Benefit Cost Analysis Guidebook

Guidelines for the Benefit Cost Analysis
Of Highway Improvement Projects
In
British Columbia

BRITISH
COLUMBIA

Ministry of Transportation and Infrastructure
Revised August 2014

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Introduction

The objective of this Guidebook is to provide guidance on benefit cost analysis for highway improvement projects in British Columbia so that the analysis carried out by different analysts is reliable, consistent, and comparable.

It is important to recognize that an evaluation of an incomplete or inappropriate set of options, no matter how sophisticated, will not generally assist in identifying the best course of action. It may simply serve to explain why one sub-optimal option is better than another. Therefore it is imperative that a thorough and appropriate set of options be developed for each project.

The objective of benefit cost analysis is not only to produce descriptive economic indicators such as Benefit Cost Ratio and Net Present Value to support option selection, project ranking, and programming. In addition, benefit cost analysis is directed at supporting a rational, systematic, and objective approach to:

- making an early determination of whether an option should be considered for further analysis (i.e. if an option is not yielding positive performance indicators based on a high level evaluation, our understanding of the problem or our perception of the solution may be flawed)

- assist in assessing whether the range of options is consistent with the problem (i.e. if the magnitude of the problem is minor in the short term and amplifying over time, we should not only be considering major short term investments that chase longer term benefits with high up-front costs)

- assessing optimal timing (i.e. is it more cost-effective to defer an investment for five years rather than proceed with implementation in the short term)

- assessing optimal phasing of a package of improvements over an extended horizon period (i.e. is it more cost-effective to proceed with a minor intersection improvement in the short term, construct a flyover in the medium term and defer full interchange construction to the long term)

- understanding which scope elements are consuming costs out-of-proportion with expected benefits

- comparing a comprehensive range of options directed at resolving the identified problem (i.e. to answer the question of what are we getting for the money)

- evaluating the merit of incremental scope additions during planning, design or construction

Chapter 1

Context for Benefit Cost Analysis – Transportation Investment Plan, Business Cases, and Multiple Account Evaluation

This chapter discusses the ministry's Transportation Investment Plan, Business Cases, and Multiple Account Evaluation (MAE) providing context for benefit cost analysis in British Columbia.

1.1 Transportation Investment Plan

Capital expansion projects add capacity, improve mobility and accessibility, and improve safety. Examples include 4-laning, passing lanes, realignments, grade separated interchanges, and major intersection upgrades.

Capital expansion projects are approved by the Capital Program Board and funded from the ministry's Transportation Investment Plan (TIP). There are 2 general phases of funding in the TIP:

1. Pre-project development funding (for planning)
2. Project funding (for design, property acquisition, and construction)

The selection of projects for pre-project development funding involves a variety of ministry staff and takes into account a number of factors including high level planning work such as system level performance analysis, systems plans, and corridor plans which should ideally indicate in reasonable detail that a problem exists and at a high level that viable options exist.

Pre-project development funding generally funds the project planning phase including data collection, project level performance analysis, problem definition, option generation, preliminary design as needed to adequately develop the options, option evaluation (including risk and sensitivity analysis), and an implementation plan. The two primary outputs of the planning phase are a project planning study and a project business case.

Whereas the planning study is a write-up of all of the work undertaken during the project planning phase, the business case is more focused on making a specific recommendation and providing justification for that recommendation, all in support of a request for "project funding". Business cases must be submitted to the Planning and Programming Branch.

Project funding generally funds preliminary design, functional design, detailed design, property acquisition, and construction. The business case that was developed at the end of the planning phase should be updated after detailed design and before proceeding with property acquisition and construction.

1.2 Business Cases

A typical business case has 2 main components:

1. a recommendation (including an implementation plan)
2. justification for the recommendation

Recommendation

The recommendation answers the questions: what, where, how much, when, how and who – answers to the latter 3 questions form the basis of an implementation plan.

The recommendation should generally include:

- a description of the recommended option
- a description of where the project is located
- a project cost estimate (including all project related costs) for the design, property acquisition, and construction of the recommended option
- a schedule
- a project budget for the design, property acquisition, and construction of the recommended option – developed based on the project cost estimate, the proposed schedule, and the ministry's approved Highway Construction Inflation Rates.
- details on how design will be carried out – in-house or consultant
- a description of how construction will be delivered – day labour, conventional design and tender, design-build, etc.
- the organizational structure of the team carrying out the design or construction

Justification

The justification component answers the question – why. Why should the decision makers approve the recommendation?

In general, justification should include any information that describes significant pros and cons of the options. At a minimum, it should address the following:

- Problem Identification
- Problem Definition
- Option Development
- Option Evaluation (MAE, including benefit costs analysis)

- Uncertainty and Risk

It is important to recognize that good justification requires more than just an evaluation of the options.

Problem Identification

Problems are identified by carrying out performance analysis (safety, mobility, reliability, and infrastructure condition) to determine existing performance and then comparing that to acceptable threshold values to identify deficiencies.

Proof that performance is below an established threshold is an important part of the overall justification behind a recommendation.

For more information see "Guidelines for Preparing MoTI Business Cases, Appendix 1 – Problem Identification for MoTI Business Cases".

Problem Definition

Problem definition is the process of carefully studying the identified deficiencies to fully understand their root causes. In many cases, the root cause(s) of a deficiency is not obvious, and a detailed study of adequate data (safety, traffic, etc.) and the site are required. This step is critical to the success of the entire process, as cost effective options cannot be developed without a full understanding of the root cause(s) of the problems.

Problem definition is therefore a key part of the overall justification behind a recommended improvement.

For more information see "Guidelines for Preparing MoTI Business Cases, Appendix 2 – Problem Definition for MoTI Business Cases".

Option Development

Option development is the process of generating all relevant and feasible options to address the performance problems which have been identified and defined. If the list of options is long, it is advisable to carry out a preliminary screening evaluation (high level evaluation) to reduce the list to a reasonable number before developing the options further to support the option evaluation step that follows.

It is critical that all relevant and feasible options be identified. The evaluation of an incomplete or inappropriate set of options, no matter how sophisticated, will not generally assist in identifying the best course of action. It may simply serve to explain why one sub-optimal option is better than another.

Often project proposals are presented in isolation and compared only to a do-nothing or status quo base case. This is generally inadequate. If there indeed is a problem, then it is likely that any proposed solution may appear attractive. However, it may not be the best solution to pursue. What is required is the identification and consideration of a wide range of possible solutions to the problem at hand. Creative and innovative thinking are essential.

Clearly demonstrating that a reasonable process was followed (e.g. consultation with diverse groups) and a wide range of options were developed is an important part of the overall justification behind a recommendation.

For more information see "Guidelines for Preparing MoTI Business Cases, Appendix 3 – Option Development for MoTI Business Cases".

Suggestions to enhance the generation of options:

- Begin with a clear understanding of the root causes of the identified deficiencies.
- Make use of good brainstorming techniques.
- Don't be too quick to focus in on the most obvious or conventional options - some "lateral thinking" to identify unconventional options may yield a better solution or at least improve the more obvious solutions.
- Include diverse individuals, groups and organizations in the process. The different perspectives and expertise of users, stakeholders, and other government agencies make for a broader range of options.
- Challenge proponents of a particular option to consider what they would or could do without it.

Sometimes the best option will consist of a combination of a number of different actions rather than a single action. A preliminary list of possible actions includes:

- actions that moderate the need for transportation (i.e. land use, zoning and settlement planning)
- actions that encourage the use of other transportation modes (i.e. provision of additional non-road infrastructure)
- actions that use existing highway capacity more efficiently (i.e. transportation demand management and transportation system management)
- actions that preserve and protect the highway infrastructure (i.e. highway maintenance and rehabilitation, corridor protection)

Preliminary options that should be considered for all projects:

- alternate project scheduling (i.e. optimal timing and phasing)
- alternate project resourcing (i.e. cost-sharing, private-public partnerships, user/beneficiary pay)
- alternate design standards/geometry
- alternate design configurations within the selected route

- alternate routes within the corridor
- alternate materials and methods of construction
- non-transportation alternatives
- improvements to other modes of transportation
- enhanced maintenance and rehabilitation alternatives to delay the need for a capital improvement

The Base Case

The list of options must always include the Base Case – the existing highway receiving the minimum level of expenditure required to maintain a minimum acceptable level of service, sometimes referred to as the “do minimum”. In the option evaluation step, each option will be evaluated relative to the base case before being compared to one another.

Typically, the do minimum includes maintenance and rehabilitation funding to maintain the current standard. It is important not to overstate the scope of the do minimum, i.e. to only include in the do minimum, work which is absolutely essential to preserve a minimum acceptable level of service.

In some cases, the existing level of maintenance and rehabilitation may not be the do minimum. A lower level of maintenance and rehabilitation spending may be adequate to keep the road open, and the existing level of spending should be evaluated as an option along with other improvement options.

Similarly, replacement should not automatically be assumed to be the do minimum for a deteriorated bridge. If there are alternate routes for traffic, the do minimum may be to close the existing bridge and reroute traffic.

Option Evaluation

Option evaluation is the process of evaluating the options that were generated in the option development step. If the original list of generated options is long, it is advisable to carry out a preliminary screening evaluation (high level evaluation) first, to reduce the list to a reasonable number before developing the options further and before carrying out a detailed evaluation of each option.

The ministry’s detailed evaluation framework is called Multiple Account Evaluation (MAE). An MAE evaluates each option under 5 different accounts: financial, customer service, environmental, economic development and social/community.

The financial account addresses 3 categories of agency costs:

- Capital Costs (less salvage value)

- Annual Maintenance and Operating Costs
- Periodic Rehabilitation Costs

The customer service account addresses 3 categories of road user benefits:

- Travel Time Savings
- Collision Savings
- Vehicle Operating Cost Savings

Together, the financial and customer service accounts form the basis of a benefit cost analysis.

In short, an MAE evaluates the costs (financial account), benefits (customer service account), and impacts (environmental, economic development, and social/community) of each option.

The evaluation of each option, including the base case, under each of the 5 accounts is the most important part of the overall justification behind a recommendation. It presents all of the important implications of each option in a consistent framework that clearly explains the trade-offs that must be made in choosing one option over another.

Chapter 2 provides more detail on MAE and Chapter 3 provides more detail on benefit cost analysis. As well, additional information is available in the ministry document "Guidelines for Preparing MoTI Business Cases, Appendix 4 – Option Evaluation Guidelines for MoTI Business Cases".

Uncertainty and Risk

Uncertainty is an inherent part of any capital highway improvement project. For example, there is uncertainty in many of the factors used to estimate costs and benefits, as well as uncertainty in estimating the social, environmental and economic development impacts of a project. Where there is uncertainty, there is risk of an adverse outcome. For example, the costs could be larger than estimated, the benefits could be smaller than estimated and the impacts could be worse than estimated. Clearly the level of uncertainty diminishes with the improved understanding that comes from each subsequent stage of project development. As the level of uncertainty diminishes, so too does the level of risk.

Where uncertainty and risk are significant, they should be explicitly identified and assessed in the business case. This requires a careful review of the assumptions made in the evaluation. For example, review the uncertainty in estimates of key information, review critical assumptions, review values that were estimated versus measured, review the reliability of information sources, etc.

Sensitivity and scenario analysis are two good ways to deal with uncertainty and risk.

Sensitivity analysis is the process of varying an analysis input and determining the effect on the analysis outputs. Scenario analysis involves analyzing the combined effect of a change in a whole set of assumptions (e.g. "best case", "most likely" or "worst case" scenarios).

The assessment of uncertainty and risk should serve two basic purposes:

- it should clearly identify the sources and nature of the uncertainty facing different options and the associated risk on the evaluation results
- it should evaluate the flexibility of the options to respond to uncertain, unfolding events, and comment on how this flexibility can be managed and enhanced through appropriate risk management strategies

Clearly an assessment of uncertainty and risk is an important part of the overall justification behind a recommendation.

Chapter 2

Multiple Account Evaluation

2.1 Introduction

Multiple Account Evaluation (MAE) is an option evaluation technique to help decision-makers choose between options to address a defined set of objectives[1]. This technique presents all of the important implications of each option. The implications are presented in a consistent framework which, as much as possible, is free of previous value judgments and facilitates fair comparison of the options.

Important decisions are never free from value judgments. What the MAE technique does is to make these value judgments explicit, and to preserve for the decision-maker the right and ability to apply these judgments according to the ultimate accountability for the decision.

The options developed for evaluation are a critical part of the process. A good understanding of the problem and some creative thinking are needed to be sure that all reasonable options have been considered. Transportation is usually not an end in itself, but a means to accomplish other personal or societal goals. There are usually many ways to accomplish these goals, and all reasonable options need to be considered.

MAE involves estimating the outcome or impact in each of a number of accounts for each option. These accounts represent different areas of concern to decision-makers, such as customer service or environmental impact. The definitions of the accounts have been standardized to facilitate comparisons. Some accounts can be evaluated in monetary terms (e.g. the financial account and the customer service account present the results of a benefit cost analysis), and others are better evaluated in non-monetary terms, both quantitative and qualitative.

The resulting evaluation under each account clearly explains the trade-offs that must be made in choosing one option over another. Usually, one option will not be better than all others in every account. Decision-makers then decide between the options, by choosing the option with the most acceptable combination of outcomes for the accounts.

To summarize, MAE is a multi-criteria decision matrix tool designed to:

- provide a balanced view to decision makers - understanding the inevitable trade-offs which are required in any decision
- compare options within a project

1 The MAE framework presented in this document is based on : (a) “Multiple Account Evaluation Guidelines”, Crown Corporations Secretariat,1993; and (b) “Multiple Account Evaluation Guidelines for Transportation Investment Evaluation”, Coopers & Lybrand , Multi-Agency Draft, 1996.

- draw comparisons with other projects
- facilitate comparison with other program needs (such as health, education and social services)

A typical MAE includes a matrix that clearly summarizes the evaluation of the base case and each option under each account (see sample next page), along with supporting information that explains the evaluation summarized in the matrix.

The summary matrix can be used to define critical values - i.e. the amount that a non-monetized advantage or disadvantage would have to be in order to offset identified financial effects. As well, by identifying advantages and disadvantages, the summary matrix may suggest reconfigurations of projects that better serve all accounts. For example, a project with significant financial advantages, but serious environmental impacts, may be improved by greater investment in mitigation.

Typical Multiple Account Evaluation Summary Matrix

OPTION / ACCOUNT	Base Case	1 Passing Lanes then 4 lanes	2 Pass.Ln. converted to 4 lanes	3 Staged 4 Lane Sections	4 Bypass Option: Existing Route	4 Bypass Option: Bypass Route
FINANCIAL (millions $)			millions $1997			
Capital Cost (PV)	$1	$120	$130	$125	$1	$200
Annual Maintenance	$0	$1	$1	$1	$0	$1
Resurfacing (PV)	$5	$7	$7	$8	$5	$6
Life Cycle Cost (PV)	$9	$132	$142	$138	$223	
Incremental Cost		$123	$133	$129	$214	
CUSTOMER SERVICE			millions $1997			
Time (PV)	$273	$218	$218	$218	$100	$119
Accident (PV)	$146	$102	$102	$102	$38	$64
Vehicle Operating (PV)	$730	$715	$715	$723	$276	$319
Total	$1,149	$1,036	$1,036	$1,043	$917	
Incremental Benefit	$0	$113	$113	$106	$232	
Annual Closures (hrs)	80	80	80	60	60	20
NPV		($10)	($20)	($23)	$18	
B/C Ratio		0.9	0.8	0.8	1.1	
SOCIAL/COMMUNITY						
Average Daily Traffic (noise, pollution)	8000	8000	8000	8000	3000	5000
Residences Impacted	166	166	166	166	166	5
Business/institutional	71	71	71	71	71	0
Business Takings	0	1	1	l	0	0
Residential Takings	0	6	6	7	0	2
Commmunity Severance	⊙	●	●	●	❍	❍
Community Plans	⊙	❍	❍	❍	●	●
Business Impact (equity)	⊙	❍	❍	❍	●	⊙
Visual Impact	⊙	⊙	⊙	⊙	⊙	●
ECONOMIC DEVELOPMENT						
[redacted]		[redacted]	[redacted]	[redacted]	[redacted]	
ENVIRONMENTAL						
Land Requirements	0.0	5.0	7.0	7.0	0.0	20
Fuel (million litres)	1,825	1,900	1,900	2,000	800	1,000
CO (million kg)	456	475	475	500	200	250
Site Rehabilitation	❍	❍	❍	❍	❍	❍
Wildlife	❍	⊙	⊙	⊙	❍	●
Water Pollution	❍	⊙	⊙	⊙	❍	●
Special Areas	none	none	none	none	none	historic site

KEY

❍ Good
⊙ Fair
● Poor

PV=Present Value
NPV = Net Present Value

2.2 MAE Accounts

There are five standard accounts:

- Financial
- Customer Service
- Environmental
- Economic Development
- Social/Community

A discussion of each account follows.

It is suggested that the reader also review the ministry document "Guidelines for Preparing MoTI Business Cases, Appendix 4 – Option Evaluation Guidelines for MoTI Business Cases".

Financial Account

The Financial Account summarizes the present value of cost to the infrastructure provider for each option. Capital costs (less salvage value), periodic rehabilitation costs, and annual maintenance and operating costs are modeled over 25 years for the base case and each option. Present values are calculated using the ministry's discount rate. The cost of each option is then calculated as the incremental increase in the present value of these agency costs for each option relative to the base case.

Agency costs should be estimated in constant dollars (ignoring inflation) for the financial year in which the evaluation is being prepared (typically the current year). Interest payments, inflation and depreciation should not be included.

A list of potential financial indicators can be found in Table 1 at the end of this chapter.

Customer Service Account

The Customer Service Account summarizes the benefit that road users ("the customers") derive from each option. Travel time, accident, and vehicle operating costs (i.e. road user costs) are modeled over 25 years for the base case and each option. Present values are calculated using the ministry's discount rate. Road user benefits are then calculated as the incremental reduction in the present value of road user costs for each option relative to the base case.

User costs should be estimated in constant dollars (ignoring inflation) for the financial year in which the evaluation is being prepared (typically the current year). Inflation and depreciation should not be included.

A list of potential Customer Service indicators can be found in Table 1 at the end of this chapter.

Environmental Account

The Environmental Account documents the nature, magnitude, significance and mitigation of the major environmental impacts of the options.

There are a wide range of environmental impacts that could be relevant including: pollutant emissions to land, water and air, land and natural resource use, and wildlife and habitat impacts.

Environmental impacts should be documented from a local, regional, provincial, and global (e.g. greenhouse gases) perspective.

Generally, environmental impacts will be assessed in non-monetary terms. Assessment in monetary terms requires developing estimates of the social external cost (or benefit) on health, resource use and the environment.

The non-monetary assessment should identify the nature of the impacts and provide an assessment of their significance. As with the customer service account, it can be helpful to determine the critical value that key impacts would have to have in order to outweigh advantages (or disadvantages) on other accounts.

A list of potential Environmental indicators can be found in Table 1 at the end of this chapter.

Economic Development Account

This is not a straightforward account. The Highway Planning & Programming Branch's Manager, Economic Analysis must be contacted if the economic development account is thought to apply to any project under consideration. See the ministry document "Guidelines for Preparing MoTI Business Cases, Appendix 4 – Option Evaluation Guidelines for MoTI Business Cases".

Social/Community Account

The Social/Community Account documents the major impacts on the social fabric, values and goals of directly affected communities or groups.

This account should simply identify the nature of the impacts and provide an assessment of their significance. It could include impacts on community population stability, community services, quality of life, income distribution or equity considerations. It should not include impacts already documented under the other accounts.

A list of potential Social/Community indicators can be found in Table 1 at the end of this chapter.

2.3 Table 1 – MAE Account Indicators[2]

This table provides an extensive list of indicators for 4 of the 5 standard accounts: financial, customer service, environmental, and social/community.

Note that only a few of the indicators are mandatory for every project. Those that are mandatory are identified within the table. All other indicators are project specific. Generally, project specific indicators shall only be evaluated if agreed to by the project team or specifically requested by the decision-makers. Inclusion of a project specific indicator shall be based on a clear understanding of the value of the indicator to the decision making process, the cost to evaluate the indicator and the expected level of accuracy in evaluating the indicator.

Additional Accounts and Indicators, other than those identified below, may be appropriate for some projects.

Financial Account

Capital Costs (mandatory)	Quantitative	The present value of capital costs (less salvage values) for the proposed project, including planning, design, property acquisition and construction costs.
Increase in Periodic Rehabilitation Costs (mandatory)	Quantitative	The present value of rehabilitation costs with the improvement minus the present value of rehabilitation costs without the improvement, including pavement resurfacing and bridge rehabilitation.
Increase in Annual Maintenance and Operating Costs (mandatory)	Quantitative	The present value of average annual operating costs with the improvement minus the present value of average annual operating costs without the improvement.
Return on Investment	Quantitative	Return on Investment is a possible measure where private/public sector partnerships are developed

2 Some of the indicators in this Appendix are from: (1) P. Bein, “The Policy Context of the South Coast Transportation Plan”, 1994; and, (2) A. Greer, Crown Corporation Secretariat. “Multiple Account Evaluation of Rapid Transit Options For Greater Vancouver: BC Transit: 10 Year Development Plan, 1994.

Taxes/Charges	Quantitative	Potential benefiting area taxes or development cost charges. Expressed as the NPV of costs over the analysis period.

Customer Service Account

Value of Travel Time Savings (mandatory)	Quantitative	The present value of travel time costs without the improvement minus the present value of travel time costs with the improvement.
Route Travel Time	Quantitative	Travel time with and without the improvement.
Route Time Saved	Quantitative	Travel time without the improvement minus travel time with the improvement.
Value of Safety Savings (mandatory)	Quantitative	The present value of accident costs without the improvement minus the present value of accident costs with the improvement.
Savings in Vehicle Operating Costs (mandatory)	Quantitative	The present value of vehicle operating costs without the improvement minus the present value of vehicle operating costs with the improvement.
Flexibility to Add Capacity in the Future	Qualitative	Flexibility of the option to be further improved in the future to meet increased demand from potential changed demographic, land use and transportation requirements.
Consistency with other Transportation Plans	Qualitative	Comment on how well each option fits into local, regional, and provincial transportation plans, and the options relative importance in accomplishing the objectives of these plans.
Accessibility	Qualitative	Access to and from the secondary and local road network.
Network Connectivity	Qualitative	Comment on the relative contribution of each option to the completeness of connectivity between major activity centres and corridors in the multi-modal network, considered separately for goods and people movement.
Modal Integration	Qualitative	How well does the option support, enhance and integrate with non-automobile movement of people and goods.
Reliability	Qualitative	Comment on the consistency of the quality of the user's experience with the transportation service over a period of time.

Emergency Response	Qualitative	The impact of the option on emergency response to major and routine emergencies.
Incident Management	Qualitative	Comment on the options ability to handle traffic management during incidents.
Constructability	Qualitative	Impact to traffic during construction, number of stages and length of construction, ease of construction.
Mobility	Qualitative	Comment on the extent to which mobility is affected by each option.
Net Present Value (mandatory)	Economic Indicator	The present value of road user benefits minus the present value of agency costs.
Gross Benefit-Cost Ratio (mandatory)	Economic Indicator	The present value of road user benefits divided by the present value of agency costs.

Environmental Account

Emissions NO_X , VOC and CO_2	Quantitative	Tonnes of reduced (or increased) emissions and the NPV of benefits (or costs) from reduced (or increased) emissions over the analysis period.
Particulates	Quantitative	Tonnes of reduced (or increased) particulates and the NPV of benefits (or costs) from reduced (or increased) particulates over the analysis period.
Vegetation and Soils	Quantitative/ Qualitative	Impact to rare, unique and valuable vegetation. Impact to sensitive, productive and contaminated soils.
Site Rehabilitation	Quantitative/ Qualitative	Amount and degree of site rehabilitation required as a result of each option.
Water Quality (surface and groundwater)	Qualitative Quantitative	Will construction and operation significantly degrade (or improve) water quality? Tonnes of reduced (or increased) water pollution and the NPV of benefits (or costs) from reduced (or increased) water pollution over the analysis period.
Environmentally Protected Areas	Quantitative	Area impacted and degree of impact.
Ecological Integrity	Qualitative	Fragmentation of environmentally sensitive areas. Severance of wildlife corridors.
Wildlife	Quantitative/ Qualitative	Impact to wildlife. Impact to rare wildlife. Wildlife-vehicle collision rates.

Aquatic resources	Quantitative/ Qualitative	Impact to fish. Impact to rare and important fish.
Hydrology and Drainage	Quantitative/ Qualitative	Impact to natural hydrology and drainage features.
Non-renewable Resources	Quantitative/ Qualitative	Non-renewable resources that will be consumed as a result of each option.
Energy Consumption	Quantitative	Quantity of reduced (or increased) energy consumption and the NPV of benefits (or costs) from reduced (or increased) energy consumption over the analysis period.
Waste	Quantitative	Tonnes of reduced (or increased) waste and the NPV of benefits (or costs) from reduced (or increased) waste over the analysis period.
Health Care Costs	Quantitative	Reduction (or increase) in health care costs due to pollution related illnesses.

Social/Community Account

Residential Impacts (e.g. access or severance impacts)	Quantitative	Number of residences impacted
Residential Takings	Quantitative	Number of residences displaced (or partial takings)
Business Impacts	Quantitative	Number of businesses impacted
Business Takings	Quantitative	Number of businesses displaced
Park and Recreation Impacts	Quantitative	Number of parks or other recreational facilities impacted
Park and Recreation Takings	Quantitative	Number (or area) of parks or other recreational facilities displaced
Noise and Vibration	Quantitative/ Qualitative	During and after construction
Aesthetic Impacts	Qualitative	Relative impact of each option
Community Severance	Qualitative	Fragmentation of the community. Severance of residences and community facilities.
Future growth and development in the corridor	Qualitative	Relative impact of each option
Effectiveness in promoting compact metropolitan areas	Qualitative	Qualitative assessment of the effectiveness of each option in promoting urban densification and other region specific social goals.

Integration of new technology into the transportation system	Qualitative	Qualitative assessment of how easily new technology can be integrated into the Transportation System.
Transportation service equity	Qualitative	The impact on users of transit and other non-automobile modes of transportation.
Equity impact	Qualitative	Do some groups gain at the expense of others (e.g. commuters vs. recreational users, or through traffic vs. local traffic)
Consistency with land use and community plans	Qualitative	Evaluate how well each option fits into local, regional, and provincial land use plans, Official Community Plans, Major Street Network Plans, etc., and the options relative importance in accomplishing the objectives of these plans.
Future land use implications	Qualitative	An assessment of significant and irreversible future land use implications.

Chapter 3

Benefit Cost Analysis Basic Concepts

This chapter reviews some of the basic concepts related to the benefit cost analysis of highway improvement projects. A more detailed review can be found at a number of transportation agency web sites including Transport Canada, Caltrans and the Australian Government Department of Transport.

Benefit cost analysis involves the estimation of the present value of agency costs and the present value of road user benefits associated with a project. It is part of the ministry's overall Multiple Account Evaluation (MAE) framework. The agency costs are summarized in the Financial Account, and the road user benefits are summarized in the Customer Service Account.

3.1 Agency Costs *(Financial Account)*

For the base case and each option, there are 3 categories of agency costs that need to be modeled over the 25 year analysis period. The categories are capital costs (less salvage value), periodic rehabilitation costs (less salvage value), and annual maintenance and operating costs. The magnitude and timing of costs in each category need to be modeled. The present value of cost for each category is then calculated using the ministry's standard discount rate.

In benefit cost analysis, the costs of each improvement option (the proposed case) are expressed relative to the base case. So the present value of agency costs for any option are equal to the incremental increase (from base case to proposed case) in the present value of capital costs (less salvage value), periodic rehabilitation costs (less salvage value), and annual maintenance and operating costs (m&o). Mathematically it looks something like the formula below, where PV = present value, bc = base case, and pc = proposed case.

PV Agency Costs =
[(PV capital – PV salvage),pc – (PV capital – PV salvage),bc] +
[(PV rehab – PV salvage),pc – (PV rehab – PV salvage),bc] +
[(PV m&o),pc – (PV m&o),bc]

Note that the PV of capital and therefore salvage in the base case is often zero. Also, rehabilitation costs near the end of the analysis period may have a significant salvage value that should be accounted for.

3.2 User Benefits *(Customer Service Account)*

For the base case and each option, there are 3 categories of road user costs that need to be modeled over the 25 year analysis period. The categories are travel time costs, collision costs, and vehicle operating costs. The magnitude and timing of user costs in each category need to be modeled. The present value of cost for each category is then calculated using the ministry's standard discount rate.

The benefits of each improvement option are simply the incremental reduction in user costs from the base case to the proposed case. So the present value of user benefits for any option are equal to the incremental reduction (from base case to proposed case) in the present value of travel time costs, collision costs, and vehicle operating costs. Mathematically it looks something like the formula below, where PV = present value, bc = base case, and pc = proposed case.

PV Road User Benefits =
[(PV travel time),bc – (PV travel time),pc] +
[(PV collisions),bc – (PV collisions),pc] +
[(PV vehicle operating),bc – (PV vehicle operating),pc]

To be consistent with the MAE framework that considers all societal costs and benefits, all beneficiaries of a project must be considered in the analysis (e.g. impact to road user costs on other routes must be considered).

So benefit cost analysis of highway improvement projects boils down to estimating three agency costs (capital, rehabilitation and maintenance) and three road user costs (travel time, safety and VOC) for the base case and each option over 25 years. From there it's just a mathematical process of discounting to get present values, calculating the present value of agency costs and road user benefits based on the formulas provided above, and then carrying out the simple calculations discussed below to determine net present value and benefit cost ratio.

3.3 Discount Rate

In benefit-cost analysis, future values are discounted to present values using the discount rate. The discount rate is the real rate of interest (nominal rate of interest minus inflation) – sometimes referred to as the real cost of long-term borrowing. The discount rate is prescribed by the B.C. Ministry of Finance.

The present value of a given cash flow decreases as the discount rate increases. Because capital costs are incurred in the short term and road user benefits are experienced throughout the 25 year analysis period, an increase in discount rate has a greater effect on the present value of road user benefits than it does on the present value of agency costs. Consequently, highway improvement projects become less viable as the discount rate increases.

3.4 Benefit Cost Measures

Benefit cost measures fall into two general categories: "Measures of Worth" and "Measures of Timing". The three primary Measures of Worth are Net Present Value, Benefit Cost Ratio, and Internal Rate of Return. The two primary Measures of Timing are Payback Period and First Year of Benefits.

Net Present Value (Measure of Worth)

For highway improvement projects, Net Present Value (NPV) can be defined as the present value of road user benefits minus the present value of agency costs. NPV is the primary measure of worth.

NPV = (PV of Road User Benefits) – (PV of Agency Costs)

Benefit Cost Ratio (Measure of Worth)

Benefit cost ratio (B/C ratio) can be defined as the present value of road user benefits divided by the present value of agency costs.

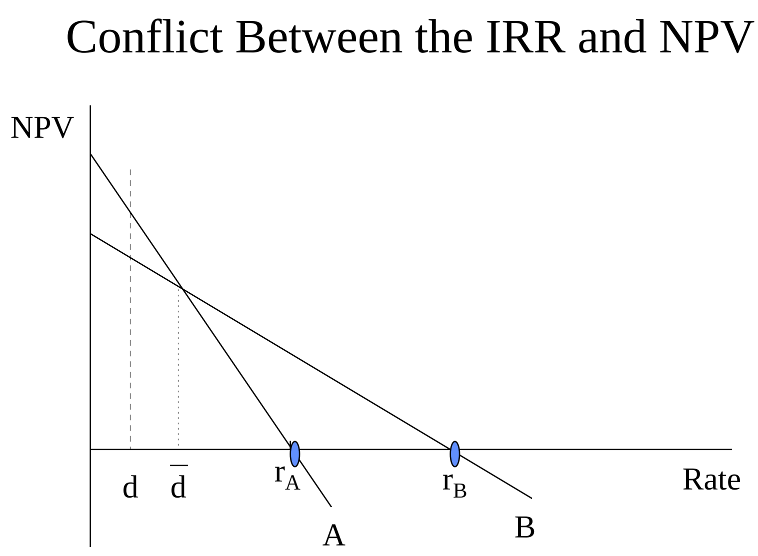
B/C ratio = (PV of Road User Benefits) / (PV of Agency Costs)

One difficulty in using the B/C ratio is its sensitivity to the definition of benefits and the definition of costs. While it would seem a positive benefit should be identical to a negative cost of the same magnitude, it clearly makes a difference in the calculation of the ratio whether the value is added to the numerator or subtracted from the denominator. This difficulty is likely to arise in the assessment of external effects, for example, pollution. Is a reduction of pollution a positive benefit to society or a reduction in cost?

Internal Rate of Return (Measure of Worth)

For highway improvement projects, the Internal Rate of Return (IRR) is the discount rate that makes the present value of road user benefits equal to the present value of agency costs (i.e. NPV = 0, B/C = 1). Given 2 or more options, the superior option is the one with the largest IRR.

Project selection based on IRR and NPV can lead to different conclusions. Refer to the figure below. For two projects, *A* and *B*, NPV is plotted as a function of the discount rate. If *d* is the accepted discount rate, then project *A* is superior to project *B* by the NPV criterion. The IRRs for the projects are r_A and r_B (i.e. NPV = 0). Note that r_B is greater than r_A; therefore, project B is superior to project A by the IRR criterion.



Source: P. Sassone, William A. Schaffer
"Cost-Benefit Analysis: A Handbook

Payback Period (Measure of Timing)

For highway improvement projects, payback period refers to the time (number of years) required to recover the agency costs with road user benefits.

When two projects are compared based on payback period, the project with the shortest payback period is considered best; however, project selection based on payback period can be misleading. For example, in the table below both project A and B involve an initial outlay of 100 and last two years. Although project A has the shortest payback period (1 year), it would be shortsighted to choose project A over project B as B has a much greater return after 2 years.

Project	C_0	$B_1 - C_1$	$B_2 - C_2$
A	100	110	1
B	100	0	1000

First Year of Benefit Ratio (Measure of Timing)

The First Year of Benefit Ratio is the benefits in the first year after construction divided by costs to date (including interest paid during construction) expressed as a percent.

This measure suffers the same shortsightedness problems as the payback period. It does not consider benefits in the second and subsequent years after the completion of the project. It favors small projects. The smaller of two projects may have a higher First Year Benefit ratio, yet yield a smaller total net benefit.

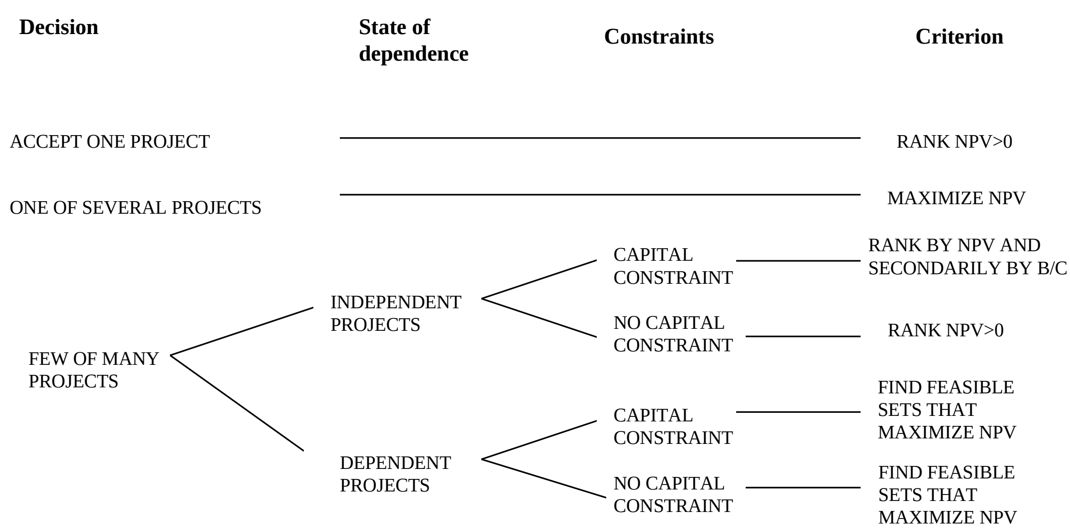
3.5 Recommended B/C Measures for Program Development

Under conditions of a constrained budget, the objective of Program Development is to select the combination of projects that maximize the cumulative NPV for the budget available. This is usually, but not always, the same projects that would be selected by descending order of Benefit Cost Ratio.

Accordingly, the 2 most important benefit cost measures are NPV and Benefit Cost Ratio.

The decision tree below illustrates how the NPV and B/C ratio should be used to select projects under various circumstances.

A DECISION TREE



Source: P. Sassone, William A Schaffer
“Cost-Benefit Analysis:A Handbook”

3.6 Data Requirements for Benefit Cost Models

Data requirements for benefit-cost models generally fall into the following categories:

- Economic data
- Project data
- Traffic data
- Collision cost data
- Travel time cost data
- Vehicle operating cost data
- Agency cost data

The level of data detail required in each category varies from model to model, but may include some or all of the following.

Economic Data

Economic data is needed to calculate the present value of future costs and includes the current year, analysis period, and discount rate.

Project Data

Project data generally describes project geometry and may include:

- environment (urban or rural)
- length of analysis section
- lane and median widths
- number of lanes
- speed limit
- lateral clearance
- specific grades
- curve radius
- capacity
- design speed
- running speed
- surface deterioration
- % no passing

Traffic Data

Traffic data includes traffic volumes and growth, percent trucks, vehicle classification, traffic profiles and speed-volume relationships.

Collision Cost Data

Collision cost savings are calculated as the incremental reduction in collision costs for each option relative to the base case.

Collision costs are a function of the expected number of collisions by severity and the unit cost of collisions. Typical data requirements to estimate the expected number of collisions include:

- collision prediction models for segments (function of service class)
- collision prediction models for intersections (function of intersection type)
- the observed number and severity of collisions in recent years
- the safety design features that differ between the base case and the proposed case (e.g. lane width, shoulder width, horizontal alignment, etc.)
- collision modification factors and the proportion of collisions targeted by each CMF for each safety design feature

Travel Time Cost Data

Travel time savings can typically account for 60% of total project benefits. Travel time savings are calculated as the incremental reduction in travel time costs for each option relative to the base case.

Travel time costs are a function of the time required to travel the route (dependent on route length, average speed, congestion, type and number of intersections) and the unit value of time.

Vehicle Operating Cost Data

Vehicle operating cost savings are calculated as the incremental reduction in vehicle operating costs for each option relative to the base case.

Vehicle operating costs are based on traffic and highway conditions. The general algorithm for estimating vehicle operating costs (VOC) is:

VOC = AADT X distance X consumption rate X unit price

Five components are typically included in VOC cost calculations:

- Fuel
- Oil
- Tires
- Maintenance
- Use (distance) related depreciation

The variables used to predict consumption rates of each VOC component typically include:

- speed
- grade
- curvature
- number of speed change cycles
- number of stop cycles
- surface conditions
- temperature

Unless there is a reduction in the length of the alignment or the elimination of some tight radius curves or long steep grades, VOC usually makes up less than 5% of total project benefits. Moreover, highway improvement projects often result in increased VOC due to higher speeds leading to greater fuel consumption.

A 1% reduction in the length of an alignment can easily increase project benefits by 10%. While a 1% reduction is small it represents 1% of a very large accumulation in user costs (accident and time as well as VOC) over the life of a project and as a result, shows up as a large benefit.

Agency Cost Data

Agency cost data includes the magnitude and timing of capital less salvage, periodic rehabilitation, and annual maintenance/operating costs.

Chapter 4

Default Values for Benefit Cost Analysis

A report describing the ministry's standard default values for benefit cost analysis can be found on the Highway Planning and Programming Publications Internet page of the ministry's Internet site. The defaults have traditionally been updated every 4 or 5 years since about 1997.

These defaults must be used in order to achieve the ministry's objective of reliable, consistent, and comparable evaluations for all projects. If an alternative value is deemed to be more appropriate for a particular project, a thorough explanation must be provided in the business case.

Chapter 5

Guidelines for Benefit Cost Analysis

5.1 General Guidelines

The analysis period shall generally be 25 years (i.e. horizon year = current year + 25).

Agency costs and road user costs will need to be estimated and modeled over the 25 year analysis period for the base case and each option.

All costs shall be modeled in the year in which they are expected to occur, but shall be estimated in constant dollars (ignoring inflation) for the year in which the evaluation is being prepared (typically the current year). In other words, regardless of the year or years in which costs are expected to occur, estimate costs in today's dollars and model them in the year they are expected to occur.

This works because the discount rate is based on the real rate of interest (i.e. nominal interest rate minus inflation rate), and the ministry's default unit costs, although not updated every year, are assumed to reflect constant dollars for the year in which an evaluation is being prepared.

5.2 Agency Costs

For the base case and each option, there are 3 categories of agency costs that need to be modeled over the 25 year analysis period. The categories are capital costs (less salvage value), periodic rehabilitation costs (less salvage value), and annual maintenance and operating costs. The magnitude and timing of costs in each category need to be modeled. The present value of cost for each category is then calculated using the ministry's standard discount rate.

In benefit cost analysis, the costs of each improvement option (the proposed case) are expressed relative to the base case. So the present value of agency costs for any option are equal to the incremental increase (from base case to proposed case) in the present value of capital costs (less salvage value), periodic rehabilitation costs (less salvage value), and annual maintenance and operating costs (m&o). Mathematically it looks something like the formula below, where PV = present value, bc = base case, and pc = proposed case.

PV Agency Costs =
[(PV capital – PV salvage),pc – (PV capital – PV salvage),bc] +
[(PV rehab – PV salvage),pc – (PV rehab – PV salvage),bc] +
[(PV m&o),pc – (PV m&o),bc]

Note that the PV of capital and therefore salvage in the base case is often zero. Also, rehabilitation costs near the end of the analysis period may have a significant salvage value that should be accounted for.

To be consistent with the MAE framework that considers all societal costs and benefits, all resources allocated to the completion of a project must be considered in a benefit cost analysis. For example, cost-shared amounts should not be subtracted from costs.

5.2.1 Capital Costs

An estimate of the total capital cost to complete each option (a "project cost estimate") is required and should include project management, planning, design, property acquisition, construction, and supervision costs. Cost estimating guidelines and tools are available on the Highway Planning and Programming Publications web page of the ministry Internet site.

Project costs which have already taken place or are irrevocably committed, and have no salvage or realizable value, are termed sunk costs, and should not be included in the project cost estimate (e.g. investigation, research and design costs already incurred).

On the other hand, project costs which have already been incurred, but still have a market value which can be realized, are not sunk costs and should be included in the project cost estimate (e.g. land).

Where land is already owned by the Ministry it shall not generally be treated as a sunk cost if it can be sold for alternative use.

When an existing road is closed, any land which becomes available for sale shall be included as a cost saving if it can be sold for alternative use.

Capital costs shall be estimated in constant dollars (ignoring inflation) for the financial year in which the evaluation is being prepared (typically the current year). Interest payments, inflation and depreciation shall not be included.

Generally the timing and magnitude of capital costs shall be based on the earliest feasible construction start, the anticipated number of years of construction, and the portion of the "project cost estimate" anticipated to be spent in each construction year.

The earliest feasible construction start will depend on the estimated schedule to complete design and acquire property, and is generally independent of expectations of funding.

Some benefit-cost tools assume that all capital costs occur the first year after the current year. If the anticipated cash flow of capital costs is different, then it can easily be converted to an equivalent single cost in the current year + 1 as per the example below. These same tools may also assume that the benefit stream begins in the second year after the current year (i.e. the year after the assumed construction year). If agency costs are being converted as per the example below, then the benefit stream would also need to be adjusted for consistency.

Assume the *Current Year* is 1997. A project is estimated to cost a total of $6,000,000 (all in 1997 dollars). The project is expected to be constructed over 3 years starting in 1999. It is estimated that $2,000,000 (1997 dollars) will be spent in each of the three years. Road user benefits start to flow from the project in 2002.

Year	**Estimate of Cost In Constant 1997 $s**	**Cost Discounted to 1998 (using a 6% discount rate)**
1999	$2,000,000	$1,886,792
2000	$2,000,000	$1,779,993
2001	$2,000,000	$1,679,239
TOTAL:	$6,000,000	**$5,346,024**

The equivalent single cost in 1998 is $5,346,024 (still in 1997 $s). If the tool is counting benefits in 1999, 2000, and 2001 these should be removed from the benefit stream.

It is important to understand the difference between the “project cost estimate”, the present value of the project cost estimate, and the project budget. These 3 values will all be different for the same project, and therefore when costs are presented in a business case they must be accurately described.

The “project cost estimate” has been described above. The present value of the project cost estimate will always be less than the estimate itself due to the effects of discounting as per the example above. The project budget is developed from the project cost estimate, the project schedule, and the ministry’s approved highway construction inflation rates and will always be greater than the project cost estimate. See the ministry’s cost estimating guidelines referenced above for further information and guidance.

Salvage Value of Capital Costs

If the expected service life of an improvement extends beyond the analysis period then there will be a residual (salvage) value at the end of the analysis period that must be accounted for. One good way to estimate the salvage value is to convert the initial cost of the improvement to an equivalent annuity over the expected service life of the improvement. The portion of the annuity beyond the analysis period is salvageable and can be discounted back to the horizon year to determine the salvage value at the end of the analysis period. This salvage value at the end of the analysis period must then be discounted back to the current year and subtracted from the present value of the initial cost of the improvement.

Given two improvements:

1. A new piece of road with assumed service life of 50 years
2. A new bridge with assumed service life of 80 years

Comparing the salvage value as a percentage of initial cost, the percentage value will be larger for the bridge due to its longer service life.

The table below provides some general guidance. It was developed using a discount rate of 6%, an analysis period of 25 years, and assuming the initial cost occurs at the end of year 1.

Expected service life of improvement	Salvage value at the end of the analysis period, as a percentage of initial cost	Present value of the salvage value, as a percentage of initial cost
50	82%	20%
80	97%	24%

5.2.2 Periodic Rehabilitation Costs

Periodic rehabilitation costs shall be estimated in constant dollars (ignoring inflation) for the financial year in which the evaluation is being prepared (typically the current year). Interest payments, inflation and depreciation shall not be included.

Ideally, rehabilitation costs should be based on local experience. Alternatively, the ministry's default unit costs can be used.

Generally, the service life of new pavement can be assumed to be 15 years.

Pavements resurfaced near the end of the analysis period are assigned a salvage value equal to:

Salvage value of resurfacing = Resurfacing cost x (1-N/10)

Where, N is the number of years remaining to the end of the analysis period. For example, N=2 for a highway resurfaced in 2020 and an analysis period ending in 2022.

Major rehabilitation costs for other highway infrastructure such as bridges shall also be included.

5.2.3 Annual Maintenance and Operating Costs

Maintenance costs shall be estimated in constant dollars (ignoring inflation) for the financial year in which the evaluation is being prepared (typically the current year). Interest payments, inflation and depreciation shall not be included.

Ideally, local experience should be used to determine maintenance costs. Alternatively, the ministry's default unit costs can be used.

5.3 User Benefits

For the base case and each option, there are 3 categories of road user costs that need to be modeled over the 25 year analysis period. The categories are travel time costs, collision costs, and vehicle operating costs. The magnitude and timing of costs in each category need to be modeled. The present value of cost for each category is then calculated using the ministry's standard discount rate.

The benefits of each improvement option are simply the incremental reduction in user costs from the base case to the proposed case. So the present value of user benefits for any option are equal to the incremental reduction (from base case to proposed case) in the present value of travel time costs, collision costs, and vehicle operating costs. Mathematically it looks something like the formula below, where PV = present value, bc = base case, and pc = proposed case.

PV Road User Benefits =
[(PV travel time),bc – (PV travel time),pc] +
[(PV collisions),bc – (PV collisions),pc] +
[(PV vehicle operating),bc – (PV vehicle operating),pc]

To be consistent with the MAE framework that considers all societal costs and benefits, all beneficiaries of a project must be considered in the analysis (e.g. impact to road user costs on other routes must be considered).

5.3.1 Travel Time Benefits

Travel time benefits are simply the incremental reduction in travel time costs from the base case to the proposed case. Thus the primary task is to estimate annual travel time costs for the base case and each option over the 25 year analysis period.

Annual travel time costs are a function of the time required to travel a route, the annual traffic volume, and the unit value of time.

The time required to travel a route is generally dependent on the environment (urban, suburban, or rural), route length and geometry, time of day, the daily traffic volume and its hourly variation, congestion, average speed, and the type and number of intersections. A number of tools can be used to estimate travel time including the highway capacity manual/software, micro-simulation tools, and field observations during different times of the day.

An estimate of travel time for all hours of the day/year is required along with the traffic volume in those hours in order to estimate annual travel time costs. Therefore the output from tools which provide an estimate of peak hour travel time will need to be expanded appropriately to determine a daily and then an annual estimate of travel time costs. Some benefit cost tools can estimate travel time costs for all hours of the year and all years of the analysis period based on inputs for AADT, annual growth rate, an hourly traffic profile, and speed-volume curves for the facility.

The ministry's default unit values of time can be found on the Highway Planning and Programming Publications web page of the ministry Internet site.

5.3.2 Safety Benefits

Safety benefits are simply the incremental reduction in collision costs from the base case to the proposed case. Thus the primary task is to estimate annual collision costs for the base case and each option over the 25 year analysis period.

Annual collision costs are a function of the expected number of collisions by severity and the unit cost of collisions.

Estimation of the expected number of collisions by severity must be done in accordance with the ministry's Collision Prediction Model and Collision Modification Factor documents. A link to these 2 safety documents can be found on the Highway Planning and Programming Publications web page of the ministry Internet site. Also available on this web page are the ministry's preferred tool for calculating safety benefits (Safety-BenCost) along with a detailed example problem. These ministry guidelines and tools generally follow the procedures described in the Highway Safety Manual which is another useful reference document.

The ministry's default unit costs for collisions can be found on the Highway Planning and Programming Publications web page of the ministry Internet site.

5.3.3 Vehicle Operating Cost Benefits

Vehicle operating cost (VOC) benefits are simply the incremental reduction in VOCs from the base case to the proposed case. Thus the primary task is to estimate annual VOCs for the base case and each option over the 25 year analysis period.

Five different VOCs are often included:

1. maintenance
2. depreciation
3. fuel

4. oil
5. tires

Annual VOCs are generally a function of AADT, distance travelled, the consumption rate, and the unit price. The variables used to predict consumption rate typically include: speed, curvature, grade, surface condition, number of stop cycles, number of speed change cycles, and temperature.

It is important to capture any changes in travel distance resulting from changed alignments. A small change in travel distance (increase or decrease) can have a significant effect on VOCs and therefore overall project benefits.

A 1% reduction in the length of an alignment can increase overall project benefits in the range of 10%. While a 1% reduction is small, it represents 1% of a very large accumulation in user costs (collision, travel time, and VOC) over the life of a project and as a result contributes to large benefits.

The ministry's default unit prices for VOCs can be found on the Highway Planning and Programming Publications web page of the ministry Internet site.

5.4 Percent Trucks

The unit travel time and vehicle operating costs of trucks is significantly greater than that of passenger cars and therefore reasonable estimates of percent trucks is important.

Many of the Ministry's permanent counters around the province are capable of measuring vehicle length and therefore can be used to estimate percent trucks. Ministry guidelines are to assume that 0% of Bin 1, 20% of Bin 2, and 100% of Bins 3/4/5 are trucks.

5.5 Consumer Surplus

When improvement projects are implemented in locations where travel demand is relatively insensitive to user costs (i.e. where induced travel is negligible) then the "cost difference method" described throughout this guidebook works fine. The "cost difference method" assumes that user benefits are simply equal to the incremental reduction in user costs from the base case to the proposed case. Travel demand is generally insensitive to user costs in rural corridors and for smaller isolated projects in urban networks. These types of projects typically do not induce new trips or induce longer distance of travel for existing trips.

However, if it is expected that an improvement will result in a substantial amount of induced travel (e.g. significant projects within major urban networks) then user benefits will need to be calculated using the "consumer surplus method" rather than the "cost difference method". The "consumer surplus method" calculates user benefits as the incremental increase in consumer surplus from the base case to the proposed case. Where consumer surplus is defined as the amount a consumer is willing to pay for something versus the amount they actually pay for it.

The problem with applying the “cost difference method” to induced travel is that the induced travel will only contribute to proposed case user costs and therefore generates negative benefits because by definition induced travel does not exist in the base case. Where in fact, induced travel should contribute to positive benefits because it has a positive consumer surplus (i.e. users choose to travel more because the amount they are willing to pay is greater than the actual cost).

Applying the “consumer surplus method” to a large urban project is not a simple straight forward task. Further, it is not the intent of this guidebook to explain the details of how this should be done. Rather the primary objective here is to create awareness that the simple “cost difference method” is not always appropriate. If it is expected that an improvement will result in a substantial amount of induced travel then the “consumer surplus method” will need to be applied.

5.6 Presenting Benefit Cost Analysis in a Business Case

The benefit cost analysis should be presented in a clear and concise manner, but in enough detail for someone else to fully understand and review what has been done.

For each option provide a summary of the key inputs including any significant assumptions, and highlight the significant differences between the option and the base case.

Summarize the benefit cost results for the earliest feasible years of construction in a simple table and provide similar information for the preferred option evaluated in the optimal year of construction.

Provide an interpretation of the results, describing what part of the project is contributing to the travel time, safety, and VOC benefits, and therefore confirm that the results are consistent with expectations.

Chapter 6

Optimal Timing

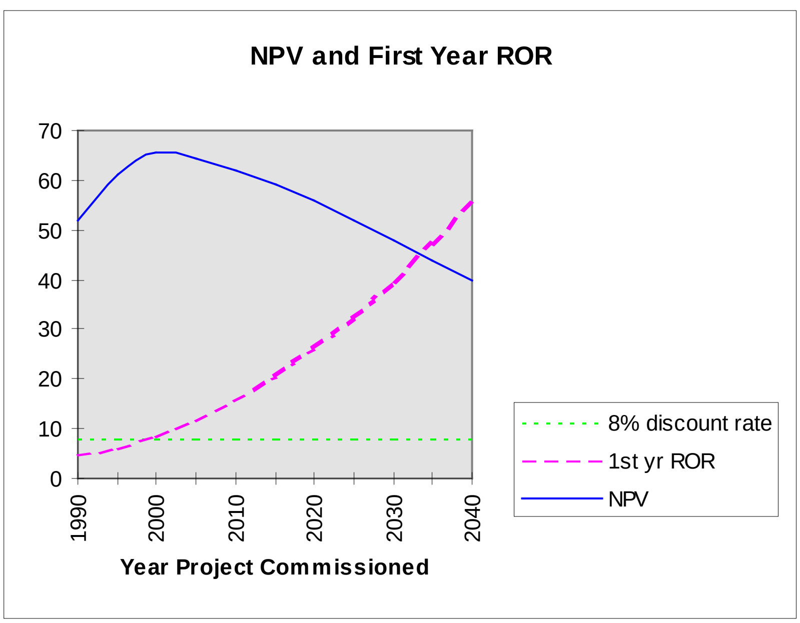
Generally, optimal timing should be completed only for the preferred option.

The optimal year to commence construction is the year that maximizes the net present value (see the graph below).

The NPV will be maximized the first year that the first year rate of return (ROR) exceeds the discount rate. The first year ROR is the benefits to road users in the first year after the project is complete divided by the project costs to date including interest during construction. Each year that the project is delayed, the first year ROR will increase due to traffic growth. The optimal year to construct is the first year that the first year ROR exceeds the discount rate (the minimum ROR required to undertake a project).

In other words, if the benefits in the first year after completion of the project divided by the project costs are less than the discount rate, then the timing is not optimal. The money would be better invested elsewhere at the discount rate. Wait until the benefits in the first year exceed the discount rate.

If the optimal year has passed and the project was not funded, then the best year to commence construction is the current year. This is because after the optimal year, the NPV continues to decline in each subsequent year.



Note – estimates of optimal timing are considered to be approximate. The objective of an optimal timing analysis is to determine if the project should be constructed in the short-term 1 to 5 years, mid-term 5 to 10 years or long-term.

Two methods are described below.

Method 1

This is a trial and error method where the year of construction is changed and the project is reanalyzed a number of times until the NPV is maximized.

Method 2

In method 2, optimal timing is estimated by modifying the benefit cost input file to provide estimates of the first year rate of return (ROR).

1. Change the discount rate to 0%.
2. Reanalyze the option.
3. Find the Discounted Benefit Summary Table in the output. It lists the benefits in each year, and because the discount rate has been changed to 0% the benefits listed will not be discounted. Find the earliest year in which the Total Benefits divided by the project costs (see note below) exceed the discount rate.
4. This is the optimal year for benefits to begin. Based on the number of years of construction, work back to determine the optimal year for construction to begin.
5. Analyze the project for construction in the optimal year to determine the NPV and B/C ratio.

Note - for project costs use the future value in the final year of construction (i.e. include interest during construction for multiyear projects, assume IDC = the discount rate). For example, for a 1 year construction project, project costs are simply the cost estimate in constant dollars (ignoring inflation) for the current year. For a 3 year construction project, costs in year 1 should be factored up by 1.06*1.06 and costs in year 2 should be factored up by 1.06 (assuming a 6% discount rate).

Chapter 7

Sensitivity and Risk Analysis

Sensitivity analysis is the process of varying an analysis input and determining the effect on the analysis outputs. The results of a sensitivity analysis should be presented in a simple table that identifies the sensitivity and the corresponding NPV and B/C ratio.

Note - sensitivity analysis shall be carried out for the preferred option only and for construction in the optimal year(s) (or the recommended year if other than the optimal year).

Mandatory Sensitivities

The following sensitivities shall be investigated.

- optimal timing of the preferred option (see the chapter on optimal timing)
- +/- 2 % variation in discount rate
- +/- 10% variation in capital cost estimates
- +/- 25% variation in capital cost estimates
- +/- 10% variation in base year traffic volumes for the existing and proposed routes (this sensitivity may be omitted when there is confidence in the estimate of the base year volume)
- +/- 0.5% variation in traffic growth rates for the existing and proposed routes

In addition, when the estimated value of any input is highly uncertain, the sensitivity of the results to that input should be investigated.

Optional Sensitivities

The following sensitivities shall be investigated if requested.

- Replace the comprehensive accident costs that are recommended in this Guidebook with Claim Costs that are paid out by the Insurance Corporation of British Columbia.
- duration of construction
- timing of rehabilitation

Risk Analysis

Uncertainty is an inherent part of any benefit cost analysis. For example, the quantities and unit costs used to develop cost estimates are uncertain, and on the benefit side, traffic volumes and traffic growth are uncertain, to name a few.

Where there is uncertainty, there is risk. Risk refers to the possibility of a negative outcome due to uncertain variables. For example, uncertainty in the volume of rock excavation poses a risk that costs could be much greater than assumed.

Risk analysis involves:

- identifying variables that have significant uncertainty
- quantifying the uncertainty
- identifying the negative outcomes that are possible
- quantifying the negative outcomes

A detailed risk analysis requires an estimate of the probability distributions of the input variables and the analysis outputs – Monte Carlo Simulation. Typically a detailed risk analysis will not be required. However, where uncertainty is significant, it should be identified and quantified, and the negative outcomes should be identified and quantified using sensitivity analysis.

Chapter 8

Passing and Climbing Lane Projects

The impact of passing and climbing lanes varies depending on volume, vehicle mix and grades. The main benefits are travel time savings and collision reductions. Generally, the collision reductions are assumed to apply to both directions, whereas the increases in travel speeds are applied to the advancing direction only.

PL and CL projects should generally be modeled with 3 segments in the base case and the proposed case.

Length of Segments

- Segment 1 (upstream segment) - Typically 2 km long. Two kilometers representing the distance between the "Auxiliary Lane Ahead" sign and the beginning of the auxiliary lane.
- Segment 2 (the treated segment) - The length of the PL or CL excluding the tapers at each end.
- Segment 3 (the downstream segment) - The effective downstream length is assumed to vary with AADT. At high volumes, platoons reform immediately downstream of the passing lane while at lower volumes, the effective distance can be several kilometers. The effective distance is estimated as the lesser of the distance to the next passing lane or:

Downstream Distance = 10 km - AADT/1500

Note that the downstream distance could be shortened due to other factors such as urban development, posted speed reductions, etc.

If the treated section is a short 4 lane section then the downstream distance can be applied in both directions.

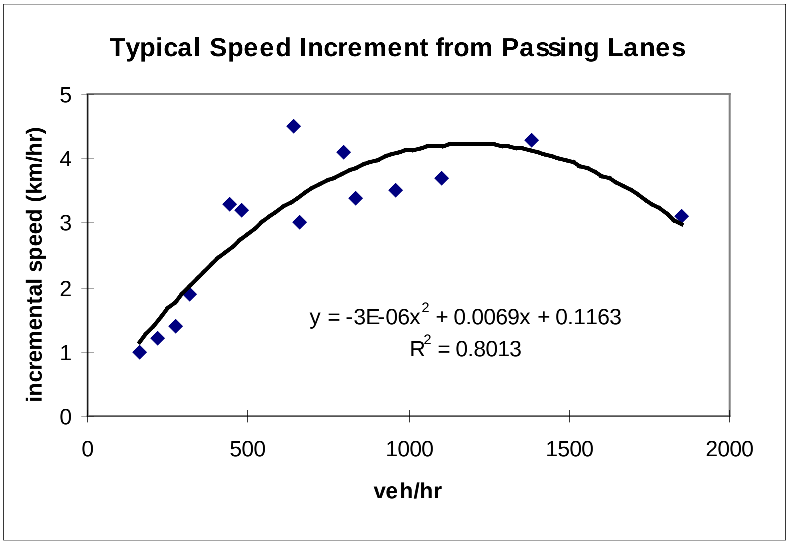
Travel Time Benefits

Ideally, the changes in travel speeds are estimated in a travel simulation model then input to a benefit cost analysis program to determine the travel time savings. Depending on traffic volumes, typical increases in travel speed in the advancing direction range from 1 to 4 km/hr in both the treated and downstream segment. If the treated segment is a short 4 lane section, then these benefits apply to both directions.

Upstream Segment – there are no travel time savings for the upstream segment as speeds will be the same for the base case and proposed case

Treated Segment – travel time savings result from the additional capacity of the added lane

Downstream Segment – If a simulation is not possible, the following chart (developed from past TRARR simulations) can be used to model the *changes* in travel speed in the advancing direction of the downstream segment.



Extension of an Existing Passing/Climbing Lane

For an extension of an existing PL or CL the travel time savings shall be as follows.

Upstream Segment - Do not model this segment as there are no additional travel time savings.

Treated Segment – Model only the extended length as there will be no additional travel time savings in the existing PL or CL. For the extended length travel time savings will result from the additional capacity of the added lane in the proposed case.

Downstream Segment - There may be some downstream benefits if the original PL or CL can be shown to be inadequate, and the proposed extension is expected to further reduce platooning and therefore reduce travel time in the downstream segment. The Analyst should provide adequate justification if any benefits are assumed. At most, these travel time savings will be some portion of the downstream savings described above for new PL or CL projects.

For example, an existing passing lane may be too short to reasonably distribute the platoon as assumed. Or an existing climbing lane may not extend to a point where trucks can reach 75% of the posted speed.

Safety Benefits

Generally collision reductions are assumed to apply to both directions.

Upstream Segment – Passing/climbing lanes are normally posted 2.0 km in advance of the treated segment. This reduces the tendency of drivers to make risky overtaking maneuvers in this 2.0 km section. The normal rate of passing related accidents in British Columbia is 2% to 4% of all accidents*3*. For planning purposes it is assumed that 100% of passing related accidents, at the 2% level, are eliminated in the upstream segment. In addition, it is recognized that there is a general "calming effect" on drivers due to their knowledge that a passing/climbing lane is just ahead. An additional 1% accident reduction will be attributed to this "calming effect".

Consequently, for the upstream segment, use a collision reduction of 3% of all accidents.

Treated Segment – For the treated segment see the ministry's document Collision Modification Factors for British Columbia. For a 1 directional PL or CL use a collision modification factor of 0.75. For a short 4-lane section use a CMF of 0.65. These CMFs apply equally to all collisions.

Downstream Segment[4]

Auxiliary lanes provide some safety benefits downstream of the treated section since platoons continue to be dispersed for some distance downstream depending on the traffic volume. Rear end type accidents, which are often attributed to following too close, make up about 10% of non-intersection accidents on rural 2-lane highways in British Columbia[5]. Including rear-end and overtaking accidents, about 12% of accidents are related to platooning. An Auxiliary lane typically reduces platooning by about 25% immediately downstream of the treated segment, which suggests an overall accident reduction of 25% x 12 % = 3%. Assuming this drops to 0% over the effective downstream length of an auxiliary lane, then the average reduction over this effective downstream length is 1.5%. Collision severity is assumed to be the same as the existing route.

In addition, it is recognized that some portion of head ons, side swipes and off road rights may also be platooning related. Therefore, the portion of all accidents that are platooning related might be greater than 12% and the average reduction over the effective downstream length may be greater than 1.5%. At this time, an additional 0.25% accident reduction will be attributed to this.

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[3] Abdelwahab, Wahlid, "PASS - An Algorithm to Identify Passing-Related Accidents on Two-Lane Highways from Police Accident Reports" Highway Safety Branch, B.C. MoTHreport # MOTH-HS93-01, January, 1993
[4] Lyall P.D., Jaganathan R., Morrall J.F.,"Auxiliary Lane Warrants for Two-Lane Highways, Prepared by ADI Limited for BC MoTH, Systems Planning Br. Victoria, B.C., 1993
[5] "1989-1993 Annual Accident Statistics on Numbered Highways" Highway Safety Branch, BC MoTH, 1993

Consequently, for the downstream segment, use a collision reduction of 1.75% of all accidents.

Extension of an Existing Passing/Climbing Lane

For an extension of an existing PL or CL, the minimum (see note below) safety benefits shall be as follows:

Upstream Segment - none

Treated Segment – Model only the extended length as there will be no additional benefits for the existing PL or CL. For the extended length use the ministry's collision modification factors described above for new PL or CL projects.

Downstream Segment - There may be some downstream benefits if the original PL or CL was unable to disperse the platoon as assumed (i.e. platooning reduced by 25% immediately downstream of the treated section) over the effective downstream length. The Analyst should provide adequate justification if any benefits are assumed in the downstream section. For example, it could be argued that the original Pl or CL was only able to reduce platooning by 15% immediately downstream of the treated segment and that the proposed extension of the auxiliary lane will produce the additional 10% reduction. Therefore the accident reduction in the downstream section associated with the extension would be (10% x 12% + 0)/2 = 0.6%.

Note - for some auxiliary lane extensions it may be reasonable to use larger CMFs and model the segments differently than discussed above, if it can be shown that the existing auxiliary lane is creating a safety hazard at the merge point because of poor site distance, too large of a speed differential (for climbing lanes), or some other reason.

Chapter 9

Ministry Tools and Guidelines

The Highway Planning and Programming Publications web page on the ministry Internet site provides links to a number of tools and guidelines related to benefit cost analysis.

Tools

1. ShortBEN – A high level benefit cost tool, generally intended for use as a screening tool prior to more complete benefit cost analysis, but in many cases is adequate for the complete benefit cost analysis of projects. Does not quantify safety benefits using the ministry Collision Prediction Model (CPM) and Collision Modification Factor (CMF) documents and therefore safety benefits need to be quantified using a different tool.
2. Safety-BenCost – A tool for the benefit cost analysis of safety improvements based on the ministry's CPM and CMF documents. The ministry requires that safety benefits be quantified using the CPMs and CMFs in these documents and prefers that Safety-BenCost be used for this purpose.
3. Cost Estimating **–** Links to 3 separate tools are provided on the web page.

Guidelines

The web page provides access to a variety of guidelines addressing topics such as planning, in-service road safety reviews, business cases, multiple account evaluation, cost estimating, benefit cost analysis, and others.