just click on the appropriate row in the grid.
- View the content of existing results files: select a file in the grid and click the "View Results" button. The Results window (see the "Results" section) will come up on the screen.

Figure 19: Results File Selection Window



Select a results file to view

The current model is: New Transit System - Grade Separated

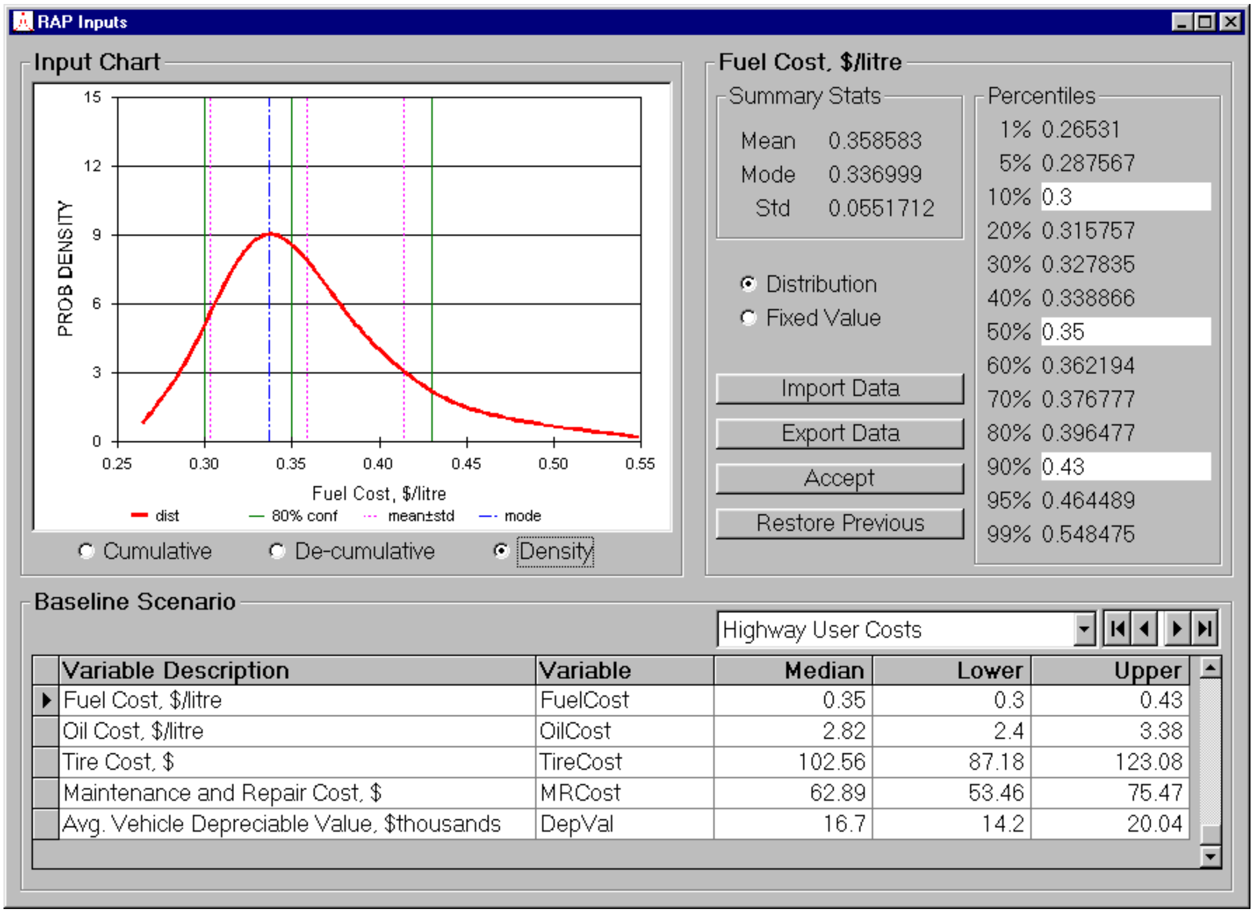
	Scenario ID	Date & Time	Trials	Random Seed	File Name	Description
▶	0	11/13/2001 10:12:24 AM	500	1	results1b	Model 1 Results New
	0	10/29/2001 4:53:45 PM	500	1	results1	Model 1 Results

Click "Return to Main" to go back to the Master Window. Note how the current settings have been updated. If you want to make the current settings the default settings click the "Save as Defaults" button. If you wish to restore the previous settings and cancel the changes you have made, click the "Restore Defaults" button.

4.9.4 Data Entry

You can access the Data Entry window (pictured below) either from the "Inputs" item of the main menu or from the "Edit Data" button in the "Select a Scenario" tab of the Project Management window.

Figure 20: Data Entry Window



Fuel Cost, $/litre

Summary Stats

Mean	0.358583
Mode	0.336999
Std	0.0551712

● Distribution
○ Fixed Value

Percentiles

1%	0.26531
5%	0.287567
10%	0.3
20%	0.315757
30%	0.327835
40%	0.338866
50%	0.35
60%	0.362194
70%	0.376777
80%	0.396477
90%	0.43
95%	0.464489
99%	0.548475

Highway User Costs

Variable Description	Variable	Median	Lower	Upper
Fuel Cost, $/litre	FuelCost	0.35	0.3	0.43
Oil Cost, $/litre	OilCost	2.82	2.4	3.38
Tire Cost, $	TireCost	102.56	87.18	123.08
Maintenance and Repair Cost, $	MRCost	62.89	53.46	75.47
Avg. Vehicle Depreciable Value, $thousands	DepVal	16.7	14.2	20.04

The Data Entry window has three main components:

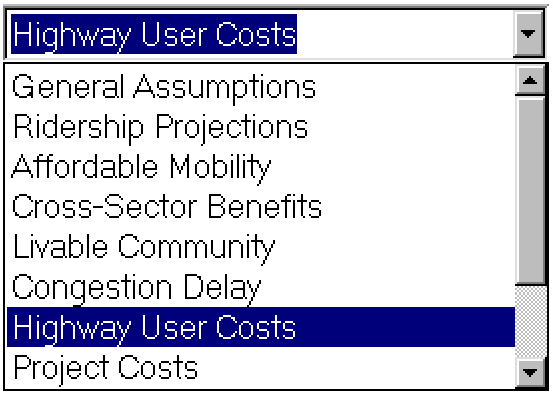
- Data Set Drop-Down List and Grid (lower portion of the screen);
- Summary Stats and Percentiles (upper right); and
- Input Chart (upper left).

A task or set of tasks is associated with each of these "components": selecting and viewing data sets, entering and modifying data, selecting and viewing input graphs.

4.9.4.1 Selecting Data Sets

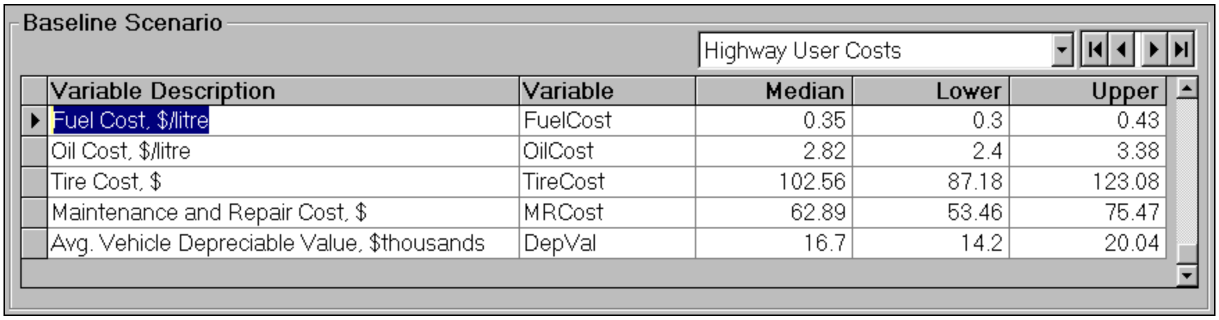
Click the down arrow to the right of the data set drop down list, pictured below, to display the list of available data sets.

Figure 21: Data Set Drop-Down List



Once you have selected a data set in the drop down list, the associated variables will be displayed in a grid, similar to the one pictured below. To move from one variable to another, use the arrow buttons located on the right of the screen. The current variable is identified by a small triangle in the header of the associated row. In the table below, for example, it is FUEL, the cost of fuel for autos.

Figure 22: Variable Selection Grid



	Variable Description	Variable	Median	Lower	Upper
▶	Fuel Cost, $/litre	FuelCost	0.35	0.3	0.43
	Oil Cost, $/litre	OilCost	2.82	2.4	3.38
	Tire Cost, $	TireCost	102.56	87.18	123.08
	Maintenance and Repair Cost, $	MRCost	62.89	53.46	75.47
	Avg. Vehicle Depreciable Value, $thousands	DepVal	16.7	14.2	20.04

The grid has five columns: Variable Description (including unit of measurement and year, for multi-year variables), Variable name, the Median value, the Lower 10% value and the Upper 90% value. Note that you *cannot* edit any of these fields from the grid. To modify the median, lower and upper values, refer to the section "Editing Data" below.

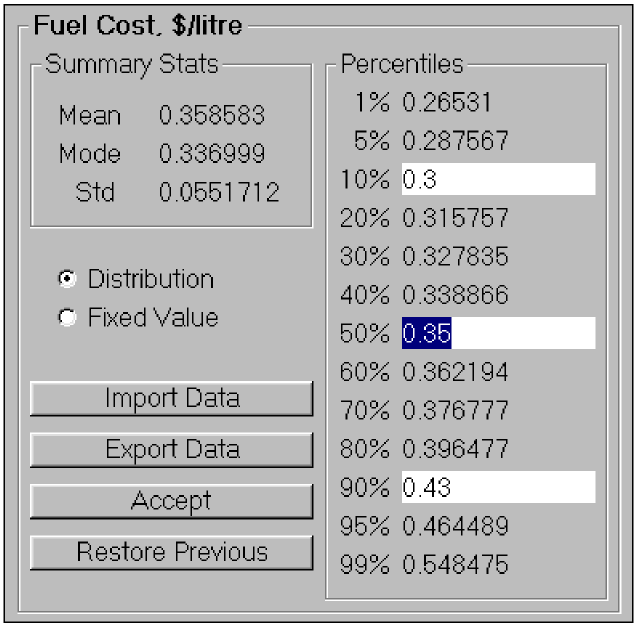
4.9.4.2 Editing Data

There are two ways to edit input data: you can either edit the data sets one after the other by typing in new values into the "Percentiles" box or you can use the "Import Data" button to paste new values into the input file.

4.9.4.2.1 Entering and Modifying Data

To modify values for the current variable, select one of the three highlighted cells in the "Percentiles" box in the upper right portion of the screen (see below). Use the mouse or Tab key to select a cell. Enter a new value by typing in a new number over the existing one. When you are done, click the "Accept" button to record the new values. If you wish to cancel the changes you have made and restore the previously recorded values, click the "Restore Previous" button.

Figure 23: Input Percentiles Box



Fuel Cost, $/litre

Summary Stats

Mean	0.358583
Mode	0.336999
Std	0.0551712

● Distribution
○ Fixed Value

Percentiles

1%	0.26531
5%	0.287567
10%	0.3
20%	0.315757
30%	0.327835
40%	0.338866
50%	0.35
60%	0.362194
70%	0.376777
80%	0.396477
90%	0.43
95%	0.464489
99%	0.548475

Note how changes in the three percentiles affect the summary statistics displayed in the "Summary Stats" box. Changing either the median, lower or upper values will recalculate the mean value, since the mean value is a weighted average of the median value and its associated probability. For example, if the range is normal (the upper and lower values are equidistant from the median), then calculated mean value will equal the user input median value. On the other hand, if the range is not normal (the upper and lower values are not equidistant from the median), then calculated mean value will exceed or fall below the user input median value, depending upon the direction of the skew in the probability density function.

If the "Fixed Value" radio button is selected instead of "Distribution", the model treats the current variable as a *deterministic* variable. The only value you have to enter in this case is the "median" value. The summary statistics cannot be calculated and N/As will appear in the "Summary Stats" box. During the simulation process, the model samples the range of each variable. For deterministic variables, it uses the median value in every simulation. This is acceptable for certain variables such as historical values, which are known and therefore have no uncertainty surrounding them. You can also select the "Fixed Value" option, if you don't want to use the risk analysis component of the models.

4.9.4.2.2 Importing Data

There are two important steps. First, copy the data you wish to import into the Microsoft Windows clipboard. If you want to copy data from a Microsoft Excel spreadsheet for example, select the appropriate cells and use the "Copy" function in the "Edit" menu, or type *CTRL+C*. Then, return to the Data Entry window of RAP32 and click the "Import Data" button located in the upper right part of the screen. Make sure that you have copied the appropriate set of data before performing this operation. You will not be able to use the "Restore Previous" button to cancel the changes made to the input file.

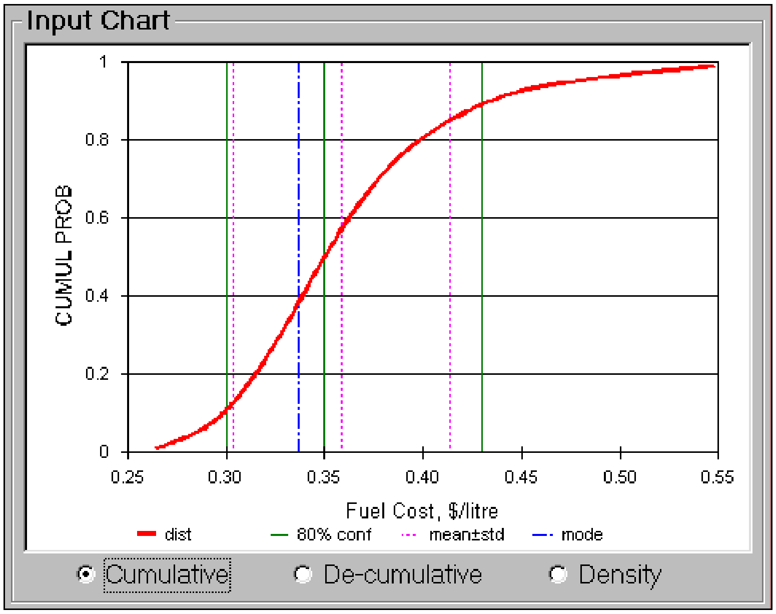
4.9.4.2.3 Exporting Data

To export data into a Microsoft Excel file, click the “Export Data” button located in the upper right portion of the Data Entry window. An Excel spreadsheet named after the current model and current scenario will be created in the application directory.

4.9.4.3 Viewing Input Graphs

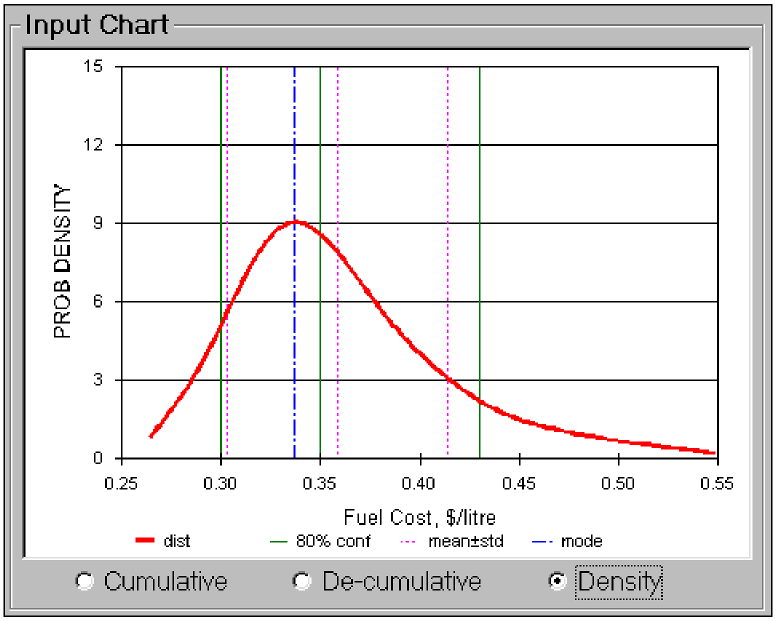
The default graph is a cumulative probability function, as pictured below. The function is represented by a thick red line. Also represented on the graph are: the 80% confidence interval (in fact, the range between the lower 10% and the upper 90% values), the mean plus or minus the standard deviation, and the mode. Again, note how changes in the “Percentiles” box directly affect the shape of the distribution and the position of the summary statistics.

Figure 24: Input Graph, Cumulative Distribution



To view another type of graph, click on the appropriate radio button located in the lower part of the “Input Chart” box. Selecting the “Density” button, for example, would draw a density function, as shown below.

Figure 25: Input Chart, Density Function



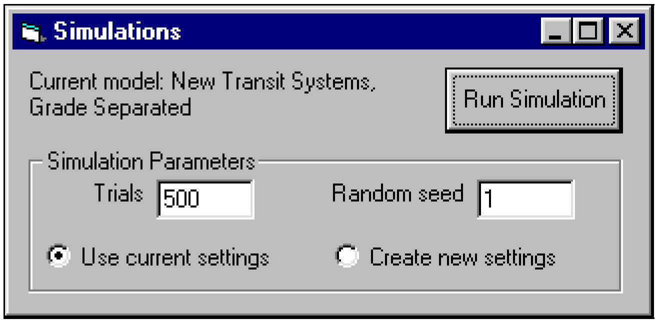
4.9.5 Running a Simulation

Once the appropriate data is entered, a Monte Carlo simulation can be run. A Monte Carlo simulation uses the median, upper and lower values to generate a unique probability density function for each variable. The software samples each distribution and obtains a unique value for every input with the resulting numbers populating the mathematical equations making up the models. A simulation trial concludes when the equations are solved and results are calculated. This procedure is repeated over and over depending upon the number of trials indicated by the user. The number of trials that you select affects the resolution of the result graph. For example, if only two trials are conducted, only two results will be calculated, and by definition the graph of these two points will be a straight line! On the other hand, if five hundred trials are conducted then five hundred results will be calculated and the graph of these points will resemble a “typical” probability distribution.

4.9.5.1 Simulation Settings

Selecting “Run a Simulation” from the Simulation menu starts the simulation process by displaying the Simulation Settings dialog box, pictured below.

Figure 26: Simulation Settings Dialog Box



Current model: New Transit Systems, Grade Separated

Simulation Parameters

Trials: 500

Random seed: 1

● Use current settings ○ Create new settings

4.9.5.1.1 Number of Trials

The greater the number of trials, the greater the precision of the estimates and the greater the resolution of the result graph. On the other hand, more trials means more computations and more time needed to complete the simulation. First, run a simulation with fifty trials to check whether you have specified all the input variables correctly. If the results make sense, increase the number of trials to five hundred, or one thousand, and rerun the simulation.

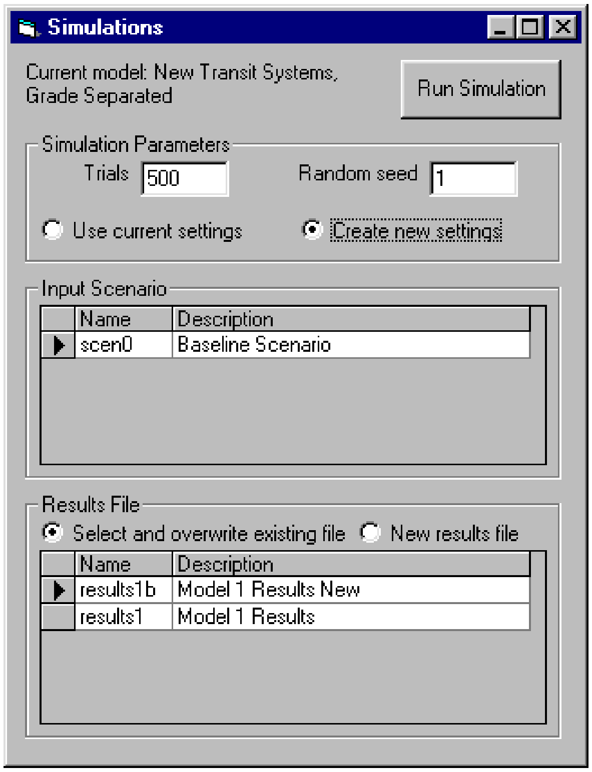
4.9.5.1.2 Random Seed

Use the Random Seed text box to specify a seed for the range sampling process of the Monte Carlo simulation. If the same random number seed is selected and a simulation is rerun, without any change to the input data, the results will be *exactly* the same. On the other hand, specifying a new random seed will produce *slightly* different results, even with no changes to the inputs.

4.9.5.1.3 Current Versus New Settings

Before running a simulation, you can specify settings that are different from the current (or default) settings. To do that, select the "Create new settings" radio button in the lower part of the Simulation Settings form. The form will be automatically enlarged to show additional features and options, as shown below.

Figure 27: Extended Simulation Settings



Current model: New Transit Systems, Grade Separated

Simulation Parameters

Trials 500

Random seed 1

○ Use current settings ● Create new settings

Input Scenario

	Name	Description
▶	scen0	Baseline Scenario

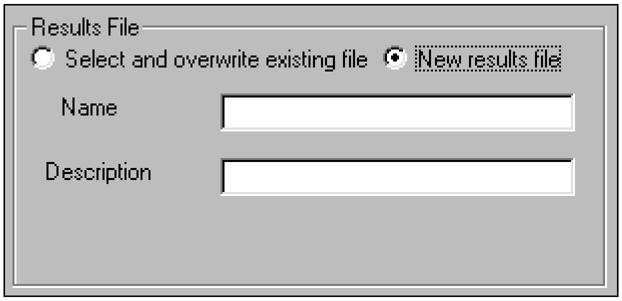
Results File

● Select and overwrite existing file ○ New results file

	Name	Description
▶	results1b	Model 1 Results New
	results1	Model 1 Results

You can select a different scenario (i.e. different from the scenario specified in the current settings) to use in the simulation by clicking a row in the "Input Scenario" grid pictured above. You can also select a different result file (i.e. different from the result file specified in the current settings). At this stage, you have two more options: selecting and overwriting an existing result file or *creating an entirely new results file*. If you choose the first option, you will have to select a file in the result file grid shown above. If you choose the second option, the bottom of the extended Simulation Settings window will change to allow you to enter a name for the new result file and a brief description of the associated simulation.

Figure 28: Creating a New Results File



○ Select and overwrite existing file ● New results file

A new Microsoft Access file will be created on the hard drive of your computer. The result file name, together with the date and time of the simulation, the number of trials, the random seed and the simulation description will be added to the list of result files.

4.9.5.2 Starting a Simulation

To run a simulation, click the “Run Simulation” button of the Simulation Settings form. As the simulation proceeds, a progress bar will be displayed. This bar indicates how much of the simulation is completed. When the simulation is over, click the “View Results” button to access simulation results.

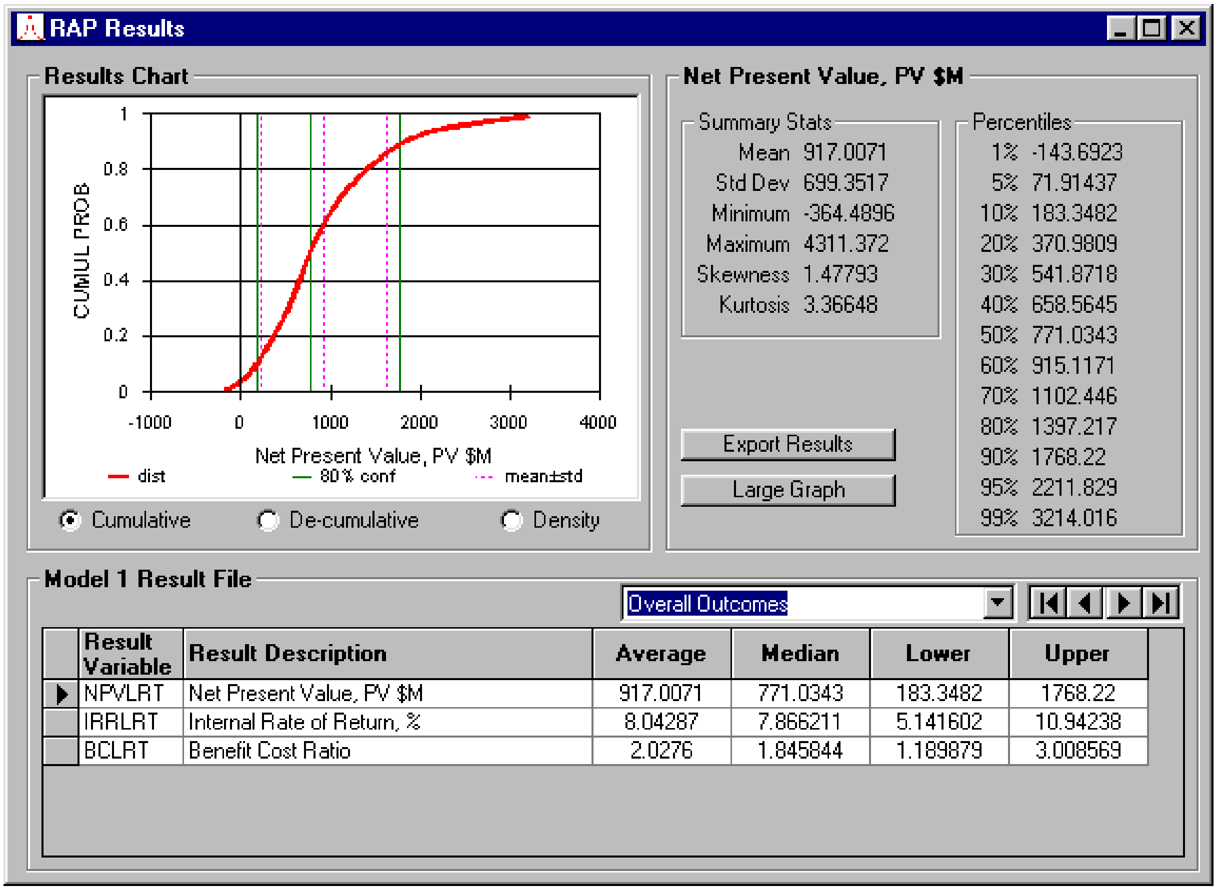
4.9.6 Simulation Results

The Results window can be displayed after running a simulation, or when browsing the list of result files (in the Project Management window). The Results window is very similar to the Data Entry window. It includes three major components:

- Results Set (lower portion of the screen)
- Percentiles and Summary Statistics (upper right)
- Results Chart (upper left)

Five crucial summary statistics are generated for each output variable: the mean expected value, the standard deviation, the median value, the lower 10% value, and the upper 10% value. Additional statistics are displayed in the upper right part of the screen, in the “Summary Stats” and the “Percentiles” boxes.

Figure 29: Results Window



● Cumulative ○ De-cumulative ○ Density

Net Present Value, PV $M

Summary Stats

Mean	917.0071
Std Dev	699.3517
Minimum	-364.4896
Maximum	4311.372
Skewness	1.47793
Kurtosis	3.36648

Percentiles

1%	-143.6923
5%	71.91437
10%	183.3482
20%	370.9809
30%	541.8718
40%	658.5645
50%	771.0343
60%	915.1171
70%	1102.446
80%	1397.217
90%	1768.22
95%	2211.829
99%	3214.016

Model 1 Result File

Overall Outcomes

Result Variable	Result Description	Average	Median	Lower	Upper
NPVLRT	Net Present Value, PV $M	917.0071	771.0343	183.3482	1768.22
IRRLRT	Internal Rate of Return, %	8.04287	7.866211	5.141602	10.94238
BCLRT	Benefit Cost Ratio	2.0276	1.845844	1.189879	3.008569

4.9.6.1 Viewing and Interpreting Result Graphs

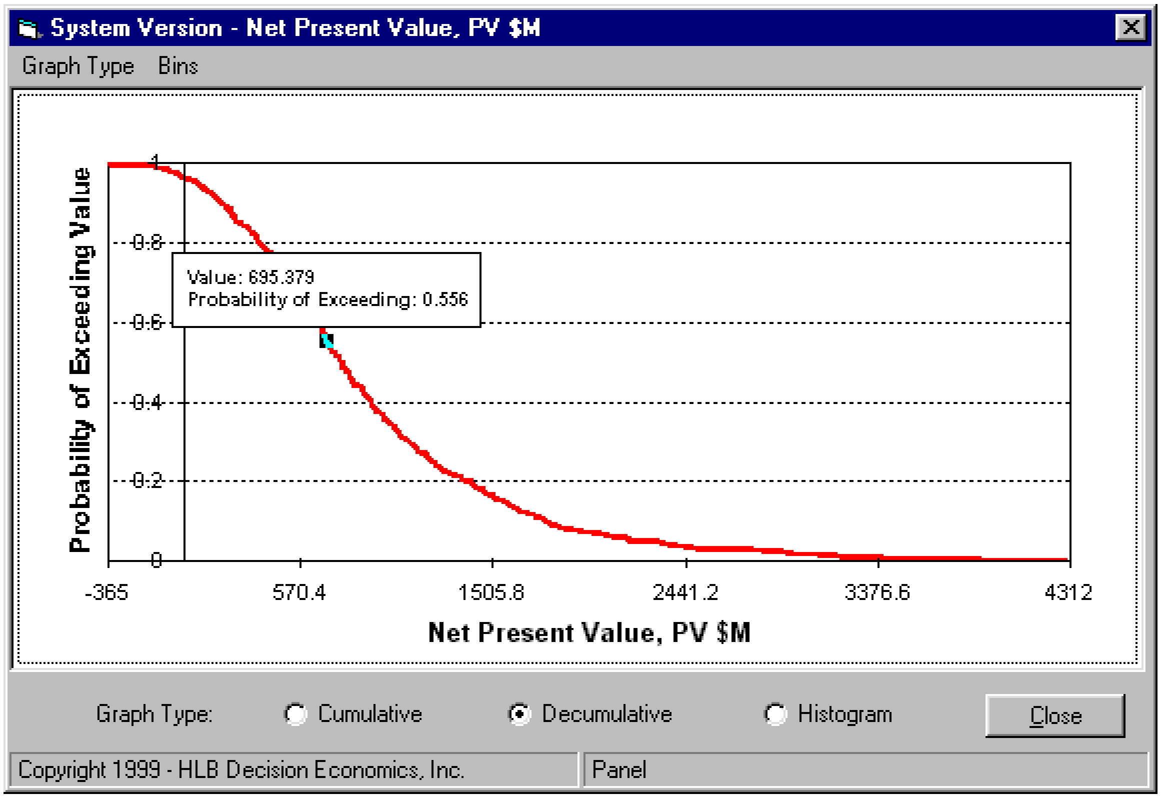
Result charts are displayed in the upper left portion of the Results window. The initial graph is a cumulative probability distribution. Clicking on the “Decumulative” radio button changes the current view to a decumulative probability distribution. Clicking on the “Density” radio button changes it to a density function. Note that the concept of a “density” function is not really appropriate for simulation results. The user should focus on the histogram offered as a large graph (see below) instead.

In the chart pictured in Figure 29 above, the plain vertical lines represent, reading for left to right, the estimates for the lower 10% value, for the median value and for the upper 90% value of the net benefits generated by the project under examination. The median value is the midpoint at which fifty percent of the calculated net benefits fall above or below the median line. The lower 10% value is the point for which there is only a ten percent probability that the results fall *below* this point; the upper 90% value is the point for which there is only a ten percent probability that the results fall *above* this point. The dashed vertical lines represent, from left to right, the estimated mean *minus* the standard deviation, the estimated mean, and the estimated mean *plus* the standard deviation.

You can also view larger graphs by clicking on the “Large Graph” button. For each output variable, there are three types of (large) graphs available: cumulative probability distribution, decumulative probability distribution, and histogram.

A decumulative probability distribution is displayed in the Large Graph window pictured below. Note that clicking on any point along the curve reveals its exact coordinates along the X-axis and the Y-axis. In the example pictured here, the X-value is 695.379 and the probability of exceeding this value (read on the Y-axis) is 0.556.

Figure 30: Large Output Graph, Decumulative Distribution



System Version - Net Present Value, PV $M

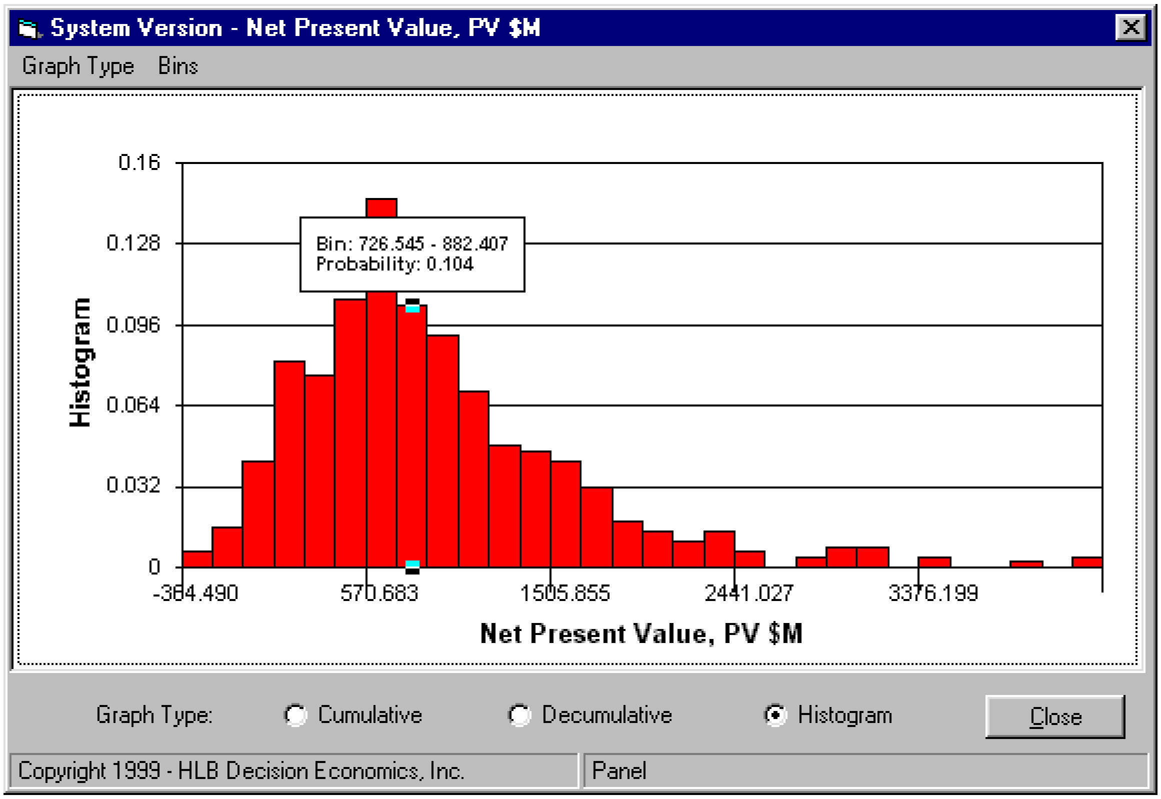
Value: 695.379
Probability of Exceeding: 0.556

Graph Type: ○ Cumulative ● Decumulative ○ Histogram

Copyright 1999 - HLB Decision Economics, Inc.

A histogram is displayed in the Large Graph window below. Clicking on any of the bins on the graph reveals the range of the bin and the probability of falling into that bin. The initial number of bins displayed in the graph is thirty, the default value. To change the number of bins, select “Bins” from the menu bar of the Large Graph window and, when prompted, type in a new number. The histogram will automatically be redrawn with the new number of bins. The number of bins refers to the number of equivalent ranges into which the results are sorted.

Figure 31: Large Output Graph, Histogram



Bin: 726.545 - 882.407
Probability: 0.104

Graph Type: ○ Cumulative ○ Decumulative ● Histogram

4.9.6.2 Exporting Results

The results of a simulation can be exported into a Microsoft Excel spreadsheet. The procedure is similar to the one used to export input data.

5. CASE STUDIES

This section summarizes the outcomes of three case studies:

- The Southwest Transit Corridor in Winnipeg;
- A bus capacity expansion project in Kelowna; and
- The replacement of a bus line by a light-rail, in Toronto.

The section also presents the benefit-cost analysis outcomes associated with a fictitious highway investment project.

5.1 Winnipeg: Southwest Transit Corridor

The Winnipeg case study, a transit modernization/upgrade project, has been conducted with Model 3.

5.1.1 Project Description

The Southwest Transit Corridor is a busway proposed to link downtown Winnipeg with the southwest part of the city, including the University of Manitoba and its 23,000 students. Most of the busway is a separate right-of-way (11 kilometers in length) for the exclusive use of transit buses. In the downtown, buses would operate on the Graham Avenue Transit Mall, a bus-only street built in 1994-95. After exiting the busway at Bison Station at the south end of the corridor, buses would operate on the regular street system in mixed traffic on Chancellor Matheson between Bison Station and the University of Manitoba Station. There are no at-grade intersections on the busway between downtown and Windermere Station. In the section between Windermere and Bison Stations, buses would operate in an exclusive right-of-way that crosses several streets at grade. Transit signal priorities would be used at street intersections to maximize bus operating speeds in the southern part of the busway.

Application has been made to the Canada/Manitoba Infrastructure Secretariat for funding of the first stage of the project (Main & River to Pembina & Jubilee). If the project were approved, the first stage would be built during fiscal year 2003 - 2004. Assuming funding approval was obtained for the second stage (Pembina & Jubilee to Pembina & Bison) and third stage (downtown to Main & River), the remaining construction would occur in fiscal year 2005 - 2006.

5.1.2 Model Inputs

Inputs for the Winnipeg case study are summarized in Table 63, on the next page. Default values are used for all other input variables.

Table 62: Winnipeg Case Study Inputs

Variable Description	Value / Comments
Investment Start	2003
Number of Years in Analysis	20 years
Transit System Opening Year	2004 for 1st Stage 2005 for 2nd Stage 2006 for 3rd Stage
Daily Bus Ridership in Opening Year	19,800
Ridership Growth	Stage 1: + 11% from current levels Stage 2 & 3: + 15% from current levels
Percent of Ridership in PEAK time	55%
Opening Year Transit Travel Time	42 minutes
Transit Travel Time Annual Growth	+ 2%
First Year Annual Average Daily Traffic	521,000
First Year Congestion Index	Pembina & McGillivray: V/C=1.24 Pembina & Jubilee: V/C=1.49 Pembina & Osborne: V/C=1.60
Percent Bus Fleet 500 PPM Diesel	Before Busway: 100% After Busway: 50%
Percent Bus Fleet 300 PPM Diesel Hybrid	Before Busway: 0% After Busway: 50%
Average Bus Fare	$1.21
Average Trip Length	8.5 km
Average Vehicle Speed, Bus	Before Busway: 19 km/h After Busway: 26 km/h
Percent of Low-Income Travelers in Total Ridership	30%
Percent of Trips for Medical Purposes	7%
Percent of Trips for Work Purposes	48%
Guideway Costs	$51.5M (Busway Construction)
Station/Stop Costs	$3.0M (Stations, Stops)
System Costs	$0M
Special Condition Costs	$2.0M (Signals, Utilities)
Right-of-Way Costs	$12.0M (Property Acquisition)
Yard-and-Shop Costs	$0M
Vehicle Costs	$0M
Add-On Costs	$6.5M (Engineering Costs)
Incremental Annual Operating and Maintenance Costs	$0.5M (Busway Maintenance)

5.1.3 Simulation Results

The benefit-cost analysis results for the case study are presented in the table below.

Table 63: Winnipeg Benefit-Cost Analysis Results

	Mean	90% Probability of Exceeding	10% Probability of Exceeding
Congestion Management			
Time Savings	$85.848	$71.966	$101.654
VOC Savings	$25.923	$16.587	$42.564
CAC Emission Savings	$1.079	$0.455	$2.178
GHG Emission Savings	$0.005	$0.001	$0.012
Accident Cost Savings	$31.765	$9.442	$61.810
Total Congestion Management	**$144.620**	**$107.135**	**$196.944**
Low Income Mobility			
Affordable Mobility	$20.417	-$6.203	$55.644
Cross Sector Benefits	$3.751	$1.493	$6.376
Total Low Income Mobility	**$24.168**	**-$4.710**	**$62.020**
Livable Community			
Residential Development	$0.000	$0.000	$0.000
Commercial Development	$0.000	$0.000	$0.000
Total Livable Community Benefits	**$0.000**	**$0.000**	**$0.000**
Grand Total Benefits	**$168.787**	**$114.283**	**$237.470**
Project Costs			
Capital Expenditures	$75.000	$75.000	$75.000
Incremental O&M Costs	$10.000	$10.000	$10.000
Total Costs	**$80.316**	**$80.316**	**$80.316**
Net Present Value	**$88.471**	**$33.967**	**$157.153**
Benefit-Cost Ratio	**2.102**	**1.423**	**2.957**
Internal Rate of Return	**8.53%**	**5.05%**	**13.40%**

Figures represent present-day value, in millions of 2001 dollars, of benefits and costs over 20 years.

5.2 Kelowna: New Bus Capacity

Model 2, New Transit Systems, Transit in Mixed Traffic, has been used to conduct the Kelowna case study.

5.2.1 Project Description

The project has two major components and two distinct time periods:

- **Commuter Service (1997 – 1999)**: This phase is an increase in capacity during the weekday peak period on 90 percent of existing routes. Capacity during peak time would *double* by the end of the investment period. Two capital projects are included within the Commuter Service project: 1) a new operations centre, to accommodate the increased bus capacity; and 2) an off-street transit exchange, located downtown, to replace the existing on-street exchange area. The benefits associated with the off-street exchange include: increased capacity, increased operational efficiency (as a dedicated facility) and higher transit profile.

- **Town Centre Shuttle (2002 – 2006)**: This phase consists of building upon the first phase of the program and supporting the Town Centre strategy of the City of Kelowna and the Regional District of Central Okanagan. The proposed service expansion will provide increased capacity connecting the Town Centres and will improve service quality (by offering express or semi-express services). Other project components include: exchanges and/or park-and-ride sites (either new or upgraded) at the Town Centres, the introduction of G.P.S. technology to provide better real-time customer information, and a new fare technology.

5.2.2 Model Inputs

Inputs for the Kelowna case study are summarized in Table 64, on the next page. Default values are used for all other input variables.

Table 64: Kelowna Case Study Inputs

Variable Description	Value / Comments
Investment Start	1997
Number of Years in Analysis	18 years
Daily Bus Ridership in Opening Year	5,150
Avg. Annual Ridership Growth Year 1 to 5	25.8%
Avg. Annual Ridership Growth Year 6 to 10	23.1%
Avg. Annual Ridership Growth Year 11 and After	22.0%
Percent of Ridership in PEAK Time	25.3%
First Year Annual Average Daily Traffic	312,100
VKT Yearly Growth 2000 to 2010	2.5%
VKT Yearly Growth 2010 to 2015	2.7%
VKT Yearly Growth 2015 to 2020	2.7%
VKT Yearly Growth 2020 and After	2.7%
First Year Observed Highway Travel Time	19.3 minutes
Observed Highway Travel Time Growth 2000 to 2010	3.4%
Observed Highway Travel Time Growth 2010 and After	4.4%
Percent Bus Fleet 500 PPM Diesel	100%
Average Bus Fare	$0.928
Average Vehicle Speed, Bus	26.5 km/h
Percent of Low-Income Travelers in Total Ridership	13.8%
Percent of Trips for Medical Purposes	4.1%
Percent of Trips for Work Purposes	34.2%
Guideway Costs	$0.00M
Station/Stop Costs	$3.87M
System Costs	$2.00M
Special Condition Costs	$0.00M
Right-of-Way Costs	$0.00M
Yard-and-Shop Costs	$1.85M
Vehicle Costs	$11.00M
Add-On Costs	$0.00M
Incremental Annual Operating and Maintenance Costs	$0.50M

5.2.3 Simulation Results

The benefit-cost analysis results for the case study are presented in the table below.

Table 65: Kelowna Benefit-Cost Analysis Results

	Mean	90% Probability of Exceeding	10% Probability of Exceeding
Congestion Management			
Time Savings	$0.352	$0.281	$0.439
VOC Savings	$7.252	$5.927	$8.649
CAC Emission Savings	$0.129	$0.064	$0.246
GHG Emission Savings	$0.001	$0.000	$0.002
Accident Cost Savings	$13.195	$4.916	$24.147
Total Congestion Management	**$20.929**	**$12.195**	**$32.964**
Low Income Mobility			
Affordable Mobility	$10.902	$5.157	$17.076
Cross Sector Benefits	$0.733	$0.350	$1.157
Total Low Income Mobility	**$11.635**	**$5.507**	**$18.233**
Livable Community			
Residential Development	$0.000	$0.000	$0.000
Commercial Development	$0.000	$0.000	$0.000
Total Livable Community Benefits	**$0.000**	**$0.000**	**$0.000**
Grand Total Benefits	**$32.564**	**$20.180**	**$46.646**
Project Costs			
Capital Expenditures	$17.412	$16.642	$17.987
Incremental O&M Costs	$8.836	$8.446	$9.128
Total Costs	**$23.313**	**$22.283**	**$24.083**
Net Present Value	**$9.251**	**-$3.042**	**$23.633**
Benefit-Cost Ratio	**1.400**	**0.871**	**2.032**
Internal Rate of Return	**9.11%**	**3.30%**	**15.60%**

Figures represent present-day value, in millions of 2001 dollars, of benefits and costs over 18 years.

5.3 Toronto: Spadina Light Rail

Model 3 (Transit Modernization, Maintenance and Repair) has been used to assess the proposed LRT service on Spadina Avenue in downtown Toronto.

5.3.1 Project Description

The Spadina LRT is a streetcar service operating on Spadina Avenue in downtown Toronto since 1997. The Spadina LRT was implemented as a supplement to the existing bus service, which showed signs of saturation. Prior to its realization, the project was expected to generate a significant number of additional transit riders, increasing total ridership from 2,400 passengers to 5,100 to 5,800 passengers in the peak hour.

Streetcars operate in reserved lanes in the centre of Spadina Avenue. Other vehicles are permitted to cross the LRT lanes during off-peak periods only. Exclusivity of the reserved lanes is acknowledged by an amendment to the Metropolitan Toronto Act. Transit lanes are higher than traffic lanes and visually delineated by a mountable rolled curb, which permit other vehicles and pedestrians to cross the lanes.

Streetcars operate between Spadina Station on the Bloor-Danforth and University-Spadina subway lines, and the Harbourfront LRT at Queen's Quay. Some streetcars operate through to Union Station via the Harbourfront LRT, while some are turned at Queen's Quay, and return to Spadina Station. Thirteen transit stops are provided on the Spadina LRT route. All stops between the north and south terminus points have both northbound and southbound platforms.

5.3.2 Model Inputs

Inputs for the Toronto case study are summarized in Table 66, below. Two scenarios are considered: base case and alternative case. Default values are used for all other input variables.

Table 66: Toronto Case Study Inputs

Variable Description	Value / Comments
Investment Start	2001
Number of Years in Analysis	30 years
Daily Ridership in Opening Year, Base Case	15,000
Avg. Annual Ridership Growth Year 1 to 5, Base Case	0%
Avg. Annual Ridership Growth Year 6 to 10, Base Case	0%
Avg. Annual Ridership Growth Year 11 and After, Base Case	0%
Daily Ridership in Opening Year, Alternate Case	20,000
Avg. Annual Ridership Growth Year 1 to 5, Alternate Case	2%
Avg. Annual Ridership Growth Year 6 to 10, Alternate Case	2%
Avg. Annual Ridership Growth Year 11 and After, Alternate Case	2%
Percent of Ridership in PEAK Time	100%
Average Door-to-Door Travel Time, Base Case	25 minutes
Average Door-to-Door Travel Time, Alternate Case	20 minutes
Percent Time Spent in Vehicle, Base Case	75%
Percent Time Spent in Vehicle, Alternate Case	80%
Percent Time Spent Walking, Base Case	15%
Percent Time Spent Walking, Alternate Case	15%
Percent Time Spent Waiting, Base Case	10%
Percent Time Spent Waiting, Alternate Case	5%
Percent Time Spent in Crowded Conditions, Base Case	0%
Percent Time Spent in Crowded Conditions, Alternate Case	0%
Percent Time Spent in Unsecured Conditions, Base Case	0%

Variable Description	Value / Comments
Percent Time Spent in Unsecured Conditions, Alternate Case	0%
First Year Annual Average Daily Traffic	150,000
VKT Yearly Growth 2000 to 2010	2.5%
VKT Yearly Growth 2010 to 2015	2.5%
VKT Yearly Growth 2015 to 2020	2.5%
VKT Yearly Growth 2020 and After	2.5%
First Year Congestion Index	0.7
Average Transit Fare, Base Case	$1.75
Average Transit Fare, Alternate Case	$1.75
Average Trip Length	11 km
Percent of Low-Income Travelers in Total Ridership	30%
Percent of Trips for Medical Purposes	5%
Percent of Trips for Work Purposes	60%
Guideway Costs	$15.8M
Station/Stop Costs	$5.5M
System Costs	$1M
Special Condition Costs	$0M
Right-of-Way Costs	$0M
Yard-and-Shop Costs	$0M
Vehicle Costs	$35.33M
Add-On Costs	$4.2M
Incremental Annual Operating and Maintenance Costs	$7.1M

5.3.3 Simulation Results

The benefit-cost analysis results for the case study are presented in the table below.

Table 67: Toronto Benefit-Cost Analysis Results

	Mean	90% Probability of Exceeding	10% Probability of Exceeding
Congestion Management			
Time Savings	$73.678	$65.739	$83.088
VOC Savings	$48.469	$28.292	$77.187
CAC Emission Savings	$0.745	$0.346	$1.453
GHG Emission Savings	$0.005	$0.001	$0.013
Accident Cost Savings	$121.271	$30.105	$246.576
Total Congestion Management	**$244.168**	**$139.051**	**$383.215**
Low Income Mobility			
Affordable Mobility	$47.765	$20.233	$77.035
Cross Sector Benefits	$3.794	$1.108	$6.956
Total Low Income Mobility	**$51.559**	**$21.341**	**$83.991**
Livable Community			
Residential Development	$0.000	$0.000	$0.000
Commercial Development	$0.000	$0.000	$0.000
Total Livable Community Benefits	**$0.000**	**$0.000**	**$0.000**
Grand Total Benefits	**$295.726**	**$166.791**	**$451.564**
Project Costs			
Capital Expenditures	$61.830	$61.830	$61.830
Incremental O&M Costs	$213.000	$213.000	$213.000
Total Costs	**$176.432**	**$176.432**	**$176.432**
Net Present Value	**$119.295**	**-$9.641**	**$275.133**
Benefit-Cost Ratio	**1.676**	**0.945**	**2.559**
Internal Rate of Return	**8.98%**	**2.94%**	**16.39%**

Figures represent present-day value, in millions of 2001 dollars, of benefits and costs over 30 years.

5.4 Highway Investment Project

Model 4 has been used to evaluate a highway investment project. This model, again, is based on the StratBENCOST model, customized for Canadian conditions.

5.4.1 Project Description

This project consists of adding one lane to an existing rural facility. Total project cost is estimated at $1.76 million. The project duration is 1 year. Other model inputs are provided in Table 68 below.

5.4.2 Model Inputs

Inputs for the highway case study are summarized in Table 68, below. Default values are used for all other input variables.

Table 68: Highway Case Study Inputs

Variable Description	Value / Comments
First Year of Analysis	2001
Number of Years in Analysis	20 years
Project Duration	1 year
Facility Length	3 km
Base Case: Facility Type (*)	10 Rural, 2 or 3 lanes
Base Case: Number of Lanes	2
Base Case: Facility Capacity	1,224 Vehicles per Hour
Base Case: Road Grade	1%
Alternate Case: Facility Type (*)	9 Rural, Multilane Partial Access Control
Alternate Case: Number of Lanes	4
Alternate Case: Facility Capacity	1,257 Vehicles per Hour
Alternate Case: Road Grade	1%
AADT in First Year	11,000
AADT Annual Growth Period 1	1.9%
AADT Annual Growth Period 2	1.5%
AADT Annual Growth Period 3	1.5%
AADT Annual Growth Period 4	1.5%
Percent of AADT in Peak Period	50%
Percent Cars Gasoline Fueled	85.6%
Percent Cars Diesel Fueled	14.2%
Percent Pick-Ups And Commercial Vans	0.2%
Percent Trucks Gasoline Fueled	54.5%
Percent Trucks Diesel Fueled < 8500 Lbs	0.0%
Percent Trucks Diesel Fueled > 8500 Lbs	45.5%
Current Pavement Service Index Value	3.1
Base Case: PSI After Resurfacing	3.1
Base Case: PSI After Repaving	3.1
Base Case: Resurfacing Deterioration Rate	0.046
Base Case: Repaving Deterioration Rate	0.046
Alternate Case: PSI After Resurfacing	3.4
Alternate Case: PSI After Repaving	3.4
Alternate Case: Resurfacing Deterioration Rate	0.046
Alternate Case: Repaving Deterioration Rate	0.046
Base Case: Construction Costs	$0.000M

Variable Description	Value / Comments
Alternate Case: Construction Costs	$1.776M
Base Case: Annual Maintenance Costs	$0.005M
Alternate Case: Annual Maintenance Costs	$0.013M

(*) The list of facility types is provided in Appendix B.

5.4.3 Simulation Results

The benefit-cost analysis results for the case study are presented in the table below.

Table 69: Highway Benefit-Cost Analysis Results

	Mean	90% Probability of Exceeding	10% Probability of Exceeding
Project Benefits			
Time Savings	$0.162	$0.084	$0.245
VOC Savings	$0.250	$0.211	$0.294
Emission Savings	-$0.138	-$0.239	-$0.071
Accident Cost Savings	$2.187	$0.928	$3.659
Total Project Benefits	**$2.461**	**$1.206**	**$3.983**
Project Costs			
Capital Expenditures	$1.691	$1.691	$1.691
Incremental Maintenance Costs	$0.100	$0.100	$0.100
Total Costs	**$1.791**	**$1.791**	**$1.791**
Net Present Value	**$0.670**	**-$0.586**	**$2.192**
Benefit-Cost Ratio	**1.374**	**0.673**	**2.224**
Internal Rate of Return	**8.66%**	**0.75%**	**17.36%**

Figures represent present-day value, in millions of 2001 dollars, of benefits and costs over 20 years.

6. THE FEDERAL ROLE IN URBAN TRANSIT

This chapter describes the current Canadian federal government role in urban transport, including issues such as planning and policy, service delivery, funding, and other support. It compares the current federal role with that of the United States and other industrialized countries, and presents options for changes to the current federal role.

Section 6.2 provides a context for the analysis, including a brief history of the federal role in urban transport, the current policy baseline, and a summary of findings from the Canada Transportation Act Review process (CTAR). A broad taxonomy of policy options is delineated in Section 6.3. In Section 6.4, the current federal role is compared with that in the United States and in other industrialized countries. Finally, Section 6.5 presents summary conclusions and selected recommendations.

It is important to note that, in reviewing alternative service delivery methods, this report does not recommend or endorse any particular approach, including the general notions of “innovative” finance or “alternative” service delivery. In some cases, an innovative financing strategy might involve methods of avoiding taxation or other transfer payments. The public policy pros and cons of such approaches are different depending upon the perspective from which the arrangements are viewed, federal, provincial local. This Chapter does not evaluate these pros and cons.

6.1 Federal Policy: History and Considerations Going Forward

6.1.1 History

Canada’s strong tradition of federalism has limited the national government’s role in many areas, including congestion management and, more generally, urban transportation. Provincial, metropolitan and municipal governments are largely responsible for planning, funding, constructing, and operating urban transport facilities.

The federal government imposed an excise tax on gasoline in 1975 and on diesel fuel in 1985. The tax, originally intended as a conservation measure during the energy crisis of the 1970s, generates revenues that are allocated to the federal government’s Consolidated Revenue Fund to support a broad range of federal programs.[21]

6.1.2 Current Federal Policy

The national government currently has no role in transit funding, organization, planning, or provision of service, except for some research and development programs. For example, the federal government has sponsored research and policy discussion on a national level in, among other areas, transit for people with disabilities and transit’s role in promoting sustainable development and greenhouse gas reductions. The research and development activities of the Transportation Development Centre, certain educational program (such as the annual

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[21] Planchard, Richardson, and Alavi, *Road Infrastructure Expenditures, Fuel Taxes, and Road Related Revenues in Canada*, 1996.

Transportation Week) and the CTAR process (see below) represent the nature of the federal government's role.

Transit subsidy policies vary substantially by province. Five provinces do not provide any routine capital or operating subsidies for transit, so all subsides in those provinces are municipal. Ontario announced the cessation of any new provincial funding in 1999, passing the responsibility to regional and municipal governments. In the other three provinces with major transit systems (Quebec, Alberta, and British Columbia), funding responsibility is shared by provincial and local governments. Fuel taxes and vehicle registration charges or surcharges provide some funding for transit agencies in these provinces.

Vancouver has a new regional transportation agency ("Translink") that has wide powers to operate and fund transit services and to fund most roads (except provincial highways). Translink has the authority to levy charges on motorists in the form of annual vehicle registration fees, parking surcharges, and road tolls. Montreal can levy surcharges on parking, but, as yet, has not done so.

The most common funding source for roads at the federal, provincial, and territorial levels is general tax revenue. Local governments fund their street networks mostly from property tax revenues. The CTAR analysis demonstrates that more is collected in road user charges and taxes than is expended on roads. The federal government contributes a relatively small amount to road programs – about $200-300 million per year. This despite the fact that the federal excise tax on fuel brings in about $4 billion annually (CTAR Report[22], Chapter 10).

6.1.3 Canada Transportation Act Review (CTAR) Findings and Recommendations

The recently completed comprehensive review of the Canada Transportation Act of 1996 (CTAR) addressed a series of issues related to national transportation legislation and related policy. Key observations about urban transportation and congestion management from the CTAR Report (Chapter 12) include:

1. The national interest in the success of urban transport is the efficient movement of people, which affects the economic and social well being of cities.
2. The most pressing policy issue appears to be future funding.
3. Transit is threatened by planning and infrastructure polices that serve car travel.
4. Transit service levels, fares, and subsidy amounts are decided by local or provincial elected officials.
5. Transit decisions are usually made with a commendable degree of consultation with transit users and taxpayers.

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[22] Minister of Public Works and Government Services, Canada*, Vision and Balance, Report of the Canada Transportation Act Review Panel*, 2001

In proposing alternatives to the current regime of transit planning, provision, and funding, the following points about urban transport are made in the CTAR Report (Chapter 12):

> The current status of urban transit reflects a mutual agreement [i.e., on the part of those parties mentioned in Items 4 and 5 above] that transit is a necessary exception to general policies of user pay, that the services are essential and worth their large subsidies, and that their delivery by government is appropriate.

The CTAR Report (Chapter 12) also contains the following recommendations with respect to congestion management:

> 12.1 – That transit operating agencies and their funding partners seek the most cost-effective ways of improving their services.
>
> 12.2 – That experimentation with innovative forms of service (smaller vehicles, shared taxis) be encouraged.
>
> 12.3 – That urban transit be permitted to qualify for funding from road user charges.
>
> 12.4 – That payment to transit authorities be made on the basis of their actual performance in inducing shifts from private automobile use to transit.

Importantly, while CTAR acknowledged the role of subsidy in financing public transit, the Commission's report emphasized that subsidy is a "second-best" solution, necessitated, in part, by the failure of highway authorities to levy tolls or other forms of roadway user charges that reflect the social marginal costs of congestion.

6.2 Available Policy Options

The federal government can directly or indirectly influence the nature of urban transport (and in the process help manage congestion) in various ways. These range from direct authority and responsibility (implementation and operation of transit service) to very indirect and nuanced participation in the form of facilitation, research and education. A taxonomy within which to consider the federal role in congestion management is displayed in Table 70, below.

Table 70: Taxonomy of Congestion Management Roles

Category	Role/Action/Activity
1. Planning and Policy (Law & Regulation)	Regional Planning Land use and development Environmental quality Resource Pricing Safety Taxation Travel restrictions and prohibitions
2. Implementation and Service Delivery	Project Planning Design Construction and right-of-way acquisition Operation and maintenance
3. Funding	Planning Transit capital facilities and right-of-way Transit operations and maintenance Other related facilities and services (Other Modes)
4. Facilitation	Public education Professional training Research and technical assistance Sponsorship Planning and mediation

As noted previously, the federal government has, at present, virtually no role in direct implementation of congestion management projects, programs and policies, and maintains only limited roles in funding and regulation. The government is, however, increasing its activities as a facilitator of congestion management strategies. The following material suggests whether, to what extent, and how it might increase its participation in other ways.

6.3 Current Policy and Practice in Other Industrial Countries

6.3.1 Introduction

This section summarizes recent and current practices with regard to the provision of urban transport services in several industrialized countries, including the United States. The subjects addressed in this section include three of the four areas listed in Table 70, above, namely:

- Planning and Policy Formulation
- Implementation and Service Delivery; and
- Funding

A rich source for international policy comparisons is a report prepared by the U.S. Transportation Research Board. In this research, funded by the Transit Cooperative Research Program (TCRP), a committee of experts was charged with comparing U.S. policies and attitudes about urban form, transit, and highways with those of other industrialized nations. The committee consisted of academics, transit operators and planners, and included representatives from Canada and the United Kingdom. The study was broadly defined, examining cultural and social differences as well as policy at various levels of government. While it did not directly pose the question of what the "ideal" role of a national government should be, there is much useful information contained in the report.

Beyond polices and funding methods for transit, the study final report, *Making Transit Work* (MTW)[23] identifies several "success factors" that affect the ability of transit to attract passengers and to serve as an effective tool for congestion management. Urban governance, land use, and co-ordination of transportation services are some examples (MTW, page 91).

The role that road policies play in relationship to transit service effectiveness also should be noted. One CTAR observation (No. 3, above) states that car travel is a "threat" to urban transport. Road transport, its governance and funding structure, play a key role in congestion management. The authors of *Making Transit Work* laud the Canadian example of planning and funding for both highways and transit being performed by the same levels of provincial and metropolitan government, and thus are seen as being highly co-ordinated and effective (MTW, page 103). One might look at ways the federal government could improve the situation further. For example, the federal government could further harmonize the two transport sectors without taking a direct role in doing so. It could adopt policies that provide incentives to the metropolitan agencies to co-ordinate road and transit even further. Policy options for transit necessarily involve the consideration of policies for planning, funding, and pricing of road travel in urban areas.

6.3.2 United States

6.3.2.1 Planning, Pricing and Other Policy Control

Since the *Making Transit Work* report was prepared from an American perspective, we will begin with examining the U.S. experience. American experts would argue that transit in Canada has been especially successful, in a league similar to Western European countries. The added value of Canada as a model for the U.S. is that urban growth in Canada has occurred, in many cases, relatively recently, as in the U.S., and unlike in Europe. Moreover, automobile fuel and other costs of auto ownership and operation have not been as heavily taxed in Canada as in Western Europe and elsewhere. From an outcomes perspective, Canadian urban transport is held up as a model from which the U.S. may draw lessons.

Making Transit Work (page 77, *et seq.*, page 91, *et seq.*) points out that, apart from cultural (value) differences that might explain differences in the success of transit in the U.S. as compared to Canada, the U.S. suffers from a number of major policy and procedural disadvantages, including:

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[23] U.S. Transportation Research Board, Committee for an International Comparison of National Policies and Expectations Affecting Public Transit, Special Report No. 257, *Making Transit Work: Insight from Western Europe, Canada, and the United States,* 2001.

1. Fragmentation of land use policy among the lowest levels of municipal government;
2. Lack of coordination between land and transportation planning;
3. Land use and infrastructure planning oriented toward auto travel;
4. Low motor fuel cost and taxation; and
5. Hidden subsidies and lack of comprehensive auto-related pricing signals.

The integration and co-ordination of land use and transportation planning and funding in Canada, in contrast to the U.S. situation, is a major advantage noted by the authors of *Making Transit Work*. Provincial and/or metropolitan government structure, organization and actions are put forward as examples of "best practices." They cite others who believe this arrangement instills greater spending discipline, reduces bureaucratic delays, and gives local governments the flexibility to meet their own particular transportation needs.[24] Notably, the lack of federal involvement [in Canada] in not an issue in the authors' view:

> "...there is virtually no federal involvement in transit funding or planning in Canada. Provinces and municipalities share responsibility for determining and implementing urban transport policy and are thus responsible for allocating subsidy funds" (MTW**,** page 141).

If there is any change in Canadian federal congestion management policy in Canada, according to this view, a primary goal should be to retain the benefits of the existing planning and funding structure.

Direct road pricing in the United States, as manifested in the implementation of toll roads, is more widespread than in Canada. Even so, it is employed as a means of raising revenue and generally not as a congestion management strategy. Since 1991, the United States federal government has employed a more deliberate policy of encouraging the use of tolls to finance highways, as documented by the U.S. Congressional Budget Office:

> "The toll provisions of ISTEA marked a major break with tradition. Beginning in 1916, the federal government had maintained a policy that required roads built with federal aid to be free of tolls. In 1956, the Congress reinforced the policy by decreeing that highways on the Interstate System would be toll-free. Over the years, some exceptions were carved out – for existing toll roads that became part of the Interstate System, for bridges and tunnels on the system, and for cases in which states paid back the federal aid they had received for a highway. But in general, until ISTEA (1991), the federal government had discouraged states from developing toll roads.[25]"

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[24] (Soberman, R., Urban Transportation in the U.S. and Canada, Logistics *and Transportation Review*, 1983, Vol. 19, No. 2, pp 99-109; Pucher, J., Public Transport Developments: Canada vs. The United States*, Transportation Quarterly*, 1994, Vol. 48, No. 1, pp.65-78; Cervero, R., Urban Transit in Canada: Integration and Innovation at Its Best, *Transportation Quarterly*, July 1986, pp. 293-316)

[25] U.S. Congressional Budget Office, *Innovative Financing of Highways: An Analysis of Proposals*, 1998

In recent years, a number of toll roads have been constructed in southern California, Colorado, and Virginia. In spite of their projected financial success, many of these facilities have been commercial failures, with bonds trading below par and downgraded to junk status in a significant number of cases.

The user costs of owning and operating a private automobile are relatively low in the U.S. They are higher in Canada and higher still in Western Europe. In considering the goal of congestion management, many researchers believe that the automobile must bear more of its share of the direct and indirect social costs of the congestion it creates. The number of passenger cars per capita in Canada is second only to the United States in a comparison including selected Western European nations (MTW, page 82). In the United States, there has been no effort to reduce or slow the growth of the passenger car fleet through taxation or registration, unlike in Europe, where that is a specific goal of government policy.

In a similar vein, U.S. taxes gasoline are among the lowest in the world, and the resulting low price encourages driving. Canadian fuel costs are lower than those of any of the Western European nations studied in the MTW research. While the cost of ownership affects how many cars are in the total fleet (in each country), the cost of fuel is the primary influence on the amount of driving. Not surprisingly, the U.S. leads most other nations in the amount of passenger car travel. Again, there has been no real effort to increase the cost of gasoline for congestion management purposes in the U.S.

Other measures to discourage car use are employed in Western European countries (such as roadway design features, strict limits on parking for new construction, and banning cars from a majority of streets in certain districts) are not employed in any significant way in the United States. In fact, in most American cities, the municipal governments prescribe a minimum number of public parking spaces. Canada is cited as maintaining parking policies more in line with those in Western Europe (MTW, page 85).

Land use decisions in the United States are reserved to the municipal level, with limited involvement from higher levels of government (MTW, page 92 *et seq.*). Local goals are to protect and enhance property values, which usually means low-density housing and discontinuous street systems that make provision of transit service difficult. Higher density housing almost always generates community opposition. In fact, the desire to enhance property values and raise property tax revenues is a primary concern of municipal government. The same can be said about sales tax revenue is some areas, as well. Since California constrained property taxes beginning in 1978, governments have competed with each other for new commercial development, especially retail, that would increase local sales tax revenue. Transportation issues caused by the approval of such developments are usually an afterthought.

There are rare examples in the United States of metropolitan or regional bodies that have exerted some power over land use, transportation, and taxation. Portland, Oregon is one, and to a lesser extent, Minneapolis-St. Paul, and Atlanta (MTW, page 92).[26]

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[26] (Downs, A., *New Visions for Metropolitan America*, Brookings Institution and Lincoln Institute of Land Policy, Washington, D.C. and Cambridge, Mass., 1994; Eplan, L., Atlanta Airs its Options, *Planning*, November 1999, pp 14-16; Katz, B., and J. Bradley, Divided We Sprawl, *The Atlantic Monthly*, December 1999).

Results in these regions have been mixed. In Portland, transit advocates argue that that city's aggressively transit-oriented planning process for year 2040, including an "Urban Growth Boundary" are succeeding, particularly with respect to preventing the worst of the "doughnut" effect seen in many urban areas (where poverty is concentrated in the central city and older suburbs and jobs and wealth flee to the outer suburbs). The real estate community in Portland, on the other hand, argues that growth restrictions have resulted in a rapid increase in housing prices, with a corresponding deterioration in affordability of housing for low-income residents.[27]

The Metropolitan Council of Minneapolis–St. Paul was created in 1967 by the Minnesota legislature for coordination of an area wide sewer system. Since then, responsibilities have expanded to include long-range plan development for services such as aviation, transportation, parks and open space, water quality, and wastewater management.[28]

A strong metropolitan transportation authority, the Georgia Regional Transportation Authority (GRTA), was approved for Atlanta in March 1999 by the Georgia state legislature. The GRTA's powers to regulate land use stem from the requirement that it review and approve so-called "Developments of Regional Impact (DRI)." If the GRTA Board feels that a DRI will have a negative impact on traffic or air quality, it can vote to withhold public money from roads associated with the development. (A super majority of local governments can override the decision to withhold funds.)[29] At this writing, it is too early to determine what the impact of the GRTA will have on Atlanta's congestion and air quality challenges.

6.3.2.2 Implementation and Service Delivery

"Contracting out" or competitive bidding for transit services is not widely used in the U.S. as means for delivering service. The exception is among the smaller operators and specialized services such as transportation for persons with disabilities, or maintenance. However, a few large systems such as Denver, San Diego, and Las Vegas have aggressively embraced the concept for significant portions of their operations. "Contracting out" is seen as a way to improve efficiency by allowing competition among various contractors, and has both supporters and detractors predictably arrayed across the political spectrum.

The overwhelming majority of public transportation services in the United States are provided by government monopolies. The irony is that the United States is perceived to be a major promoter and practitioner of free-market principles. Cox and Duthion (2001)[30] argue that when public transport companies were unable to obtain local or state regulatory approval to raise fares to cover costs, public transport policy was nationalized (federalized) and the public monopoly model replaced the former regulated private system. Along with the greatly expanded federal role came large infusions of capital funding and costly labour provisions. Cox and Duthion

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[27] Harmon, T., Portland, Oregon: Who Pays the Price for Regional Planning? How to Link Growth Management and Affordable Housing *Planners Network Online*, Number 128, March/April 1998

[28] Hall, D. Regional Profiles: Metropolitan Governance and Regional Planning
Four Cities, Four Approaches, *Planners Network Online*, Number 128, March/April

[29] Georgia Regional Transportation Authority, "GRTA to Review Large Development Projects," Press Release of September 14, 2000

[30] Cox, W. and Duthion, B. "Competition in Urban Public Transport A World View," Presented to the 7th Annual Conference on Competition and Ownership in Land Passenger Transport, June 2001

calculated that national transit spending per passenger trip increased 141 percent and total expenditures increased 155 percent (in constant dollars) from 1970 to 1999, while ridership increased six percent.[31]

During the 1980's, the Reagan administration explored competitive bidding. The percentage of services under competitive bid rose to 10%. Later administrations have not been interested in encouraging further efforts in this direction, so there has been little to no increase since that time. A major exception is paratransit (demand responsive services for senior citizens and the disabled), where 70 percent of services are competitively bid.

There are three metropolitan areas in the United States that employ various levels of competitive bidding: Las Vegas, San Diego, and Denver. Cox and Duthion (2001) performed case studies on all of them and found they experience significantly lower costs and higher productivity that the rest of the U.S. transit industry. A brief summary follows for each of these cities:

The City of Las Vegas established a new public transit bus system in the early 1990's that replaced a much smaller privately owned operation. Since the system was new and expanded, public transit unions did not oppose the competitive bidding of all services. In 1999, Las Vegas had the lowest cost per vehicle hour for any of the 33 largest U.S. bus systems. Ridership has climbed significantly compared to the previous system.

In San Diego, California, the Metropolitan Transit Development Board (MTDB), the agency which built the area's first light rail line, was authorized in the mid-1980's by the state legislature to oversee a gradual conversion to competitive bidding. The conversion is accomplished at the rate of employee attrition, so that no layoffs are required. As of 2000, approximately 44 percent of bus services were competitively bid. Competition has generated downward cost pressure on San Diego Transit, the governmental bus operator, whose costs per hour have decreased 17 percent since 1979. Competitively bid costs are about 42 percent lower than those of San Diego Transit.

A 1988 Colorado law mandated a partial (20 percent) opening of Denver, Colorado's Regional Transportation District (RTD) bus routes to competitive bidding. The portion of service required to be bid in this way was increased to 35 percent in 1998. Denver's requirement for competitive bidding is the only such mandatory arrangement in North America. Unlike the examples from Europe, Australia and New Zealand, the RTD, while overseeing the competitive process, is also still a significant provider of services whose operations are being spun off to private competitors. In addition, labour unions are interested in containment of the increase in privately operated services. Due to the controversies, various studies were commissioned by RTD, labour unions, and the state. In general, they show a significant efficiency benefit, although different assumptions produced a variation in the level of efficiency gains. The analysis by Cox and Duthion (2001) of these studies and their independent calculations show that, even with only 22.4% of service hours provided under the competitive program in 1999, costs per hour are below those experienced by RTD in 1978 (constant dollar comparison).

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[31] Estimated by the authors from American Public Transit Association and National Transit Database data.

The Table 71 below presents a summary of the Alternative Service Delivery picture in the United States.

Table 71: Summary of U.S. Experience with "Contracting Out"

Country	Description	Level of Governments Involved	Results/Benefits
United States	Very Little Competitive Bidding Except for Services for Elderly/Disabled and in Small Communities, and in Las Vegas, San Diego and Denver	Local Government Units Provide Transit Services	1. Relatively High Cost 2. Declining Annual Productivity (Vehicle Kilometres per Constant Dollar) Except in Three Cities Practising Competitive Bidding

Sources: Cox and Duthion (2001).

6.3.2.3 Funding

In the United States, the federal government provides roughly half of all transit capital funding and very limited operating funding.[32] (See Table 72, below.) States and local governments provide the remainder. For the most part, federal transit funding obligations are met from a 20 percent allocation of federal motor fuel tax revenue, though general revenue (principally from personal and corporate income taxes) is sometimes used. Federal law requires that federal funds be matched from non-federal sources at a ratio of not less than 20 percent non-federal to 80 percent federal. In practice, this non-federal matching requirement can sometimes exceed 50 percent. Besides the local match requirement, funding recipients must comply with numerous other federal requirements associated with federal funding assistance, as well as other specific provisions attached to transit funding, such as "Buy-America" provisions for rolling stock, "prevailing wage" labour laws, etc.

Table 72: Transit Funding Sources in the United States

Country	Operating Funding Support			Capital Funding Support		
	National	Regional	Local	National	Regional	Local
United States (a)	*(b)*	P	P	P	S	S

Source: *Making Transit Work*, page 142.

P – Primary role

S – Secondary role

a – Availability of dedicated revenue varies by state and locality.

b – U.S. operating support is more significant for smaller systems, but is still less tan 10% of total cost.

Some would argue that the need for transit authorities to comply with different, and often conflicting, federal requirements (MTW, page 139), compromises transit management autonomy

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[32] U.S. Transportation Research Board, Committee for a Study of Contracting out Transit Services, *Contracting for Bus and Demand-Responsive Transit Services: A Survey of U.S. Practice and Experience*, Special Report No. 258, 2001.

and results in inefficiencies in attaining broad regional goals. Nevertheless, while some countries in Western Europe, particularly Germany, provides block grants to local governments that can be used to subsidize transit, the magnitude of the federal assistance in the United States is such that almost never does a potential recipient decline them to avoid the restrictions attached.

The present U.S. focus on transit capital assistance, as contrasted with operating subsidies, has advantages and disadvantages. Major rail projects can obtain funding from the Federal Transit Administration's New Starts program. This program has enabled many transit rail projects in recent years; indeed, it is difficult to imagine how the major capital investments required by rail projects could be funded by state and local jurisdictions alone. On the other hand, some argue that the much greater availability of capital funding creates incentives for transit operators to implement capital-intensive solutions, and perhaps even to construct facilities or purchase vehicles that they cannot afford to maintain over the long term. The *Making Transit Work* report cites the danger of overcapitalization, as evidenced by the proliferation of rail projects (MTW, page 140).

So-called "innovative" financing strategies have been encouraged in the U.S. for some time by the Federal Transit Administration (and, to a lesser extent the Federal Railroad Administration and Federal Highway Administration). In 1998, the FTA published a handbook entitled *Innovative Financing Techniques for America's Transit Systems*. In it, the FTA encourages a number of methods for transit agencies to stretch existing funding or generate new revenues, including:

1. Certificates of Participation: State-issued, tax-free debt that results in the transit agency leasing the equipment or facility. Several transit agencies may time their rolling stock orders requirements in one purchase. The result is a stabilization and reduction in capital costs.

2. State Revolving Loan Fund: A state may use FTA grant funds to establish revolving loan funds. The interest income remains with the fund and can be used for additional loans.

3. Capital Leases: FTA funds may be used in repayment of capital leases.

4. Joint Development of Transit Assets: In some cases, land near a station can be developed by the private sector. In some cases, agencies could lease or mortgage a subdivided parcel that was not acquired by federal funds. Air rights over stations and/or right of way can also be leased or sold.

5. Cross Border Leases: The tax laws in some countries outside the United States provide an incentive for investors in that country to lease equipment to U.S. operators. A potion of the tax benefit in the lessor's home country is realized by the operator in lower lease costs.

6. "Super Turnkey" and other Private Financing: In a super turnkey project, a project engineer or consortium undertakes to build, operate for a time, and transfer a facility to a purchaser. Construction delays, start-up problems, and change orders are minimized.

7. Delayed Local Match: An FTA grantee may defer its share of a project under certain circumstances. The grantee may use the timing differences to engage in arbitrage with non-federal funds.

8. Toll Revenue Credits: The FTA allows revenues on public roads and bridges to be counted a part of the local match. However, those funds can be expended on another project. This is termed a “soft match.”

6.3.2.4 The U.S. Federal Program

With the federal government of the United States now having almost forty years of experience in funding public transit, it may be instructive to look at its experience as an indication of what such a policy and program decision can mean. The financial commitment from the federal government has varied as a function of national policies and national budgets, but has been particularly strong in recent years. Since 1991, under the Intermodal Surface Transportation Efficiency Act (ISTEA) and later the Transportation Equity Act for the 21st Century (TEA-21), there has been a commitment for a substantial program, funded largely from the federal gasoline tax, with a smaller share coming from general revenues. Currently, more than $6 billion a year is provided by the U.S. federal government in direct transit assistance, in addition to another $1 to $2 billion transferred to transit from so-called “flexible” funds where state and local governments have a choice of highway or transit projects. Total yearly spending on transit in the United States from all sources (for both capital and operating purposes) is about $15 billion.

The evolution of federal funding policy towards transit, both in terms of program structure and in terms of national expectations for transit performance has changed over time. The program began in the 1960s and 1970s as a part of general federal support for cities and urban development, reflected by the fact that the origins of the current Federal Transit Administration (FTA) trace back to a beginning as the Urban Mass Transportation Administration (UMTA) in the Department of Housing and Urban Development. It was well after the Department of Transportation (DOT) was created that the program was transferred by a Presidential reorganization order to DOT and even today the United States Senate has maintained the jurisdiction for oversight of the program through its Committee on Banking and Housing.

In those early years, the primary focus of UMTA was the stabilization of an industry undergoing significant change, moving private sector operations into the public realm and reorganizing most of them into public transit authorities of one sort or another. Another hallmark of the early development was the strong positioning of the federal government as a partner, but not a dominant funder, of these systems. Even today, the $6 to $7 billion annual commitment by the Federal Government to the development of public transit is matched almost 2 for 1 by state and local resources as well as by the revenues of the systems.

Moreover, while the initial stabilization of the industry led to a period in which a significant portion of the annual federal commitment was used for direct operating assistance, the legacy of the 1980s included a refocusing of the federal role. When the federal government, under President George H. W. Bush, recommitted to a strong transit role in the Intermodal Surface Transportation Efficiency Act of 1991, part of the dynamic was a redefinition of the federal role. Support from Washington, at least for the larger systems (regions of 200,000 population and more) is restricted to capital investment, and only within small regions and in rural America can federal transit aid be used, as a matter of local choice, for operations. Elsewhere, funds provided largely through formula grants with a formula at least partially reflective of transit need are dedicated for capital investment. In those larger metropolitan areas, transit grants of fixed and predictable amounts are allocated through the planning process to bus and rail rehabilitation and construction projects that rise in local priority, with a matching ratio of 80% federal and 20% local on each funded project.

Further emphasizing the federal commitment to capital investment, the current legislation maintains a relatively smaller share of funds, in the neighbourhood of $1.2 billion, for discretionary "new start" projects, most of which represent new fixed guideway systems or corridor extensions on existing systems. These projects are very competitive, with a degree of shared decision making by the Executive and Legislative branches, and with an effectiveness process of program justification administered by FTA. When such a project is undertaken, there is an implicit – but not contractual – Federal commitment to a fixed investment level for the project, to be delivered over a number of federal fiscal years. This commitment is embodied in a somewhat confusingly named "Full Funding Grant Agreement," not signifying that the federal government is committed to full funding but rather that the expressed amount is the full extent of federal participation, with state and local sponsors absorbing all other costs. In practice, the cost sharing on these discretionary projects has approximated 50% federal/50%state-socal, with the non-federal sponsors agreeing to less than the statutory 80% federal share as an inducement to project funding. The stability of these agreements is shown by the fact that in recent years it has been possible for local project sponsors to raise money in the financial markets in anticipation of their federal grants in order to accelerate projects.

In addition to its support of capital investment, the federal government, through the FTA, has carried out various research, development and policy projects to advance the state of the industry. The FTA is also a major participant, along with the Federal Highway Administration (FHWA), in the conduct of the federally-required transportation planning process leading to the adoption of regional transportation plans and programs and the linked process by which air quality standards are implemented.

With the maturing of the program has come a better-articulated set of policies that support Federal investment in public transit. This has been an evolutionary process, but one that has indeed accelerated in recent years. While it may have been fair to characterize the early program as largely oriented to giving budget relief to big city mayors and job opportunity to transit workers, the policy climate is now much more richly developed. Transit investment has come into its own as a tool of federal policies, and with the leverage afforded by substantial local funding, is serving as such an effective tool.

The U.S. government has in recent years adopted a program of strategic planning and performance management under the Government Performance and Results Act, which passed the Congress in 1993. Each federal department, including the Department of Transportation, is charged with the creation and periodic renewal of a guiding strategic plan and the development of annual performance plans to support their budget requests. These performance plans are very explicit in terms of the departmental goals, the strategies to be employed and the measures of success. Under this rubric, the maturing federal transit program has been recognized and managed as an element in department-wide strategic thinking. Within the Department's five strategic goals, namely Safety, Mobility, Economic Growth, Human and Natural Environment and National Security, there are explicit connections to the transit program and explicit results expected from the funds that are being invested. FTA is expected to articulate the case for its investments within this framework and to position rigorous justifications from local sponsors accordingly. Evidence of this comes not only through the FTA's budget documentation but also in their periodic reviews of program performance. As a matter of law, FTA is required to provide Congress with a biennial report on *Transit System Conditions and Performance*, paralleling a longstanding series of such reports for the nation's airports and highways. With the focus on policy, these transit documents have transformed from being wish lists for funding to actual measurements by which such funding contributes to acknowledged national goals. The measures of program performance are not just the physical condition of the nation's transit system, but the degree to which transit is contributing to public policy needs such as mobility, congestion management and community livability – strategies that support the goals of the Department of Transportation's strategic plan.

With articulated policies, and with alignment of agency goals such as those of the FTA with the broader goals of the USDOT, much greater opportunities open up for success. The concerns raised in earlier years that public transit was merely disguised revenue sharing or unrestrained subsidy exposure can be answered. The linkages between national, or even international, goals and the expectations for particular programs are measurable and it is clear that what can be measured is what will be managed. With the alignment of goals, the national government is better able to balance its investments as well as to demand similar degrees of analytical rigor from its partners in state and local government. The process is more transparent and documentable than in the past. It is also clear from experience that transit investment alone is not enough to achieve all of the hoped for results in terms of the agreed upon national goals. But where supportive state and local policies are essential, as in the area of land use or better transportation systems management, the leverage of nationally driven planning processes and the availability of limited but significant discretionary authority becomes a tool to encourage such supportive steps.

Because transportation strategies must now be measured very specifically, not only in terms of their national results but also in the way they play out at the local level, FTA has been compelled to develop a measurement framework designed to match goals with measurable metrics. Developed over the past five years, the FTA framework involves a battery of measurement and analysis techniques that employ the methods of Cost-Benefit Analysis to give quantitative expression to the policy goals of transit (congestion management, affordable mobility and livable communities) at both the national level and the local (project) level.

In summary, the U.S. federal transit program has evolved substantially from its big city beginnings. It is a program of national scope, urban and rural, large city and small. It is designed to achieve a partnership with substantial cost exposure at the local levels and with consequent concerns for efficiency. In addition, in recent years, it has become a program subjected to measurement and to the expectations that measurement brings to key issues of management and resource allocation. In the next two years, the U. S. government expects to reconsider the nature of its transportation commitments, with the expiration date of current authorizations under TEA-21 falling due in October 2003. The arc of policy development that began with ISTEA and has continued since is likely to continue – a multi-modal federal program, distributed in its delivery, but to an increasing degree accountable for results against an explicit set of policy objectives.

6.3.3 Western Europe and Other Selected Industrial Countries

6.3.3.1 Planning and Service Delivery

Governance of innovative programs for reducing urban congestion in Western Europe is moving toward implementation at the local level. A consistent theme in these countries, with the exception of the United Kingdom, is a trend toward more local control of transit and traffic management. If there is a trend, it is toward alternative service delivery. Responsibility for subsidy determination has been pushed to a lower level in some cases, but the provision of transit service has been shifted away from full, direct, government provision of service to various degrees of privatization in order to reduce or contain subsidies at the national level, and increase efficiency and quality of service. Most privatization mandates have come from the national government level, while competitive bidding is conducted at the local level.

General policies and practices are summarized here by country.

Germany. The federal role in urban transportation planning and service delivery is diminishing, although the federal government has a national transportation plan. The German constitution mandates the federal government to establish a national land use plan to serve as a guide for state and local planning. Local regulations must conform to these federal guidelines.

Scandinavia, Generally. Finland, Sweden and Denmark have all undertaken national public transportation policy reforms over the last decade. One of the main thrusts of the reforms has been to reduce unit operating costs of services by tendering (i.e. contracting out) services to the most competitive bidder.[33] The aims in all three countries appear consistent:

- Lower unit operating costs
- Improved quality of the bus fleet, and
- Improved customer satisfaction.

Sweden. A phased reform program in Sweden, underway since 1990, has shifted transit funding, policy, and operations responsibility entirely to the nation's 24 counties, with the major exception of the Stockholm region. In most cases, the counties have formed management companies responsible for policy, financing, marketing, bids, and contract supervision. Private bus firms and public-private rail companies operate local and commuter services. Counties and local communities share in the subsidy of services; the national government no longer provides subsidies.

Under a national agreement worked out by the major political parties, called the "Dennis Agreement," the national government is funding major rail (and road) infrastructure in the Stockholm region. Responsibilities for carrying out the transit reforms mandated by the Dennis

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[33] TCRP, *Research Results Digest*, May 1998, Number 27 *ibid.*

Agreement in the region are shared by Sweden's Road and Rail Administrations and Stockholm Transport (SL).[34]

As of 1999, operation of all bus and rail systems in Stockholm had been converted to competitive bidding. Capital and operating expenses have declined, service levels are up, productivity has increased, and ridership is at an all time high.[35]

Denmark. In 1989, Danish parliament began mandating competitive bidding of bus services in Copenhagen. The government owned bus system was not allowed to compete, so it could objectively manage the bidding process. Later, the scope of the bidding mandate was expanded and the operating portion of government bus company, HT, was privatized through sale. HT is now the entity that bids bus operation contracts. Any company, Danish or foreign, can freely compete for these contracts.

Competitive bidding of all bus services was completed in 1995. As in Sweden, operating costs have declined, service has increased, productivity is up, and ridership has increased by 9 percent following years of decline.[36]

The United Kingdom. The national government has considerable influence on urban governance. Most taxes are collected at the national level and distributed to local governments. Land use planning is the responsibility of local officials, but is subject to national guidance. Local authorities determine zoning in their urban development plans, which are subject to approval and revision by the national government.

The British national government establishes overall transportation policy and funding, while local authorities produce local policies and programs designed to implement nationally developed and funded policies. For example, privatization laws were passed by Parliament that changed the role of regional passenger transport authorities from transit service providers to a role of planning and decision-making regarding which supplemental bus services deserve subsidy. Highway planning is a national government responsibility. The co-ordination of urban transportation and land use occurs at the national level; however, local co-ordination is managed through local transport plans that are part of the broader urban development plans linking transportation programs with education, health, welfare, and other public services.

A. Bus Privatization. Beginning in 1984, Parliament took steps that eventually led to the opening of all bus routes to competitive bidding. Cox and Duthion (2001) report that the 1984 legislation and subsequent deregulation efforts were in response to a large increase in bus costs per vehicle kilometre. As measured by these researchers, the London Transport unit cost increase from 1970 to 1985 was 79 percent in real terms. By 2000, all bus routes were competitively bid. Costs per vehicle kilometre decreased 51 percent, service expanded 35 percent, and by 2000, ridership increased to the highest level since 1978. More than 95 percent of both capital and operating costs in London are now covered by passenger fares.

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[34] TCRP, *ibid.*

[35] Cox, W. and Duthion, B., "Competition in Urban Public Transport A World View"

[36] Cox, W. and Duthion, B. "Competition in Urban Public Transport A World View"

Outside London, public transit was deregulated, with similar cost savings, but substantial losses in ridership occurred. A few "socially necessary" routes continue to be subsidized.

The authors of MTW (page 76) express the conclusion that the results of British bus deregulation and privatization have been mixed, as some communities gained services and service quality and other lost. They consider the reduction in costs and therefore subsidies in London to be a significant benefit.

B. London Underground Public Private Partnerships ("PPP"). Most of the examples of competitive bidding involve bus services. The competitive bidding of the operation of rail transit systems or lines is less frequent. However, transport authorities in London have developed plans that could result in contracting out the operation of designated rail transit lines.

In 1997 Britain's national government decided that London Transport would enter into "public-private partnerships" with up to six private vendors or ("consortia"). Each vendor is to be responsible for the operation and upkeep of one or more designated lines on the London subway system (known as the "Underground"). Under the "PPP" framework, the private vendor is to be contractually responsible for achieving and sustaining a wide range of specified performance standards, covering schedule reliability, journey times, facility cleanliness, vehicle maintenance and availability and so on. Established by London Transport, the performance standards are meant to reflect economically optimal service levels as revealed by detailed Cost-Benefit Analysis studies. London Transport has spend the last three years conducting Cost-Benefit Analysis studies to determine the performance standards that, in effect it (London Transport) would put in place if it had sufficient capital funds. That level of service has been integrated into Requests for Proposal as the performance requirements that private vendors, using their own capital resources, will be expected to achieve in return for 100 percent access to the revenue stream from fares (for a 30-year contract period). The competition for PPP contracts is now underway.

The precision of the performance requirements set out in the RFP is evident in the following examples (excerpts from the RFP were made available to HLB by London Transport for the purposes of its report to the government of Canada):

Average scheduled journey times shall achieve the following averages, within plus or minus three percent, 95 percent of the time

	Average Journey Time Per Customer, (in minutes)
Bakerloo	**13.47**
Central	**21.56**
Victoria	**13.19**
Waterloo-City	**9.96**

Excess customer perceived journey time over and above the scheduled journey time caused by factors that prevent the immediate recovery of the train service following disruption

	Excess Customer Perceived Journey Time (in minutes)
Bakerloo	**2.74**
Central	**2.42**
Victoria	**3.18**
Waterloo-City	**2.33**

Standardized surveys have been developed for measuring performance on a regular basis. The contract defines a schedule of financial penalties for failure to achieve the targets, as revealed by the standardized surveys. The financial penalties increase in severity with the degree and duration of variances from the targets.

Although the RFP has been issued, the likelihood that PPPs will actually be established is in some doubt. The national government has decided to devolve the ownership and operation of the London Underground to London's new mayoral government. That new government has declared its opposition to the PPP concept, indicating that it would prefer to run the system along traditional public authority lines. The national government is insisting that the PPP framework must be implemented as a condition of devolution. The Mayor (Mr. Ken Livingston) is challenging the government in Court. The case is presently at the appeals level (the first trial having found in favour of the national government).

The Netherlands. The national government establishes land use directives for regions and has the authority to review all local land use plans and regulations for compliance. Most transportation planning is managed by the national government. As a result, both land use and transportation planning appear to be closely co-ordinated.

New Zealand. Beginning in the late 1980's the national government enacted reforms as part of an effort to stem the country's economic decline. Reformers targeted public transportation in order to curb government subsidies and improve efficiency in governmental transit agencies with a reputation for inefficiency. The Local Government Amendment Act required the separation of funding and service delivery, the sale of government-owned transportation assets and prohibited the continued government operation of transit services. The Transportation Service Licensing Act set up rules for competitive bidding of service and the development of plans by region councils as mechanism for determining which services would be subsidized.[37]

The nation's intercity and metropolitan rail assets were sold to a private consortium in 1993 ("Tranz Rail"), and Wellington and Auckland bus assets were sold to a company called Stagecoach in 1992 and 1998 respectively. Tranz Rail is a profit-making, publicly traded company. Freight business is the primary reason for the profitability; intercity passenger is a

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[37] TCRP, *Research Results Digest*, December 1999, Number 36

break-even operation and commuter rail requires continuing subsidies. Some observers have noted a lack of capital for Tranz Rail and a need for additional maintenance. Due to ridership increases and operating efficiencies introduced by Stagecoach, an increasing number of bus routes are self-supporting: 50% as of 1999. In Wellington, service levels have increased and ridership have increased dramatically and subsidy requirements have been reduced. Farebox recovery is 84%.[38]

In the view of the national government, the goal of subsidy exposure containment has been achieved. In all cases service and operating efficiency has improved. Capital investment is the responsibility of the private service providers.

Australia. The national government of Australia produced a National Competition Policy in the early 1990's. The policy recommends the "commercialization" of some government functions in the interests of increasing efficiency. Any inherent economic bias favouring public-sector service delivery should be removed. The comparison of costs of service between public and private service providers should be analyzed. The policy is not statutory, but has been embraced by the Australian states, the political subdivision below the national level. State governments, similar to Canadian provinces, possess wide authority, autonomy, and responsibility. Therefore, the degree of commercialization varies by state.[39]

Conversions to competitive bidding have been completed in Melbourne, Adelaide, and Perth. Noteworthy is the fact that two French companies, Connex and Transdev, are involved in the operation of bus and rail transit services in Melbourne, Perth and Sydney.[40] The local and state government authorities who solicit bids for services retain a large degree of control over many facets of service quality: fare and service levels, operating performance standards, and a prohibition against bus and rail competition. This model is similar to that in many European countries, and differs somewhat from the New Zealand policy of less government responsibility for and control of service quality.[41]

A summary and comparison of the Alternative Service Delivery policies and practices in selected countries is shown in Table 73 below.

6.3.3.2 Funding

Surface transportation funding in the West traditionally has been based on user fees – either directly in the form of transit fares or tolls, or indirectly through taxes on motor fuel and other auto-related products and services. Funding today comes from a much broader array of taxes, fees, assessments, charges, tolls and exactions, though auto-related taxes and charges remain central to both roadway and transit funding.

Funding responsibility for transit by level of government varies considerably from country to country though, as shown in Table 73, below, there is consistency with respect to operating

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[38] TCRP, i*bid.*

[39] TCRP, *Research Results Digest*, December 1999, Number 36

[40] Cox, W. and Duthion, B. "Competition in Urban Public Transport A World View"

[41] TCRP, *ibid.*

support – it is considered to be a local matter. Additional discussion of current funding practices in other industrialized countries follows immediately below.

Germany. The German federal government provides states with block grants that can be used to subsidize commuter rail services or otherwise employed to support mass transit. The federal government also contributes aid to specific capital projects, with state and local governments sharing in the cost using revenues derived from motor fuel taxes.

France. The national government finances transit directly in Paris and its surrounding suburbs. National subsides are minimal in the provinces, however, with the exception of funding for large rail transit additions or improvements.

Sweden. The national government's contribution is limited mainly to the funding of major rail infrastructure projects. In the case of Stockholm, an agreement between the political parties determined that the national government and the Stockholm County Council are funding new transit infrastructure in the that region.

United Kingdom. Most transportation financing is managed by the national government's ministry of transportation. The national government has primary responsibility for funding rail and bus transit in greater London. It also subsidizes commuter rail outside London by providing funds to local passenger transport authorities. In other areas, local authorities support some transit services with grant aid from the national government.

Netherlands. The national government provides most transit subsidies, contributing to both operations and capital in this small nation. It also sets fare and service policies.

Table 73: Alternative Service Delivery Experience in Selected Industrial Countries

Country	Description	Level of Governments Involved	Results/Benefits
Sweden	Competitive Bidding, National-Local Share in Capital Transit Investment in Stockholm	National Reform: County/Local Responsibility for Funding, Policy and Operations Except in Stockholm	1. Farebox recovery increase 2. Major cost savings at 75% of the transit lines that had been bid by 1997
Denmark	Full Bidding of Copenhagen Bus Services	National Policy, Bidding at Local Level (Administered by Government Bus Agency)	1. Reversed Ridership Decline 2. Service Increased. 3. Reduction in Operating and Capital Cost.
United Kingdom	Privatization of All Bus Services Through Competitive Bidding	National Policy; Bidding Administered Locally	1. Lower Cost and Subsidies 2. Service/Ridership Increase (London) 3. Ridership Losses (outside London)
New Zealand	Aggressive Privatization. Separation of Subsidy Funding and Service Delivery: Sale of Government-owned Assets and Prohibition of Government Provision of Services. Competitive Bidding for Operating Services.	National Government Reform Statutes, Local councils decide what services warrant subsidies	1. Subsidy containment 2. Reversed ridership declines 3. Government capital investment obligations drastically reduced
Australia	Competitive Awarding of Franchises, With Detailed Service Requirements; Some Direct Governmental Provision of Service Continues, but Operation Separated from Capital Assets	State-Initiated Based on General National Policy of “Commercialization”	1. Targeted reductions in state subsidy 2. Bus ridership and revenue increases in Melbourne 3. Productivity gains

Sources: MTW and Cox and Duthion (2001).

6.4 Conclusions and Recommendations

6.4.1 Introduction

In the view of many transit professionals, there is much to recommend the current Canadian system for transportation planning, programming and funding, and most would not support major changes in the federal role. As mentioned previously, the authors of *Making Transit Work* believe that a primary objective of any future change in federal policy should be to ensure that the benefits of the existing provincial and local system are not lost. Specific conclusions and recommendations are provided below.

6.4.2 Planning and Policy

Virtually all countries examined establish broad national policies regarding transport, land use, the environment, etc., but delegate detailed implementation to regional and local authorities. The current Canadian federal role is more limited than that found in most industrialized countries, in that most high level goals, objectives, and policies are set at the provincial level.

In concert with an expanded federal role in capital funding (see Section 5.5.4, below), the federal government should establish more explicit transit-friendly planning and policy principles (guidelines, goals, etc.) at the national level in order to channel regional and local decisions in the direction of a more efficient, resource-conserving urban transport system. Potential areas for these principles include:

- Land Use Planning Principles – Density, Open Space Preservation, etc.
- Tax policy initiatives – Feebate, etc.
- Road/Congestion Pricing
- Environmental, Conservation, and Health Principles

Table 74: Transit Funding Sources in Selected Countries

Country	Operating Funding Support			Capital Funding Support		
	National	**Regional**	**Local**	**National**	**Regional**	**Local**
Canada	-	**P**	**P**	-	**P**	S
Norway	-	**P**	**P**	-	S	**P**
Sweden	-	-	**P**	S	-	**P**
Denmark	-	-	**P**	S	-	**P**
Germany (*e*)	-	**P**	**P**	**P**	S	S
Netherlands	**P**	-	-	**P**	-	-
Austria (*e*)	-	**P**	**P**	**P**	S	S
France (*f*)	*(b)*	**P**	**P**	**P**	S	S
United Kingdom	*(c)*	-	**P**	*(c)*	-	-

Source: *Making Transit Work*, page 142.

Note: Most European *commuter* rail systems are owned and funded by national governments.

P – Primary role

S – Secondary role

b – Subsidies provided to the Paris/Capital Region only.

c – National government subsidizes rail systems, bus service in London, and selected bus service elsewhere.

e – Revenue from city-owned utilities may be used to transit operating deficits.

f – Employer transportation payment tax revenues are used for capital funding.

6.4.3 Implementation and Service Delivery

As detailed in Section 5.4, above, much has been made of "privatization," or contracting-out of public services to private, for-profit engineers, constructors, and operators in order to "rationalize" the provision of transit services by putting them on a "business" footing. Experience has shown, however, that wholesale efforts to "sell off" public transit assets to private interests are fraught with difficulty due to the complexity of issues, competing interests, and unforeseen ("unintended") consequences. While successful in small communities, fully privatized operations will frequently run afoul of formidable, conflicting political interests in large urban areas, particularly those associated with organized labour, disadvantaged groups, and neighbourhood organizations. At the same time, any number of "opt-out" clauses for the private operator may leave the public sponsor awash in controversy in the event that major service disruptions, fare increases, or other problems occur.

There can be little doubt that competition, properly controlled, can provide a number of benefits in the form of reduced costs, improved customer service, etc., however. The federal government should, therefore, encourage, though not require, local transit providers to seek competitive bids from private *and public* operators for discrete service elements such as, for example, a geographic grouping of bus routes, special or ancillary services and, possibly, select rail operations.

Experience elsewhere convincingly suggests that the federal government *should not* become directly involved in urban transport service implementation or operation except to provide technical oversight and assistance, quality assurance, and financial control when federal funds are involved.

For the same set of reasons, the government *should not* seek to increase funding assistance on a formula or block grant basis. Such funding can lead to undesirable project outcomes and could establish a basis for spiralling financial commitments.

6.4.4 Funding

Federal funding assistance is provided in a majority of the countries investigated for this analysis, particularly for capital construction and acquisition. In direct contrast, the trend has been *away* from federal operating support. The Canadian government should seriously consider establishment of a transit capital funding program *targeted* at specific types of projects and under specific sets of conditions. It has been the American experience that the FTA "New Starts" rail program provides a strong matching incentive for local governments, so much so that competition among regions for limited funding has pushed the local matching requirement up to as much as 50 percent from the 20 percent statutory minimum.

Through such a targeted transit capital program, the federal government could obtain real leverage with provincial and local governments with regard to land use, environmental, and efficiency goals and policies without risk of open-ended financial commitments. Such a program would not need to be limited to new rail projects, but could also address modernization of existing guideway systems, and bus-related capital investment as well.

The funding program as recommended steers a middle course among the mix of policy options described in Section 5.3. On one end of the continuum the federal government could make voluntary recommendations with respect to policy, which could be ignored. At the other end would be strong federal mandates, which could prove disruptive and counter-productive. The provision of limited financial incentives to provincial and local governments is an effective way to foster implementation of federal policies, especially as those polices evolve in the future.

6.4.5 Facilitation

The federal government should increase its investment in research, education, and direct technical assistance to transit service providers and project sponsors. Such services can not only improve project quality and cost-effectiveness, but also help in achieving broader policy goals with respect to land use, environmental protection, and economic development.

6.4.6 Use of Economic Benefits Model

In light of a prospectively greater federal role in urban transportation planning and funding, Transport Canada might consider employing the economic benefits model developed by HLB in one or more of several possible contexts, ranging from the evaluation of individual projects up to assessment of the entire national transportation program. The model could be used proactively to help define optimal planning and funding policy guidelines, project definitions, and funding program allocations, or retrospectively to evaluate the effectiveness of same, either in support of funding approval or in the context of post-facto research and program assessment. Further, Transport Canada might choose to employ the model directly, or simply to mandate or encourage its use by provincial and local governments in order to establish a consistent template for evaluation.

With respect to the possible nature of future federal roles and policies outlined in Section 5.3, a set of specific options for use of the model is suggested in Table 74, on the next page.

Table 75: Conceptual Economic Benefits Model Applications

Role/Activity	Model Use
1. Planning and Policy (Law & Regulation)	Analysis of benefit/cost implications of: • Regional transport planning • Land use and development planning • Resource pricing and taxation • Travel restrictions and prohibitions • Modal trade-offs • Federal budget trade-offs
2. Implementation and Service Delivery	Evaluate effectiveness and feasibility of: • Project alternatives • Service Delivery alternatives
3. Funding	Evaluate return on investment of funding options by: • Mode • Source • Service delivery option • Related policy guidelines and constraints
4. Facilitation	Use model: For education and training As a platform for economic & planning research In provision of technical assistance

APPENDIX A: ECONOMIC THEORY OF MODAL CONVERGENCE

The theory presented here follows the standard model from public economics of utility maximization under a budget constraint with an external effect. Consider an individual who derives utility from consuming z units per week of a basket of commodities. In order to generate the income required to purchase the consumption good, he (or she) must take x trips per week (say, five inbound and five outbound) from a residential area to a central business district. The individual derives disutility, however, from the amount of time spent traveling. While disutility may be derived differently from different types of travel time (i.e., driving, riding, walking, waiting in congestion, etc.) for simplicity, the individual is assumed to be indifferent between travel times of different types. The individual can choose to travel by one of two modes, highway or high-capacity transit, each of which has a money price associated with the trip.

If there are I individuals, the utility maximization problem of the ith individual is expressed as:

$$\max \; u^i(z, t)$$
$$s.t. \; x_1^i P_1 + x_2^i P_2 + z \leq y^i \qquad \text{eq. 1}$$

Where t represents time spent commuting, $x_1{}^i$ and $x_2{}^i$ are the number of trips taken by the highway and the transit modes, respectively. The prices P_1 and P_2 are the money cost of a trip by each mode, y^i is the individual's income and z is a numeraire representing all other goods.

The utility function is assumed to be continuous and twice differentiable, having the following properties:

$$u^i_z > 0, \; u^i_{zz} < 0, \; u^i_t < 0 \text{ and } u^i_{tt} < 0 \qquad \text{eq. 2}$$

The conditions on z are the regular strong concavity conditions for consumption goods. Time spent traveling is a "bad" which the individuals would be willing to pay to avoid. Concavity with respect to t implies an increasing marginal disutility – the more time spent traveling, the greater the disutility from additional travel time.

The individual must allocate his total number of trips among the two modes:

$$x^i = x^i_1 + x^i_2 \qquad \text{eq. 3}$$

The trip time by the highway mode is an increasing function of the number of trips taken by all travelers:

$$t_1 = d + a\left(\frac{X_1}{v - X_1}\right)^b \text{ where } X_1 = \sum_{i=1}^{I} x_1^i \qquad \text{eq. 4}$$

d represents an uncongested, "freeflow" travel time and v represents the capacity constraint of the highways, i.e., the upper bound on the number of trips which could be taken by highway which would result in gridlock and an infinite trip time (the extreme case, of course, is not actually observed but this formulation represents a stylized version of the congestion dynamic). a and b are structural parameters reflecting the speed-volume relationship of the highway network. X_1 represents the total number of trips by all travelers via the highway mode.

The high-capacity transit mode is assumed to be completely unaffected by additional trips and the trip time is a fixed value:

$$t_2 = c \qquad \text{eq. 5}$$

The transit mode is assumed to be a "high-speed" mode where the linehaul segment of a journey is rapid relative to, say, the expressway segment of a highway journey thus compensating for slower speeds accessing the high-capacity mode including walk and wait times.

The absence of an external effect from additional riders on the high-capacity mode is expressed by eq. 5. Of course, crowding on transit results in some riders standing and other inconvenience. However, the key operational assumption is that travel times on the high speed mode are unaffected by changing volumes of passengers which corresponds to the actual scheduling practice in rail transit systems.

Time spent commuting is given by the sum of trips weighted by the average time per trip. The ith commuter's total travel time is given by:

$$t^i = x_1^i t_1 + x_2^i t_2 \qquad \text{eq. 6}$$

The total trip time by the individual can be expressed as a function of the number of highway trips by substituting eq. 4 and eq. 5 into eq. 6:

$$t^i(x_1^i) = x^i c + (d - c) + a\left(\frac{X_1}{v - X_1}\right)^b x_1^i \qquad \text{eq. 7}$$

The first order conditions of utility maximization are given by:

$$P_1 - P_2 = \frac{u_{x_1}^{\;i}}{u_z^i} = \frac{u_t^i}{u_z^i}\,\frac{\partial t^i}{\partial x_1^i} \qquad \text{eq. 8}$$

Where:

$$\begin{aligned}\frac{\partial t^i}{\partial x_1^i} &= (d - c) + a\left[\frac{X_1}{v - X_1}\right]^b \left[1 + \frac{x_1^i\ b\ v}{(v - X_1)\ X_1}\right] \\ &= t_1 - t_2 + \left[\frac{abv}{v - X_1}\right]\left[\frac{x_1^i}{X_1}\right]\left[\frac{X_1}{v - X_1}\right]^b\end{aligned} \qquad \text{eq. 9}$$

Some individuals will maximize utility by choosing all trips by one mode or another. However, some individuals will find their optimum allocation of trips by a mix of trips on both modes.

These are "casual" switchers – that is, their circumstances or preferences do not lock them into a particular mode – and they correspond to the modal explorers discussed in the introduction. Note that eq. 9 can be re-arranged to give:

$$\left[(P_1 - P_2) \frac{u_z^i}{u_t^i} \right] - \left[\left(\frac{abv}{v - X_1} \right) \left(\frac{x_1^i}{X_1} \right) \left(\frac{X_1}{v - X_1} \right)^b \right] = t_1 - t_2 \qquad \text{eq. 10}$$

Or, the condition under which door-to-door journey times across modes will be equal is given by:

$$\left[(P_1 - P_2) \frac{u_z^i}{u_t^i} \right] = \left[\left(\frac{abv}{v - X_1} \right) \left(\frac{x_1^i}{X_1} \right) \left(\frac{X_1}{v - X_1} \right)^b \right] \qquad \text{eq. 11}$$

Condition 11 tells us what combinations of prices, congestion, personal preferences and highway speed-flow relationship will result in equal travel times. However, it can be readily shown that under the assumptions described above – especially the assumption of a growing marginal disutility with respect to travel time – with sufficient levels of congestion both the left and right hand sides of eq. 11 approach zero.

What happens under congested conditions? The left hand side tends to zero due to the growing marginal disutility from increased travel time (also, the left hand side approaches zero with increasing income – the individual becomes indifferent to the price differential as trip cost consumes a smaller portion of his income). The theory also implies that congestion pricing will be less effective as congestion becomes more severe. It can be readily shown that if u_t^i is not bounded then for any combination of prices and capacity equation parameters, and for any small value $\varepsilon > 0$, there is a level of congestion (number of total trips) sufficiently large such that:

$$|t_1 - t_2| < \varepsilon \qquad \text{eq. 12}$$

APPENDIX B: HIGHWAY FACILITY TYPES

Table 76: Highway Facility Types

No.	Location / Facility Type
Urban	
1	4 Lanes Full Access Control
2	6+ Lanes Full Access Control
3	4 Lanes Partial Access Control
4	6+ Lanes Partial Access Control
5	2 or 3 Lanes
6	Multilane Undivided
7	Multilane Divided
Rural	
8	Multilane Full Access Control
9	Multilane Partial Access Control
10	2 or 3 Lanes
11	Multilane Undivided
12	Multilane Divided