Alberta Government

Benefit Cost Model

User Guide

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ABSTRACT & SUMMATION: This User Guide is a companion document to the
Alberta Transportation Project Benefit Cost Model - ATBenefitCostModelV1Z.xlsx

Contents

Glossary

(Ordered alphabetically)

Benefit Cost Analysis[1]

Benefit Cost Analysis is the exercise of evaluating a planned action by determining what new value it will have. Benefit cost analysis finds, quantifies, and adds all the positive factors. These are the benefits. Then it identifies, quantifies, and subtracts all the negatives, the costs. The difference between the two indicates whether the planned action is advisable. The key to doing a successful cost-benefit analysis is making sure to include all the costs and all the benefits and properly quantify them. Where the benefits of a project exceed costs, it can be determined it would be beneficial to undertake the project. Where more than one project is considered, the alternative where benefits exceed costs the most would be the preferred project.[2] This is consistent with the principle of Pareto efficiency or optimality (see below).

Benefit Cost Ratio[3]

The benefit cost ratio is the present value of benefits divided by the present value of costs. Where the B/C ratio is greater than 1, benefits exceed costs and the project provides positive net benefits. This measure however, does not consider the scale of expenditures. For example, a small project may produce a greater B/C ratio but have a smaller overall benefit.[4]

Discount Rate[5]

The purchasing power of money normally decreases over any given period of time due to inflation and uncertainty. A discount rate adjusts the value of money for time, expressing expected future monetary quantities in terms of their worth today.

Internal Rate of Return[6]

The internal rate of return is the rate of discount that makes the net present value of the benefits minus the costs over time equal to zero.[7] Where the IRR is greater than the discount rate, the benefits of the project are greater than the expected or required return on the investment.[8]

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[1] Appendix 3: Benefit Cost Analysis Guide, ATU (1991) page 1

[2] http://www.inc.com/encyclopedia/cost-benefit-analysis.html

[3] Appendix 3: Benefit Cost Analysis Guide, ATU (1991) page 31

[4] Appendix 3: Benefit Cost Analysis Guide, Treasury Board of Canada Secretariat, 2007, page 27

[5] Appendix 3: Benefit Cost Analysis Guide, ATU (1991) page 21

[6] Appendix 3: Benefit Cost Analysis Guide, ATU (1991) page 31

[7] Appendix 3: Benefit Cost Analysis Guide, Treasury Board of Canada Secretariat, 2007, page 27

[8] The Principles of Practical Cost-Benefit Analysis, Sugden, R & Williams, A, Oxford University Press 1978, page 20.

Net Present Value (NPV)[9]

The Net Present Value (NPV) measures the net benefit of a project in today's dollar terms. Money has a time value, known as an opportunity cost, which means that money invested today could earn interest elsewhere. To compensate, future payments need to be higher so that they equal today's dollars. Additionally, time value accounts for the cost of capital, the cost for a company to borrow investment money, over time, at a specific interest rate. The cash flows are the amounts and times of the various costs and investments, and these are brought into a common term, today's dollars, so that the net benefit can be evaluated. The NPV savings calculation consists of two financial concepts that evaluate a set of costs and benefits over time:

- The “net” is the difference between all costs and all benefits (savings and other gains)
- The present value takes into account the time value of money; this adjusts to expenditures and returns, as they occur over time, so they can be evaluated equally

Payback Period[10]

Payback period refers to the period of time required to recoup the funds expended in an investment, or to reach the break-even point.

Pareto Efficiency[11]

Pareto efficiency, or optimality, is a state of the economy where resources are allocated in such a way that it is not possible to make any individual better off without making at least one individual worse off. For example, if a change in economic policy eliminates a monopoly and that market subsequently becomes competitive and more efficient, the monopolist will be made worse off. However, the loss to the monopolist will be more than offset by the gain in efficiency. This means the monopolist can be compensated for its loss while still leaving a net gain for others in the economy, a Pareto improvement.[12]

Sunk Costs [13]

Sunk costs, or expenditures that have occurred in the past and are therefore not recoverable, are not relevant for consideration in benefit-cost analysis. Benefit-cost analysis is forward looking with the aim of providing information about future investment decisions.

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[9] Appendix 3: Benefit Cost Analysis Guide, ATU (1991) page 30
[10] Appendix 3: Benefit Cost Analysis Guide, ATU (1991) page 20
[11] Appendix 3: Benefit Cost Analysis Guide, ATU (1991) page 8
[12] http://en.wikipedia.org/wiki/Pareto_efficiency
[13] Appendix 3: Benefit Cost Analysis Guide, ATU (1991) page 20

Section 1: Overview

Purpose of the Model

Benefit cost analysis is an analytical tool that provides information about the economic merits of a proposed investment or alternative investment options. With regards to transportation project evaluation, benefit cost analysis measures the changes in benefits and costs over time arising from an investment in one of several alternatives, as compared to a status quo option, or "do minimum" option (if the status quo is not an option).

A benefit cost analysis determines whether a proposed project is economically desirable (when benefits exceed costs). Benefit cost analysis can also be used with other information to select which project among competing project alternatives should be funded given a budget constraint, and to compare the effects of projects that may accomplish different objectives.

The purpose of the Alberta Transportation Project Benefit Cost Model is to determine which road or bridge project, given a number of project alternatives, provides the best return on investment.

Analysis Components

The Alberta Transportation Project Benefit Cost Model evaluates the impact of various project alternatives in each of the following areas:

- Initial Construction Project Costs (Investment)
- Maintenance and Operating Costs
- Rehabilitation Costs (capital costs required to maintain the asset at a specified condition)
- Road User Costs:
    - Vehicle operating costs – see model features for two different calculation approaches. **<u>Important:</u> It is recommended the California (Fuel & Non-Fuel) approach be used for all projects unless the curvature or gradient varies significantly between alternatives, in which case the Texas (Curvature & Gradient) approach would be used.**
    - Travel time costs
    - Collision costs, and
- Environmental costs associated with vehicle emissions.

Other Costs

It is noted that other cost types may be relevant for some projects. For example, there may be costs associated with the protection of environmental assets, or costs associated with the mitigation of potential negative environmental impacts of a project. These costs can be defined in user defined categories as either a capital cost or an on-going operating cost, whichever is most appropriate.

Model Features

The Alberta Transportation Project Benefit Cost Model includes a number of features that allow for flexibility in evaluating different types of projects under different circumstances. The key features of the model include the following:

- Analysis of up to three Alternatives (including a Status Quo, or “do minimum”, Alternative). These Alternatives refer to different or alternative projects that could be undertaken, which are usually compared to a Status Quo, or ‘do minimum’ alternative. The Status Quo Alternative, or ‘do minimum’ alternative would typically be Alternative 1 in the model. Other alternatives should represent reasonable options to the Status Quo Alternative that are technically feasible, but likely to have different costs and potential cost savings. While three alternatives will likely suffice for most instances, if additional alternatives need to be considered, it is recommended to duplicate the model file with the Alternative 1 data contained in the file. Two additional alternatives to the ‘do minimum’ (Alternative 1) can be specified in the new duplicate model file.

- Analysis of each Alternative for up to three Scenarios. Scenarios are variations on the Alternatives with some parameter, or parameters of the alternative, that are varied. Scenarios are normally used to evaluate external factors such as: the discount rate, capital costs, operating and maintenance costs, road user costs (vehicle operating costs, travel time costs and collision costs) and emission costs.

- Up to eighty (80) year timeframe for the analysis.[14]

- Flexible project definition categories: The user can define up to 10 different types of projects for analysis.

- Flexible construction cost categories: The user can define up to 8 different types of project construction costs. This will allow for the definition (and separation) of costs that might be specific or unique to a project, such as environmental impact mitigation costs.

- Flexible construction period: The construction period is defined for each Alternative.

- Flexible operating and maintenance cost categories: The user can define up to 5 operating and maintenance cost categories.

- Flexible vehicle definition categories: The user can define up to 10 different types of vehicles for the analysis.

- Vehicle Operating Costs can be calculated in one of two ways:

Important: **It is recommended the California (Fuel & Non-Fuel) approach be used for all projects unless the curvature or gradient varies significantly between alternatives.**

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[14] The analysis results can be viewed for any time period, up to 80 years, including the construction period. For example, if the construction period is 5 years, the operation of the project would be projected for a total of 75 years. The results for any individual year in the forecast period can be viewed in the ‘Results’ tab of the model.

  - California (Fuel/Non-Fuel Option): Utilizes average fuel and non-fuel vehicle operating costs by vehicle type similar to the CalTrans model. This approach should be used where horizontal and vertical geometry is not a factor (does not vary significantly) between alternatives. The vehicle operating costs for the California option are currently based on a value of $0.505/km/passenger. This is the current calibration to suit Alberta conditions. The calibration may be changed if warranted based on changing conditions. **In the user guide and model, this option will be referred to as <u>California (Fuel & Non-Fuel)</u> approach.**

  - Texas (Curvature & Gradient Option): This option utilizes curvature and gradient cost factors. This approach uses road operating costs that were originally estimated by the Texas Research Development Foundation for the Federal Highway Administration (1982 US). These costs were adjusted for inflation to reflect the Alberta context in 1989.[15] This option should be used when the curvature and gradient of some or all of the alternatives vary significantly. **In the user guide and model, this option will be referred to as <u>Texas (Curvature & Gradient)</u> approach.**

- Vehicle Operating Cost and Collision default values can be redefined for specific projects where the default values are not appropriate.

- Benefit Cost Analysis Results: The model uses standard Benefit Cost Analysis results to measure the relative desirability of each alternative.

  - Internal Rate of Return (IRR): The discount rate that makes the net present value of all cash flows from a particular project equal to zero. The internal rate of return on the investment in one alternative (or scenario) is compared to the Base Scenario of Alternative 1 (Scenario 1).

  - Payback Period: The number of years that it takes to recover the costs in one alternative (or scenario) compared to the Base Scenario of Alternative 1 (Scenario 1).

  - Net Present Value (NPV): Net present value in this analysis compares the net cost savings of one alternative (and scenario) against the first Alternative (Scenario 1). This is necessary because all the analysis information represents costs (e.g. there are no revenues as is typically the case in benefit/cost analysis of business alternatives). As a result, it is the net cost savings of one alternative against another that is relevant.

  - Investment Costs (in net present values): Investment costs include Construction costs plus any associated Rehabilitation costs. Investment costs for a given alternative are compared to Alternative 1 (Scenario 1) so they can be used as the denominator for the Benefit Cost Ratio.

  - Benefits (in net present values): Benefits of an alternative are the cost savings (if any) as compared to Alternative 1 (Scenario 1). This is the numerator for the Benefit Cost Ratio.

  - Benefit Cost Ratio: This is equal to the Benefits (non-Construction cost and Rehabilitation cost) or cost savings of the selected alternative as divided by the costs of Alternative 1 (Scenario 1).

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[15] Benefit Cost Analysis - Vehicle Running Costs, Alberta Transportation & Utilities, Traffic Engineering Branch, January 1989.

Limitations of the Model

The Project Benefit Cost Model has the following known limitations that should be understood by the analyst.

- There are limited benefit cost analysis indicators for Alternative 1 (the Status Quo or 'do minimum' alternative) as most indicators require the estimation of 'benefits'. 'Benefits' are the savings in costs determined by comparing the net present value of costs for one alternative/scenario against Alternative 1/Scenario 1. The benefit cost analysis indicators available for Alternative 1 (Scenario 1) are: Net Present Value; and Investment Costs (NPV). For example, a low volume road that meets the requirement for grade widening and Alternative 1 is no widening with zero cost and zero benefits.

- As with all models, the quality of the analysis and results will depend on the quality of the information used to conduct the analysis.

- The model is limited to evaluating individual projects and not the infrastructure system.

- For bridge projects, the 80 year time frame for analysis is limiting considering the expected life of a bridge is typically 100 years.[16] However, any benefits or costs expected beyond year 80 may be discounted back to 80 years and entered for that year (year 80). For example, for year 81 all benefits or costs would be multiplied by F_{81}:

$$F_{81} = \frac{\text{Benefits or Costs}_{\text{Year 81}}}{(1 + \text{discount rate})^{81-80}}$$

Model Components

The Alberta Transportation Project Benefit-Cost Model has four main components as follows:

- **Model Parameters:** This section of the model consists of 9 tabs as follows:
  - **Parameters:** This tab contains default information, including Scenario & Analysis Definitions, Project Type Categories, and various Cost Categories. Some of these variables can be altered for specific analyses (in the Project Definition tab) where the default values are not appropriate. This tab does not need to be updated for each analysis, but should be reviewed periodically.
  - **Rehab Costs:** This tab provides the Rehabilitation costs for each Project Type Category or transportation facility (e.g. interchange, overpass, lane addition, etc.) defined by the user in Parameters. These costs should reflect the expected stream of capital costs required to uphold the facility over an 80 year timeframe. NOTE: these costs are not the expected on-going operating costs of regular maintenance associated with the project.

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[16] As the length of the analysis increases, the discounted value of these future values becomes increasingly smaller. For example, the discounted value of a $100 investment 50 years in the future discounted at an annual rate of 4% is equal to $7.85.

  - **Maintenance:** This tab provides the Maintenance costs for each of the three Scheduled Maintenance categories and calculates the associated costs for each segment of the project alternative.

  - **RUC Alt# (3 tabs):** This tab calculates the road user costs (per day) associated with vehicle running costs, travel time costs and emission costs. These costs are estimated by vehicle type for each segment of the project defined by the user in the 'Project Definition' area. A separate tab exists for each Alternative (up to three alternatives can be defined by the analyst).[17]

  - **Collision Rates:** This tab provides the rate of collisions (per 100 million vehicle kms) by varying AADT for different road types. NOTE: The user has the option of using this information, which must be input manually into 'Project Specific Values,' or using the default values if the applicable rates are not available.

  - **Emissions:** This tab provides the rate of emissions (gms/km) by the speed of vehicle for each vehicle type and for each emission type defined by the user in Parameters. NOTE: If new vehicle types are added, the emissions tab (gms/km) will need to be updated to reflect the new categories defined by the user.

  - **Fuel Consumption:** The California (Fuel & Non-Fuel) approach to estimating running costs (vehicle operating costs) by fuel and non-fuel costs per km takes into account an estimate of fuel consumption by speed and vehicle type. This tab provides a cost factor from the average cost defined in Parameters.[18] The fuel consumption per vehicle type is estimated based on current information published in the California model. This is one of the items taken into account in the calibration of the model to an Alberta value.

- **Project Definition:** This section of the model consists of 7 tabs as follows:

  - **Project Definition (Defn):** This tab contains information specific to the project being analyzed. This includes the labels that will be used for the model, the definition of the project type and possible changes to default values that have been set in the Parameters tab.

  - **Alt # (3 tabs):** This tab contains information specific to the alternative being analyzed. This tab requires inputs about each Alternative that will be considered in the analysis. Usually Alt 1 will be the Status Quo, or minimal option, against which other Alternatives are evaluated.

  - **Traffic Alt# (3 tabs):** This tab calculates the traffic projected for each Alternative and applies this forecast to the unit costs for vehicle operations, travel time, emissions and collisions.

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[17] Note that the Texas (Curvature & Gradient) approach to estimating Road User Costs using definitions and values of gradient and curvature for different road surfaces (pavement/gravel) and vehicle type have not been updated to reflect changes in fleet composition in this version of the model. The figures from the Texas (Curvature & Gradient) analysis have been adjusted to reflect the change in inflation over the period from when the original figures were produced (1989) to 2013.

[18] This factor is built into the model and is set by the Department.

- **Analysis Results:** This section of the model provides a summary of the costs calculated for the analysis, and the benefit-cost analysis results.
    - **Project Costs # (3 tabs):** This tab summarizes the costs associated with each Alternative defined by the user over the 80 year analysis timeframe.
    - **Results:** This tab calculates the detailed benefit-cost analysis results for each year and each of the Alternatives and Scenarios defined by the user.
    - **Summary:** This tab provides a summary of the benefit-cost analysis results for each of the Alternatives and Scenarios defined by the user.
- **Analysis Support Data:** A number of worksheets (located in a separate file) have been used to calculate data input to the model. The user does not have access to these worksheets. These worksheets will be modified by the Department if warranted. These include:
    - Emissions Conversion Table: This table takes the CalTrans Benefit Cost[19] model's vehicle emissions estimates (as input by the user) and converts the imperial measures for speed and volume to metric. This data is imported into the Emissions tab in the model.
    - Value Updates Table: This spreadsheet uses historical cost indexes to update various values used in the model.

Valuation of Analysis Components

At the core of any benefit cost analysis is the valuation of incremental changes in expenditures or revenues that may be associated with a project or its alternatives. How these expenditures or revenues are evaluated and incorporated in the analysis is a critical consideration.

Real Dollars

This benefit cost model deals with all values expressed in real base year dollars. As a result, all base values and expenditure data used in the model will need to be expressed in these terms. Where expenditures include inflation or are expressed in real values for another year, other than the base year, these values will need to be converted to the base year dollars using an appropriate inflation factor.

Real Discount Rate

As this benefit cost model does not include inflation, the discount rate used to account for the time value of money, and bring all future dollar values back to the base year, must be a 'real' discount rate.[20] The default value used in the model is 4% per annum.

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[19] California Life-Cycle Benefit/Cost Analysis Model (Cal-B/C). February 2009.

[20] Appendix C: Benefit Cost Analysis Guide ATU (1991), page 22

Perspective

The components of a benefit cost analysis and the valuation of these components depends upon the perspective, or point of view defined for the analysis. For this benefit-cost model, the perspective is the social point of view for the Province of Alberta. This social perspective should consider all relevant expenditures and costs for society’s point of view, limited to Alberta.

Inputted Values - Shadow Prices[21]

In some instances the market does not provide values for some components that are relevant for this analysis. In other cases, the market value may not reflect the ‘social’ value of these components from the perspective discussed above. As a result, where this is relevant, there may need to be adjustments to the values used in the analysis. In other instances, where these values are not available from market information, inputted values or shadow prices should be considered. For example, the travel time associated with passengers has no ‘market’ value. However, studies have been conducted into the ‘social’ value of travel time for passengers. The most relevant of these estimates should be used in the analysis to quantify this component. The most significant examples of factors that are currently used in the model include the costs for passenger travel time and emission costs. The model provides ‘default values’ that may be over-written by the user where warranted.

Direct Expenditures and Costs[22]

The undertaking of new economic activities, such as construction, not only contribute to the growth in the economy through the funds spent on the project, but also create the potential for additional expenditures on indirect and induced economic activities. These additional indirect and induced expenditures are associated with upstream purchases of goods and supplies required to support the project and the subsequent income effects generated by the project. In this benefit cost model, only the direct expenditures and costs have been included in the analysis.

Transfers[23]

Some types of revenues and expenditures, from a social perspective, do not represent real change, but are rather transfers from one group of economic agents in the economy to others. This typically includes subsidies, grants and taxes, all which are transfers from taxpayers to other groups in the economy. From a ‘Pareto’ efficiency point of view, transferring benefits or costs from one economic agent to another has no effect on economic efficiency.

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[21] Appendix C: Benefit Cost Analysis Guide ATU (1991), page 13

[22] Appendix C: Benefit Cost Analysis Guide ATU (1991), page 12

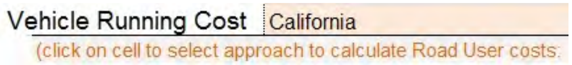
[23] Appendix C: Benefit Cost Analysis Guide ATU (1991), page 18

Section 2: How to Work with the Model

Where to Enter Information

The model has been designed so that all user inputs are entered in cells with the following formatting:

In some instances, a drop down menu has been built into the model with pre-defined selections for the user to choose from. To get the drop down menu, click in the cell and the selection options will become visible.



Vehicle Running Cost California

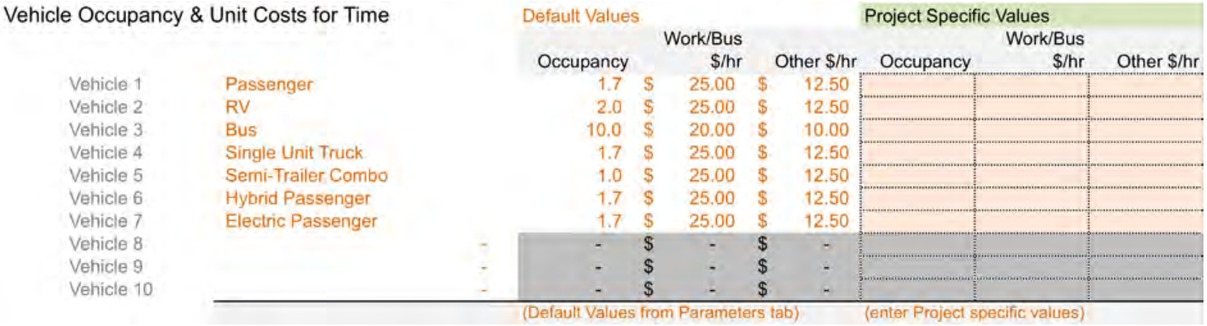
(click on cell to select approach to calculate Road User costs.

The model has pre-selected Vehicle Running Costs to be calculated by the California (Fuel & Non-Fuel) method. When selection of the Texas model is warranted, the user may select it from the drop-down menu. If changed, the selected method will be shown after the user hits ‘return’.

Reminder: It is recommended the California (Fuel & Non-Fuel) approach be used for all projects unless the curvature or gradient varies significantly between alternatives, in which case the Texas (Curvature & Gradient) approach would be used.

Entered Information

Information that has been entered in the model and used elsewhere in the model is displayed as orange text in either a white or grey background as follows:



Vehicle Occupancy & Unit Costs for Time

			Default Values			Project Specific Values		
			Occupancy	Work/Bus $/hr	Other $/hr	Occupancy	Work/Bus $/hr	Other $/hr
Vehicle 1	Passenger		1.7	$ 25.00	$ 12.50			
Vehicle 2	RV		2.0	$ 25.00	$ 12.50			
Vehicle 3	Bus		10.0	$ 20.00	$ 10.00			
Vehicle 4	Single Unit Truck		1.7	$ 25.00	$ 12.50			
Vehicle 5	Semi-Trailer Combo		1.0	$ 25.00	$ 12.50			
Vehicle 6	Hybrid Passenger		1.7	$ 25.00	$ 12.50			
Vehicle 7	Electric Passenger		1.7	$ 25.00	$ 12.50			
Vehicle 8		-	-	$ -	$ -			
Vehicle 9		-	-	$ -	$ -			
Vehicle 10		-	-	$ -	$ -			

(Default Values from Parameters tab) (enter Project specific values)

In this example, each of the vehicle types (e.g. Passenger, RV, etc.) have been entered by the user elsewhere in the model and are shown here in orange text. Similarly, the Default Values for Occupancy, Work/Bus $/hr and Other $/hr were entered elsewhere.

In many cases, the default Scenario specified values may be modified when data is available at a Project level. However, the changes to default values should only be made in the user input cells. This process is outlined in more detail below.

Cell Protection

All cells that do not require an input from the user have been 'locked' and 'protected'. This will ensure that these cells are not accidentally altered. Altering cells that do not require information from the user may affect the integrity of the calculations in the model.

Section 3: How to Complete an Analysis

Preparing for an Analysis

Before working with the model, it may be valuable to review the required information so it can be collected and/or generated prior to starting the analysis. Every analysis will require the development of information for a ‘status quo’ or ‘do minimum’ (Alternative 1) option and at least one (up to two) Alternative options. The same information will be required for each of these Alternatives.

NOTE: It is important that Alternative 1 be defined as the ‘status quo’ or ‘do minimum’ alternative for the calculation of the Benefit/Cost Ratio. The determination of Benefits (or Cost Savings) are based on a comparison of the Non-Investment cost savings of each alternative against Alternative 1.

Project Definition

The Project Definition tab includes the definition of variables that will affect the evaluation of the project as a whole. The Alternatives to be analyzed are defined in the Alt # tabs.

Vehicle Running Costs - Choosing an Approach

The model contains two approaches to estimate vehicle running costs. The California (Fuel & Non-Fuel) approach, **which is the default approach,** is centered on that used in the CalTrans model and is based on distance-related fuel and non-fuel costs. The California (Fuel & Non-Fuel) vehicle running costs are estimated using fuel and non-fuel vehicle operating costs for each vehicle type based on the segment length and running speed, not considering the effect of gradient or curvature specified in the model.

The Texas (Curvature & Gradient) approach relies on the definition of segment curvature and gradient for each segment of the project, and the unit costs by vehicle type associated with the gradients and curvature. **It is recommended that the Texas approach only be used if the curvature or gradient varies significantly between alternatives.**

The factors used in the Texas (Curvature & Gradient) approach originated in part from data compiled by the Texas Research and Development Foundation in 1982 for the Federal Highway Administration. For the original Alberta Transportation Benefit-Cost Model, these numbers were converted to 1988 Canadian dollars using Alberta consumer prices for items such as fuel, oil, tires, depreciation, etc. These were then updated from 1988 to 2012 based on the Transportation Price Index. These 2012 factors are used in the new version of the model.[24]

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[24] Benefit Cost Analysis - Vehicle Running Costs, Alberta Transportation & Utilities, Traffic Engineering Branch, January 1989.

Either approach can be used to estimate vehicle running costs. When gradient and/or curvature improvements are an important feature of an alternative being evaluated, it is recommended that the Texas (Curvature & Gradient) approach be used. Sensitivity analysis can be conducted using either the Texas (Curvature & Gradient) or California (Fuel & Non-Fuel) approaches to see how the benefit-cost results vary with each approach.

The desired approach to estimating road user costs can be implemented by clicking on the cell to the right of Road User Cost and selecting either California (Fuel & Non-Fuel) [the default], or Texas (Curvature & Gradient).[25]

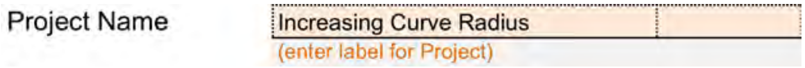
Vehicle Running Cost	California	*California - Fuel & Non-Fuel Costs per km*

(click on cell to select approach to calculate Road User costs: Choose Texas for Curvature & Gradient or California for Fuel & Non-Fuel approach)

<u>Reminder:</u> It is recommended the California (Fuel & Non-Fuel) approach be used for all projects unless the curvature or gradient varies significantly between alternatives, in which case the Texas (Curvature & Gradient) approach would be used.

Project Name

The project being evaluated should be labeled by entering a Project Name.

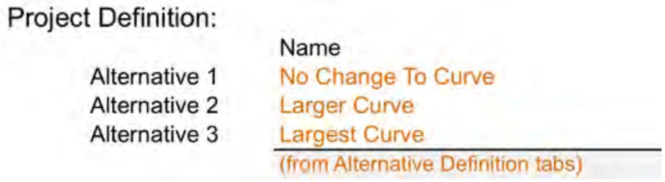


Project Name	Increasing Curve Radius

(enter label for Project)

Project Definition

This table provides an overview of the Alternatives' names. Up to three alternatives can be defined for each project being evaluated. The names are defined in the Alt # tab(s).



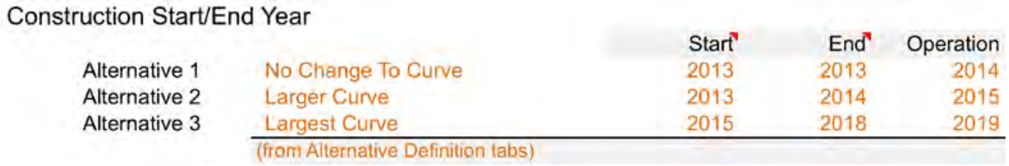
Project Definition:

	Name
Alternative 1	No Change To Curve
Alternative 2	Larger Curve
Alternative 3	Largest Curve

(from Alternative Definition tabs)

Construction Start/End Year

This table provides an overview of the construction start and end dates, and when the project would begin operations. The timing of construction is defined in the Alt # tab(s).



Construction Start/End Year

		Start	End	Operation
Alternative 1	No Change To Curve	2013	2013	2014
Alternative 2	Larger Curve	2013	2014	2015
Alternative 3	Largest Curve	2015	2018	2019

(from Alternative Definition tabs)

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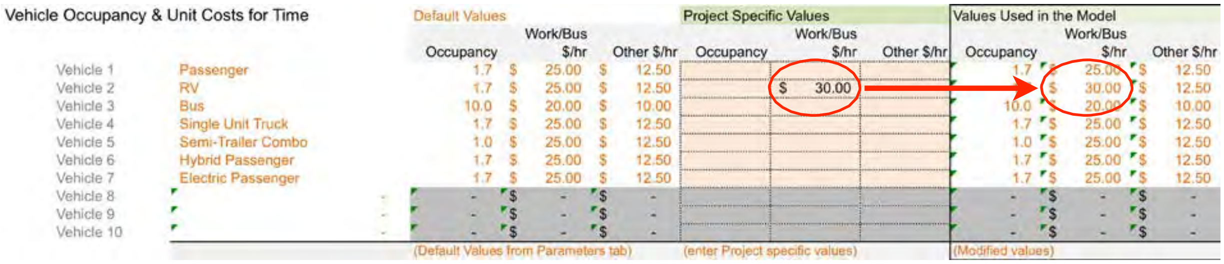
[25] Parameters by vehicle type and road surface type can be edited in RUC Alt1 AY42:BA47.

Vehicle Occupancy & Unit Costs for Time (Default Value Change)

The default values for vehicle occupancy and the unit values (from the Parameters tab) can be modified for the project by entering the desired value in the ‘Project Specific Values’ field. This updated value is then reflected in the ‘Values Used in the Model’ portion of the table.

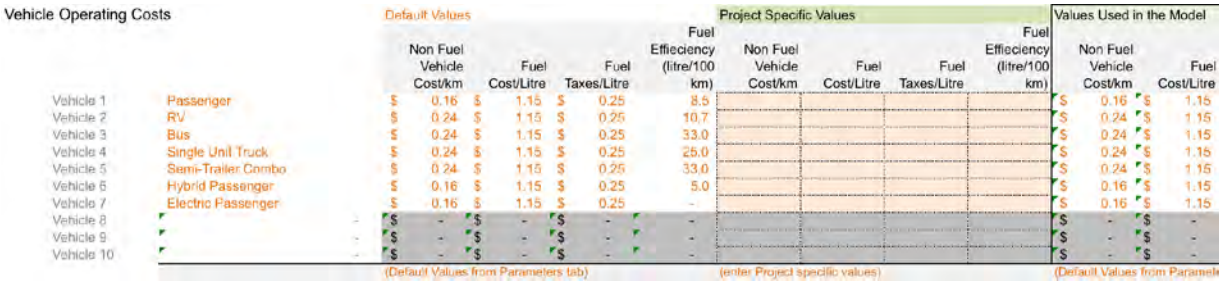


Vehicle Occupancy & Unit Costs for Time

		Default Values			Project Specific Values			Values Used in the Model		
		Occupancy	Work/Bus $/hr	Other $/hr	Occupancy	Work/Bus $/hr	Other $/hr	Occupancy	Work/Bus $/hr	Other $/hr
Vehicle 1	Passenger	1.7	$ 25.00	$ 12.50				1.7	$ 25.00	$ 12.50
Vehicle 2	RV	1.7	$ 25.00	$ 12.50		$ 30.00		1.7	$ 30.00	$ 12.50
Vehicle 3	Bus	10.0	$ 20.00	$ 10.00				10.0	$ 20.00	$ 10.00
Vehicle 4	Single Unit Truck	1.7	$ 25.00	$ 12.50				1.7	$ 25.00	$ 12.50
Vehicle 5	Semi-Trailer Combo	1.0	$ 25.00	$ 12.50				1.0	$ 25.00	$ 12.50
Vehicle 6	Hybrid Passenger	1.7	$ 25.00	$ 12.50				1.7	$ 25.00	$ 12.50
Vehicle 7	Electric Passenger	1.7	$ 25.00	$ 12.50				1.7	$ 25.00	$ 12.50
Vehicle 8		-	$ -	$ -				-	$ -	$ -
Vehicle 9		-	$ -	$ -				-	$ -	$ -
Vehicle 10		-	$ -	$ -				-	$ -	$ -
		(Default Values from Parameters tab)			(enter Project specific values)			(Modified values)		

Vehicle Operating Costs (Default Value Change)

The default values for vehicle operating costs used for the California (Fuel & Non-Fuel) approach to estimating vehicle running costs (from the Parameters tab) can be modified for the project by entering the desired value in the ‘Project Specific Values’ field. This updated value is then reflected in the ‘Values Used in the Model’ portion of the table.



Vehicle Operating Costs

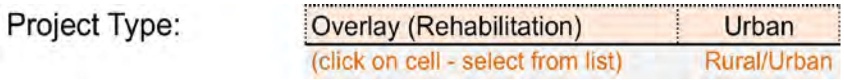
		Default Values				Project Specific Values				Values Used in the Model	
		Non Fuel Vehicle Cost/km	Fuel Cost/Litre	Fuel Taxes/Litre	Fuel Effiециency (litre/100 km)	Non Fuel Vehicle Cost/km	Fuel Cost/Litre	Fuel Taxes/Litre	Fuel Efficiency (litre/100 km)	Non Fuel Vehicle Cost/km	Fuel Cost/Litre
Vehicle 1	Passenger	$ 0.16	$ 1.15	$ 0.25	8.5					$ 0.16	$ 1.15
Vehicle 2	RV	$ 0.24	$ 1.15	$ 0.25	10.7					$ 0.24	$ 1.15
Vehicle 3	Bus	$ 0.24	$ 1.15	$ 0.25	33.0					$ 0.24	$ 1.15
Vehicle 4	Single Unit Truck	$ 0.24	$ 1.15	$ 0.25	25.0					$ 0.24	$ 1.15
Vehicle 5	Semi-Trailer Combo	$ 0.24	$ 1.15	$ 0.25	33.0					$ 0.24	$ 1.15
Vehicle 6	Hybrid Passenger	$ 0.16	$ 1.15	$ 0.25	5.0					$ 0.16	$ 1.15
Vehicle 7	Electric Passenger	$ 0.16	$ 1.15	$ 0.25	-					$ 0.16	$ 1.15
Vehicle 8		$ -	$ -	$ -	-					$ -	$ -
Vehicle 9		$ -	$ -	$ -	-					$ -	$ -
Vehicle 10		$ -	$ -	$ -	-					$ -	$ -
		(Default Values from Parameters tab)				(enter Project specific values)				(Default Values from Paramete	

Defining Project Alternatives

The Alternatives to be evaluated are defined in the Alt # tab (i.e. Alt 1, Alt 2, Alt 3). To conduct an analysis, at least 2 Alternatives must be defined. It is recommended that Alt 1 be the ‘Do Minimum’ or Status Quo alternative against which other alternatives are evaluated.

Project Type

Select an option from the list of project type categories. The project type will define a number of default values used in the model such as running speed, project life, and rehabilitation and maintenance costs. The project should also be given a locale - either rural or urban.

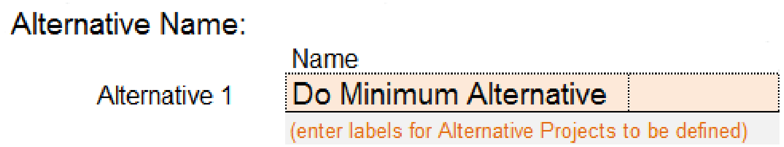


Project Type:	Overlay (Rehabilitation)	Urban
	(click on cell - select from list)	Rural/Urban

The project type categories can be modified in the Parameters tab. The process for modifying the project type categories is described in Section 5: Project Type.

Alternative Name

Enter a name that reflects an identifiable characteristic of the Alternative.



Alternative Name:

	Name
Alternative 1	Do Minimum Alternative
	(enter labels for Alternative Projects to be defined)

Construction Start/End

Define the years over which construction of the Alternative will take place. The year following the end of the construction period is assumed to be the first year of operation.

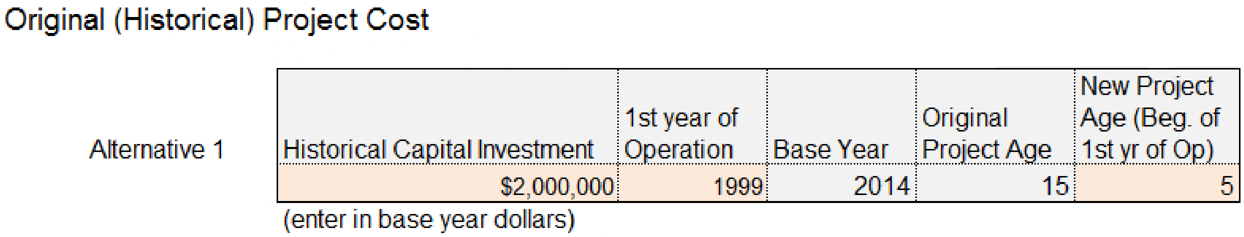
Construction Start/End Year

		Start	End	Operation
Alternative 1	Do Minimum Alternative	2014	2017	2018
	(enter Start/End year for project construction period)			

Historical Capital Investment

Defining the original (historical) cost of the project is required only when no significant construction costs are needed for the alternative being examined.[26] The first year of original project operation may be entered when the project is not entirely new (for example, the widening of an existing road).[27]

The Base Year is assumed to be the project start date. The Original Project Age is calculated as the difference between the Base Year and the First Year of Original Project Operation.



Original (Historical) Project Cost

	Historical Capital Investment	1st year of Operation	Base Year	Original Project Age	New Project Age (Beg. of 1st yr of Op)
Alternative 1	$2,000,000	1999	2014	15	5
	(enter in base year dollars)				

Construction Costs

The construction cost categories (defined in the Parameters tab) and construction period will define the cells that are available to enter the associated construction costs (orange cells). The total cost by category is provided in each column and total cost by year in each row.

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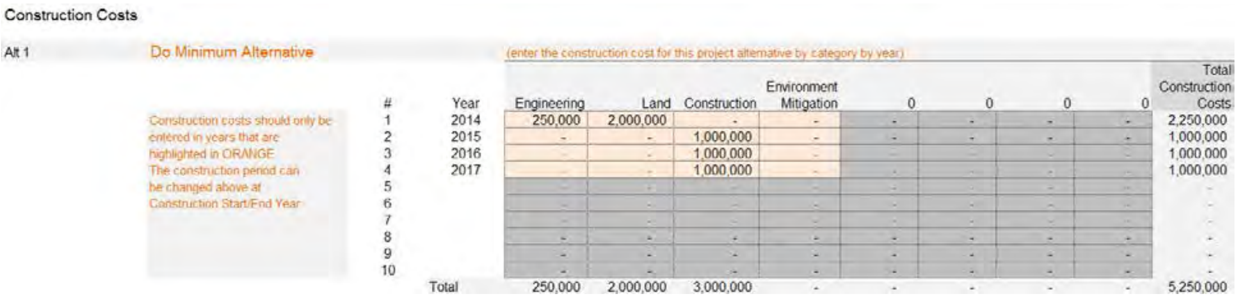
[26] The use of Historic Costs is only for the calculation of Life Cycle Costs and Replacement Costs going forward. In benefit-cost analysis terms, any costs incurred prior to the analysis are considered to be 'sunk costs' and not relevant to the future investment decision making.

[27] Where there are no Alternative construction costs the historical capital cost is required for the model to estimate Life Cycle Costs and Replacement costs.



Construction Costs

Alt 1 Do Minimum Alternative (enter the construction cost for this project alternative by category by year)

Construction costs should only be entered in years that are highlighted in ORANGE
The construction period can be changed above at Construction Start/End Year

#	Year	Engineering	Land	Construction	Environment Mitigation	0	0	0	0	Total Construction Costs
1	2014	250,000	2,000,000	-	-	-	-	-	-	2,250,000
2	2015	-	-	1,000,000	-	-	-	-	-	1,000,000
3	2016	-	-	1,000,000	-	-	-	-	-	1,000,000
4	2017	-	-	1,000,000	-	-	-	-	-	1,000,000
5		-	-	-	-	-	-	-	-	-
6		-	-	-	-	-	-	-	-	-
7		-	-	-	-	-	-	-	-	-
8		-	-	-	-	-	-	-	-	-
9		-	-	-	-	-	-	-	-	-
10		-	-	-	-	-	-	-	-	-
	Total	250,000	2,000,000	3,000,000	-	-	-	-	-	5,250,000

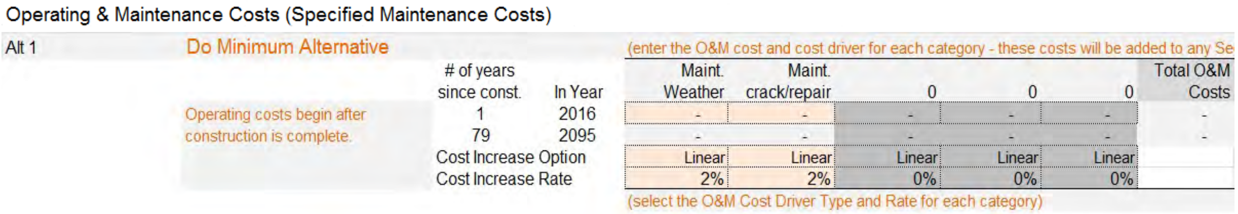
Operating & Maintenance Costs

There are two approaches to determining the operating and maintenance costs: **Specified** Operating and Maintenance costs that are defined by the user; and **Scheduled** Maintenance Costs that are from the Alberta Transportation's RODA model. It is possible to use either of these options, or a combination of the two.

The user **Specified** operating and maintenance cost categories are used to enter the associated costs (orange cells). The total operating and maintenance costs for the first year of operation are totaled in the year 1 row. Should the user wish to not use one or all of these categories, a zero can be entered in the relevant cell(s).

It is also necessary to select a Cost Increase Option (i.e. linear,[28] exponential,[29] traffic growth[30]). If linear or exponential growth is selected a Cost Increase Rate is also required.[31] **It is recommended that the linear growth driver be used to project traffic growth, as this is the common practice of the Department.**

IMPORTANT: Entering any **Specified** operating and maintenance costs will be added to **Scheduled** operating and maintenance costs identified by segment as discussed below. If you want to only use **Scheduled** operating costs, enter a zero in each of the **Specified** operating and maintenance cost categories. If you want to add to or adjust the **Scheduled** maintenance costs enter the adjusted amounts and associated growth driver information in the **Specified** operating and maintenance cost categories.



Operating & Maintenance Costs (Specified Maintenance Costs)

Alt 1 Do Minimum Alternative (enter the O&M cost and cost driver for each category - these costs will be added to any Se

Operating costs begin after construction is complete.

	# of years since const.	In Year	Maint. Weather	Maint. crack/repair	0	0	0	Total O&M Costs
	1	2016	-	-	-	-	-	-
	79	2095	-	-	-	-	-	-
Cost Increase Option			Linear	Linear	Linear	Linear	Linear	
Cost Increase Rate			2%	2%	0%	0%	0%	

(select the O&M Cost Driver Type and Rate for each category)

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[28] Linear growth adds the same amount to operating and maintenance costs each year (e.g. simple interest calculation).

[29] Exponential growth compounds the growth year over year (e.g. compound interest calculation).

[30] Traffic growth is the accumulation of all growth defined for the project by project segment (see Project Segment Definition).

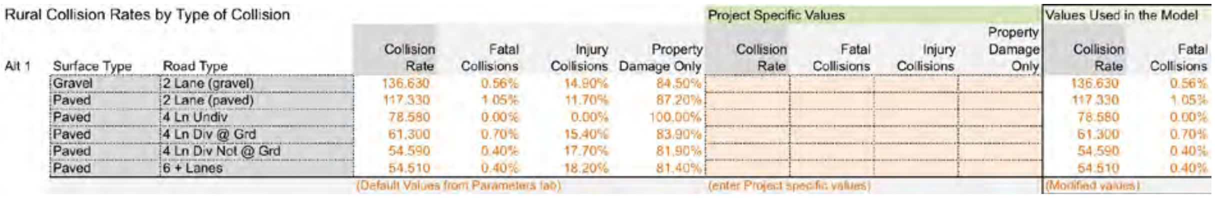
[31] The analyst should select the most appropriate growth driver that would reflect how operating and maintenance costs would be expected to grow for this project alternative.

The **Scheduled** operating and maintenance costs are defined by segment in the 'Project Segment Definition' table. The **Scheduled** maintenance costs may be turned off by selecting the 'Do Not Use' option in the 'Maintenance Cost Category' column of the 'Project Segment Definition' table. The **Scheduled** operating and maintenance costs are unique to each segment in the project and must be specified for each segment to be used in the analysis. See Maintenance Cost Categories by Surface Type (**Scheduled** Maintenance) below.

<u>IMPORTANT</u>: If you wish to only use **Specified** operating and maintenance costs, specify these costs as described above and select 'Do Not Use' for each Project segment as described in the Maintenance Cost Categories by Surface Type (**Scheduled** Maintenance) section provided below.

Collision Rates by Collision Severity (Default Value Change)

The default values for the collision rate and distribution of collisions by collision severity (from the Parameters tab) can be modified for the Alternative by entering the desired value in the 'Project Specific Values' field. This updated value is then reflected in the modified 'Values Used in the Model' portion of the table. Collision rates from 2012 are available for various road types at varying levels of AADT and can be obtained from the charts in Appendix 2, and may be entered as 'Project Specific Values'. If the charts do not contain data that applies to the situation, the default values may be used.

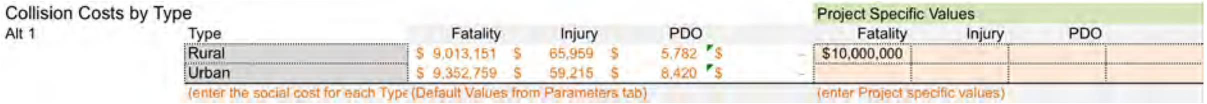


Rural Collision Rates by Type of Collision

							Project Specific Values				Values Used in the Model	
Alt 1	Surface Type	Road Type	Collision Rate	Fatal Collisions	Injury Collisions	Property Damage Only	Collision Rate	Fatal Collisions	Injury Collisions	Property Damage Only	Collision Rate	Fatal Collisions
	Gravel	2 Lane (gravel)	136.630	0.56%	14.90%	84.50%					136.630	0.56%
	Paved	2 Lane (paved)	117.330	1.05%	11.70%	87.20%					117.330	1.05%
	Paved	4 Ln Undiv	78.580	0.00%	0.00%	100.00%					78.580	0.00%
	Paved	4 Ln Div @ Grd	61.300	0.70%	15.40%	83.90%					61.300	0.70%
	Paved	4 Ln Div Not @ Grd	54.590	0.40%	17.70%	81.90%					54.590	0.40%
	Paved	6 + Lanes	54.510	0.40%	18.20%	81.40%					54.510	0.40%
			(Default Values from Parameters tab)				(enter Project specific values)				(Modified values)	

Collision Costs by Type (Default Value Change)

The default values for the cost of collisions by type of collision (from the Parameters tab) can be modified for the project by entering the desired value in the 'Project Specific Values' field. This updated value is then reflected in the modified 'Values Used in the Model' portion of the table.[32]



Collision Costs by Type

						Project Specific Values		
Alt 1	Type	Fatality	Injury	PDO		Fatality	Injury	PDO
	Rural	$ 9,013,151	$ 65,959	$ 5,782	$ -	$10,000,000		
	Urban	$ 9,352,759	$ 59,215	$ 8,420	$ -			
	(enter the social cost for each Type	(Default Values from Parameters tab)				(enter Project specific values)		

Project Segment Definition

The project segment definition is required to calculate various components of road user costs. The inputs on this table support both the California (Fuel & Non-Fuel) and Texas (Curvature & Gradient) approaches to estimating vehicle running costs, as well as other road user cost components including generating a forecast of traffic volumes for an alternative.

Before entering data into this table, depending on the complexity of the project being analyzed, it may be necessary to plan how the inputs are best defined. While there are 20 possible segments that can be defined for the project, for very complex projects, it may be necessary to combine components that have common features, such as gradient and curvature.

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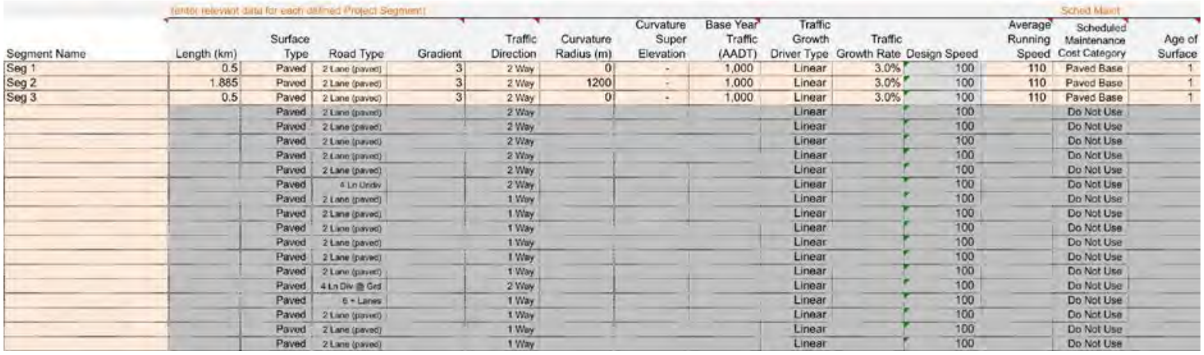
[32] Note that the threshold for reporting Property Damage Only (PDO) collisions increased from $1,000 to $2,000 on January 1, 2011.

Where components of a project are combined it will be important to also combine other relevant information, such as length and traffic volume.

Another important consideration is to combine only components of a project into segments that share common features, such as surface type or traffic direction.



(enter relevant data for each defined Project Segment)

Sched Maint

Segment Name	Length (km)	Surface Type	Road Type	Gradient	Traffic Direction	Curvature Radius (m)	Curvature Super Elevation	Base Year Traffic (AADT)	Traffic Growth Driver Type	Traffic Growth Rate	Design Speed	Average Running Speed	Scheduled Maintenance Cost Category	Age of Surface
Seg 1	0.5	Paved	2 Lane (paved)	3	2 Way	0	-	1,000	Linear	3.0%	100	110	Paved Base	1
Seg 2	1.885	Paved	2 Lane (paved)	3	2 Way	1200	-	1,000	Linear	3.0%	100	110	Paved Base	1
Seg 3	0.5	Paved	2 Lane (paved)	3	2 Way	0	-	1,000	Linear	3.0%	100	110	Paved Base	1
		Paved	2 Lane (paved)		2 Way				Linear		100		Do Not Use	
		Paved	2 Lane (paved)		2 Way				Linear		100		Do Not Use	
		Paved	2 Lane (paved)		2 Way				Linear		100		Do Not Use	
		Paved	2 Lane (paved)		2 Way				Linear		100		Do Not Use	
		Paved	2 Lane (paved)		2 Way				Linear		100		Do Not Use	
		Paved	4 Ln Undiv		2 Way				Linear		100		Do Not Use	
		Paved	2 Lane (paved)		1 Way				Linear		100		Do Not Use	
		Paved	2 Lane (paved)		1 Way				Linear		100		Do Not Use	
		Paved	2 Lane (paved)		1 Way				Linear		100		Do Not Use	
		Paved	2 Lane (paved)		1 Way				Linear		100		Do Not Use	
		Paved	2 Lane (paved)		1 Way				Linear		100		Do Not Use	
		Paved	2 Lane (paved)		1 Way				Linear		100		Do Not Use	
		Paved	4 Ln Div @ Grd		2 Way				Linear		100		Do Not Use	
		Paved	6 + Lanes		1 Way				Linear		100		Do Not Use	
		Paved	2 Lane (paved)		1 Way				Linear		100		Do Not Use	
		Paved	2 Lane (paved)		1 Way				Linear		100		Do Not Use	
		Paved	2 Lane (paved)		1 Way				Linear		100		Do Not Use	

The individual data items contained in this table include:

- Segment Name: Enter a unique identifying name for each segment of the project.
- Length: Enter the length of the segment in km.
- Surface Type (Texas [Curvature & Gradient] Vehicle Running Costs Only): Select either Paved or Gravel.[33]
- Road Type (Texas [Curvature & Gradient] Vehicle Running Costs Only): Select either 2 lane, 4-lane undivided, 4-lane divided expressway or 4-lane divided freeway.[34]
- Gradient (Texas [Curvature & Gradient] Vehicle Running Costs Only): Enter a grade that best reflects the average for the segment (an integer between -8 to +8).
- Traffic Direction (Texas [Curvature & Gradient] Vehicle Running Costs Only): Select either 1 Way or 2 Way.[35]
- Curvature Radius (Texas [Curvature & Gradient] Vehicle Running Costs Only): Enter the value that best reflects the average for the segment.
- Curvature Superelevation (Texas [Curvature & Gradient] Vehicle Running Costs Only): Enter the value that best reflects the average for the segment.
- Traffic Growth Driver: Select either Linear or Exponential.

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[33] Different gradient unit costs for the Texas (Curvature & Gradient) approach to estimating vehicle running costs.

[34] Allows for differentiation of collision rates by Road Type.

[35] In determining gradient costs, 1 Way assumes all traffic goes in the direction of the assigned gradient. 2 Way assumes traffic is evenly split in both directions.

- Traffic Growth Rate: Enter a growth rate for traffic on the selected segment.

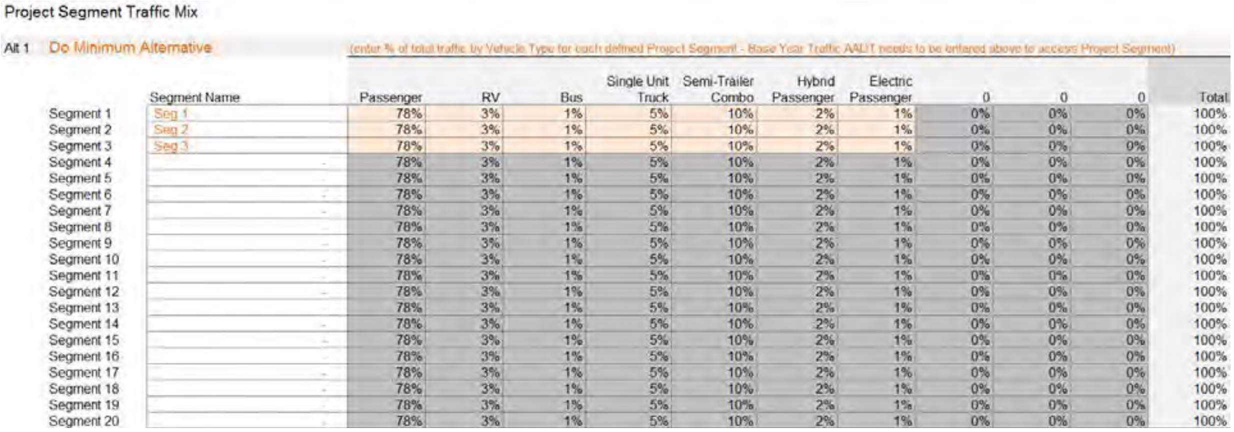
- Average Running Speed: Enter the average vehicle speed on the selected segment.

- Maintenance Cost Category (Scheduled Maintenance): Select the appropriate road maintenance cost category for the selected segment (e.g. Gravel, Paved Base, Paved 2nd). These maintenance cost categories were set up using information from Alberta Transportation's RODA model. If it is more appropriate to define specific road maintenance costs for this project, use the Operating & Maintenance Cost definitions defined in the Parameters tab and specify the appropriate costs for the option in the Alt # tab. When using this option, select 'Do Not Use' for each road segment Maintenance Cost Category.

- Age of Surface: When using the road maintenance costs from the RODA model, it is necessary to specify the age of the surface. Enter the age of the surface for each segment of the Alternative.

Project Segment Traffic Mix

The mix of traffic by Vehicle Type must be allocated for each segment. The Traffic Mix must add up to 100% for each segment.



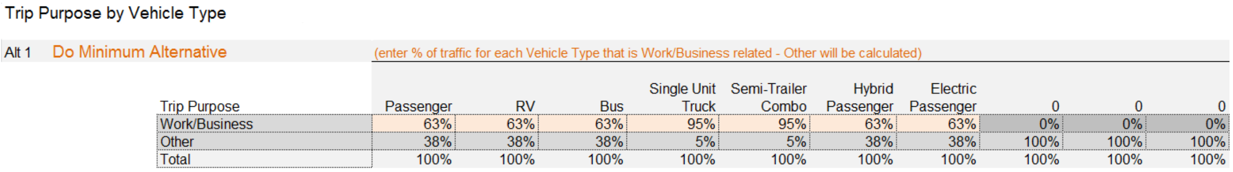
Project Segment Traffic Mix

Alt 1 Do Minimum Alternative (enter % of total traffic by Vehicle Type for each defined Project Segment - Base Year Traffic AADT needs to be entered above to access Project Segment)

	Segment Name	Passenger	RV	Bus	Single Unit Truck	Semi-Trailer Combo	Hybrid Passenger	Electric Passenger	0	0	0	Total
Segment 1	Seg 1	78%	3%	1%	5%	10%	2%	1%	0%	0%	0%	100%
Segment 2	Seg 2	78%	3%	1%	5%	10%	2%	1%	0%	0%	0%	100%
Segment 3	Seg 3	78%	3%	1%	5%	10%	2%	1%	0%	0%	0%	100%
Segment 4	-	78%	3%	1%	5%	10%	2%	1%	0%	0%	0%	100%
Segment 5	-	78%	3%	1%	5%	10%	2%	1%	0%	0%	0%	100%
Segment 6	-	78%	3%	1%	5%	10%	2%	1%	0%	0%	0%	100%
Segment 7	-	78%	3%	1%	5%	10%	2%	1%	0%	0%	0%	100%
Segment 8	-	78%	3%	1%	5%	10%	2%	1%	0%	0%	0%	100%
Segment 9	-	78%	3%	1%	5%	10%	2%	1%	0%	0%	0%	100%
Segment 10	-	78%	3%	1%	5%	10%	2%	1%	0%	0%	0%	100%
Segment 11	-	78%	3%	1%	5%	10%	2%	1%	0%	0%	0%	100%
Segment 12	-	78%	3%	1%	5%	10%	2%	1%	0%	0%	0%	100%
Segment 13	-	78%	3%	1%	5%	10%	2%	1%	0%	0%	0%	100%
Segment 14	-	78%	3%	1%	5%	10%	2%	1%	0%	0%	0%	100%
Segment 15	-	78%	3%	1%	5%	10%	2%	1%	0%	0%	0%	100%
Segment 16	-	78%	3%	1%	5%	10%	2%	1%	0%	0%	0%	100%
Segment 17	-	78%	3%	1%	5%	10%	2%	1%	0%	0%	0%	100%
Segment 18	-	78%	3%	1%	5%	10%	2%	1%	0%	0%	0%	100%
Segment 19	-	78%	3%	1%	5%	10%	2%	1%	0%	0%	0%	100%
Segment 20	-	78%	3%	1%	5%	10%	2%	1%	0%	0%	0%	100%

Trip Purpose by Vehicle Type

The share of traffic by trip purpose (work/business or other) must be set for each Vehicle Type. When the share of trips that are 'Work/Business' are entered for a Vehicle Type, the share of 'Other' trips is calculated by the model.



Trip Purpose by Vehicle Type

Alt 1 Do Minimum Alternative (enter % of traffic for each Vehicle Type that is Work/Business related - Other will be calculated)

Trip Purpose	Passenger	RV	Bus	Single Unit Truck	Semi-Trailer Combo	Hybrid Passenger	Electric Passenger	0	0	0
Work/Business	63%	63%	63%	95%	95%	63%	63%	0%	0%	0%
Other	38%	38%	38%	5%	5%	38%	38%	100%	100%	100%
Total	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

Emission Costs

Emission costs are estimated based on the fuel consumption as per the number of vehicle kilometres travelled by each vehicle type and running speed on each segment of the defined project.

These calculations are based on data from the California Life-Cycle Benefit/Cost Analysis Model, including the emission values.[36] Work is being done to estimate emission values for Alberta which can be used in the model for analysis when this work is complete.

The calculation of emission costs depends on data entered and estimated in the model for other variables and as a result, there is no additional data required to complete these calculations. A ‘factor’ has been incorporated in the model that can be used to adjust all the emission calculations up or down so they may better reflect Alberta values. This factor is located in cell BZ9 of each of the ‘Traffic Alt#’ tabs of the model.[37] A value of 1 uses the values provided in the Cal-B/C model. The user does not have access to modify this factor. The factor will be modified by the Department if warranted.

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[36] California Life-Cycle Benefit/Cost Analysis Model (Cal-B/C), Version 4.0, February 2009

[37] This factor will be modified at the discretion of the Department.

Section 4: How to Interpret the Results of an Analysis

Project Cost Summary

The costs for each Alternative defined for the project are summarized in the Project Costs tabs.[38] The costs are provided over the 80 year forecast period for each of the major project cost categories:

- Construction Costs: This includes the following cost components.
    - Historical Project Cost: Where there are no initial capital investment requirements associated with an existing asset, the historical project cost should be entered in the Alt tab. This value is reported in the Project Costs tab but NOT included in the Total Construction Costs.
    - Construction Costs by category, as defined by the user, as well as Rehab Costs (calculated in the model).
- Operating and Maintenance Costs by category, including user Specified Maintenance costs as well as Scheduled Maintenance costs.
- Road User Costs including: Vehicle Running Costs, Travel Time Costs and Collision Costs.
- Emission Costs include all cost estimates related to vehicle emissions associated with the Alternative.

Total Costs include each of the costs as defined above:

- Total Construction Costs (excluding Historical Project Cost)
- Roadway Operating and Maintenance Costs
- Road User Costs
- Emission Costs

Project Cost Graphs

For each Alternative two graphs of costs are provided. These charts are in the six tabs to the right of the Summary tab and are labeled Alt1Invest, Alt1Other, Alt2Invest, etc.

The first includes Infrastructure costs and related Life Cycle and Reinvestment costs over the forecast period.

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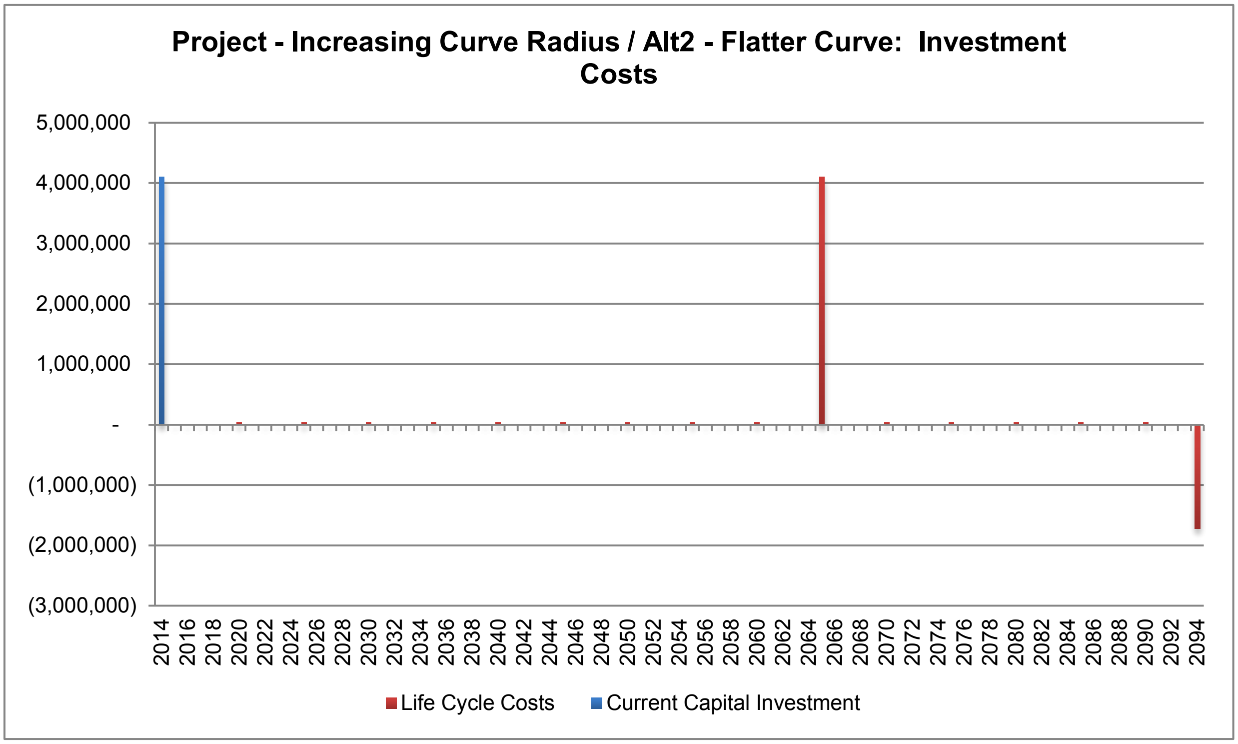
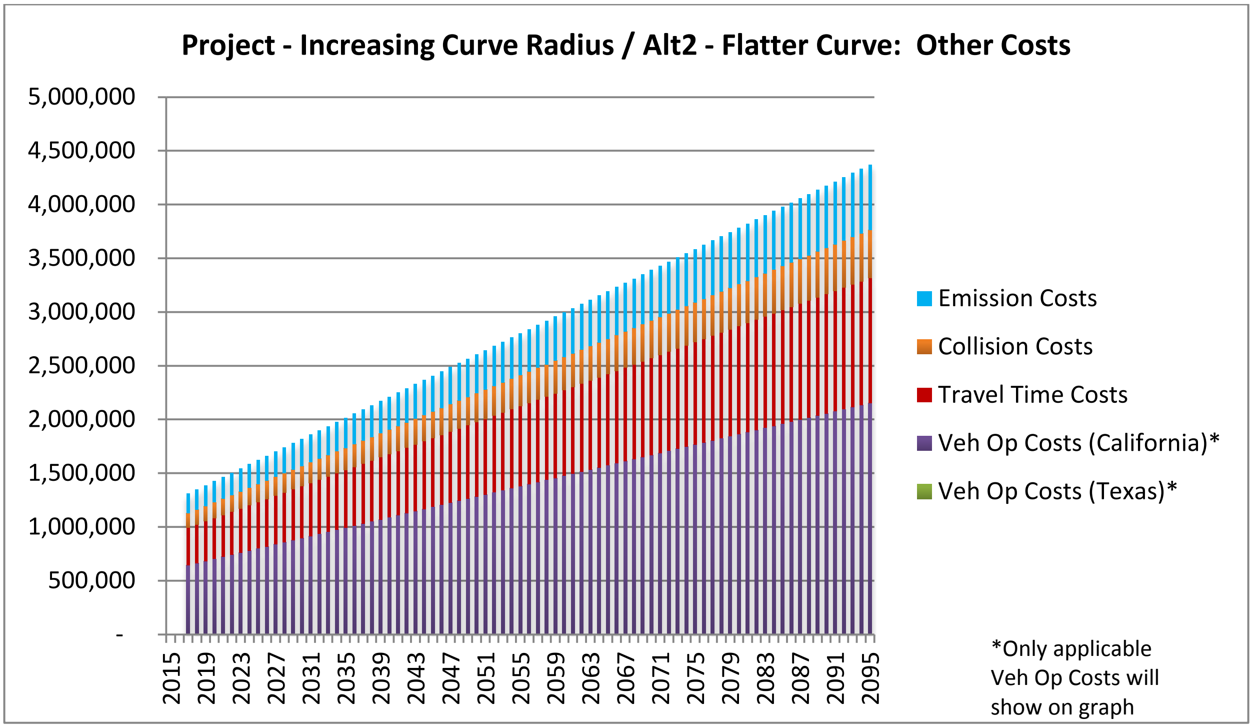
[38] A separate tab is provided for each Alternative (e.g. Project Costs Alt 1, Project Costs Alt 2, Project Costs Alt 3).



The second chart includes all the other costs associated with the selected Alternative.



Results

The detailed results of the benefit-cost analysis are summarized in the Results tab. This includes results for each Alternative (up to three Alternatives) and up to three Scenarios for each Alternative.

Results are provided for each year of the analysis for each of six benefit cost measures:

- **Internal Rate of Return (IRR):** The IRR is the discount rate which would give an NPV of zero, given expected cash flows. The IRR compares the un-discounted cash flows of two alternatives or scenarios. The higher the IRR the greater the return on the proposed investment. The standard time frame used for the IRR is 20 years.[39]

  The IRR calculation is as outlined below:

  $$\mathrm{NPV} = \sum_{n=0}^{N} \frac{C_n}{(1+r)^n} = 0$$

  Where *N* = time period selected (in years)

  n = the number of years passed to reach the year for which IRR is being analyzed

  r=IRR and,

  C_n is (Cumulative Costs[40] of Alt#)$_n$ - (Cumulative Costs of Alt#)$_n$

  Where Cumulative Costs are not discounted

- **Break Even Point:** The break-even point is the period of time where the investment breaks even or has paid for itself. At this point in the forecast period, the net present value of the costs of a project alternative or scenario are equal to the base analysis. If the project alternative or scenario always has a higher net cost, there is no break-even point (in the analysis timeframe).

  The Break Even Point formula is shown below:

  Min$_n$ where (Cumulative Costs Alt1:Scen1)$_n$ > (Cumulative Costs Alt#:Scen#)$_n$

- **Net Present Value (Discounted Cumulative Costs):** The NPV is the sum of discounted net costs over the period of analysis. A positive NPV means discounted benefits exceed the discounted value of costs. For this model, NPV of Alternative 1 is compared to those of each of the other Alternatives (Alt 1 - Alt 2).[41]

  The Net Present Value (Discounted Cumulative Costs) calculation is as outlined below:

  NPV$_n$ = (Cumulative Costs Alt#:Scen#)$_n$ > (Cumulative Costs Alt1:Scen1)$_n$

  Where Cumulative Costs are discounted at the selected discount rate

---

[39] Twenty years is a reasonable timeframe over which a public investment can be expected to provide a positive payback.

[40] Cumulative Costs include all costs (Investment and Other) from the first year of operation to the selected year.

[41] This includes the Scenarios for each of the Alternatives.

- Investment Costs (in Net Present Value): Investment costs are defined as the net present value of Construction Costs plus any Rehabilitation or Life Cycle Costs invested in the project over the forecast period, minus the salvage value of the project at the end of the forecast period. Investment Costs are used to calculate the Benefit Cost Ratio.

  The Investment Costs (in NPV) calculation is as outlined below:

  Investment Costs (in NPV)$_n$ = (Construction Costs Alt#:Scen#)$_n$ + (Rehabilitation/Life Cycle Costs Alt#:Scen#)$_n$ – (Salvage Costs Alt#:Scen#)$_n$

  Where Cumulative Costs are discounted at the selected discount rate

- Net Benefits [Non-Investment Cost Savings] (in Net Present Value): The net present value of the Benefits of a project Alternative are compared to the base alternative (defined as Alternative 1: Scenario 1 in the model. These Benefits, or Cost Savings, consider all the non-investment costs (defined above) associated with each Alternative/Scenario. In evaluating the benefits and costs of road and bridge projects there is not a stream of revenues generated by the investment, but a stream of user and social costs that will be different from alternative to alternative. As a result, the benefits of any particular alternative are reflected in the change in the resulting user and social cost streams. If an alternative reduces these costs, that change can be considered the benefits of that alternative. The Benefits are used to calculate the Benefit Cost Ratio.

  The Net Benefits [Non-Investment Cost Savings] (in NPV) calculation is as outlined below:

  Net Benefits [Non-Investment Cost Savings] (in NPV)$_n$ =
  -[(Cumulative Other Costs[42] Alt#:Scen#)$_n$ - (Cumulative Other Costs Alt1:Scen1)$_n$][43]

  Where Cumulative Costs are discounted at the selected discount rate

- Benefit Cost Ratio: The Benefit Cost Ratio is equal to the Net Benefits [Non-Investment Cost Savings] for an Alternative/Scenario minus those for the base alternative (defined as Alternative 1: Scenario 1), divided by the Investment Costs for the alternative minus those for the base alternative (defined as Alternative 1: Scenario 1).[44]

  The Benefit Cost Ratio calculation is as outlined below:

  Net Benefits [Non-Investment Cost Savings] (in NPV)$_n$ =

---

[42] Other Costs include all Non-Investment (Construction/Rehabilitation) Costs: Operating & Maintenance Costs, Road User Costs, and Emission Costs.

[43] If the Cumulative Other Costs for an alternative are less than those for Alt1:Scen1, the benefits (as measured by cost savings) will be positive.

[44] Alternative 1: Scenario 1, the ‘do minimum’ alternative, does not have a Benefit Cost Ratio because the benefits (defined for this model as cost savings) cannot be calculated.

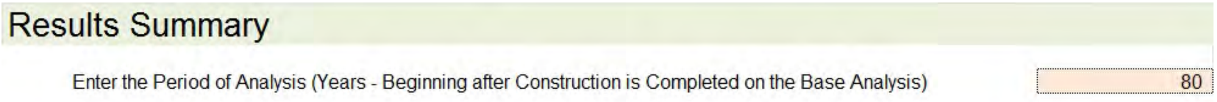
$$\frac{-[(\text{Cumulative Other Costs}\text{[45]}\ \text{Alt\#:Scen\#})_n - (\text{Cumulative Other Costs Alt1:Scen1})_n]\text{[46]}}{[(\text{Cumulative Investment Costs Alt\#:Scen\#})_n - (\text{Cumulative Investment Costs Alt1:Scen1})_n]\text{[47]}}$$

Where Cumulative Costs are discounted at the selected discount rate

Summary

An overview of the benefit cost analysis results is provided in the Summary tab. This includes Internal Rate of Return, Break Even Point, Net Present Value (Discounted Total Cumulative Costs Year 80), Investment Costs (in NPV), Net Benefits [Non-Investment Costs] (in NPV) and Benefit Cost Ratio.

The results for the analysis can be viewed for any point in the 80 year analysis time frame by entering the selected period as shown below. The results provided in the Results Summary will be updated and reflect the selected Period of Analysis.

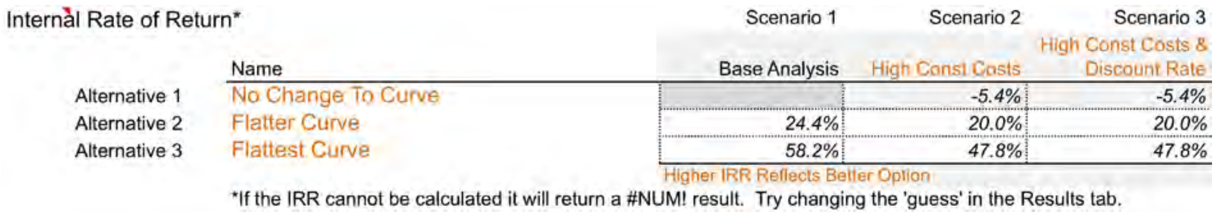


Results Summary

Enter the Period of Analysis (Years - Beginning after Construction is Completed on the Base Analysis) 80

Internal Rate of Return

The Internal Rate of Return (IRR) is summarized by project alternative and scenario. Each of the results is compared to Alternative 1: Scenario 1. The IRR results presented here provide the maximum return over the 80 year forecast period. These results may vary over the forecast period, so the Results tab should be reviewed.



Internal Rate of Return*

	Name	Scenario 1 Base Analysis	Scenario 2 High Const Costs	Scenario 3 High Const Costs & Discount Rate
Alternative 1	No Change To Curve		-5.4%	-5.4%
Alternative 2	Flatter Curve	24.4%	20.0%	20.0%
Alternative 3	Flattest Curve	58.2%	47.8%	47.8%

Higher IRR Reflects Better Option

*If the IRR cannot be calculated it will return a #NUM! result. Try changing the 'guess' in the Results tab.

The Internal Rate of Return represents the break even interest rate of return on the investment. The higher the Internal Rate of Return result, the better the option.

In some instances, the IRR cannot be calculated. This may be due to analysis results, or the IRR guess is not close enough to the solution to allow Excel to arrive at a result through the iterative calculation process required to determine the IRR. To fix the latter problem, the IRR guess can be modified in Results tab cell AJ10 when a #NUM! result is presented to see if a different guess will yield an IRR result.

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[45] Other Costs include all Non-Investment (Construction/Rehabilitation) Costs: Operating & Maintenance Costs, Road User Costs, and Emission Costs.

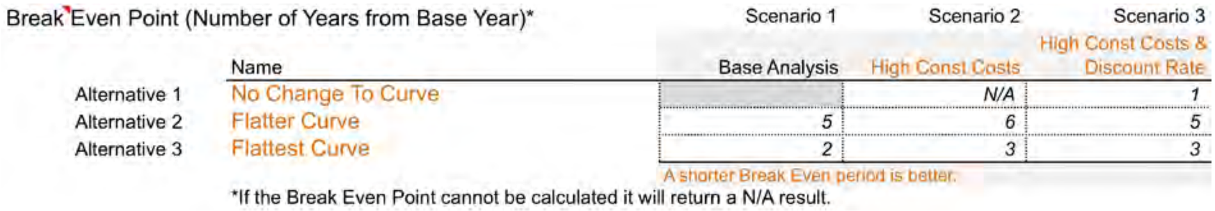
[46] If the Cumulative Other Costs for an alternative are less than those for Alt1:Scen1, the benefits (as measured by cost savings) will be positive.

[47] The denominator is the incremental investment required for the alternative as compared to Alt1:Scen1.

Technical Note: The IRR in Excel requires a guess at the IRR. The guess should be the expected internal rate of return. If the guess is not close enough for the algorithm to estimate the IRR, it will return a #NUM! error. This may be remedied by trying a different IRR guess. To change the IRR guess select the Results tab and go to the Alternative/Scenario where the results are providing a #NUM! result, and modify the Guess cell. Depending upon the information specific to the Alternative/Scenario being analyzed, there may not be a solution, or a unique solution to the IRR calculation in a particular year, or for any years in the analysis timeframe.

Break Even Point

The Break Even Point indicates when the net costs of the Alternatives are equal to the base alternative. A shorter period to recover the investment in the project is better than a longer period. In some cases, the Scenario or Alternative never does as well as the base alternative, and a break-even point is not achieved in the timeframe (e.g. High Construction Cost Scenario for Alternative 1, Scenario 2).



Break Even Point (Number of Years from Base Year)*

		Scenario 1	Scenario 2	Scenario 3
	Name	Base Analysis	High Const Costs	High Const Costs & Discount Rate
Alternative 1	No Change To Curve		N/A	1
Alternative 2	Flatter Curve	5	6	5
Alternative 3	Flattest Curve	2	3	3

A shorter Break Even period is better.

*If the Break Even Point cannot be calculated it will return a N/A result.

Technical Note: In some cases, it will not be possible to calculate a Break Even Point. In this case, an N/A error will occur in the relevant cell.

Net Present Value (Discounted Total Cumulative Costs)

The Net Present Value calculation evaluates the total cumulative costs discounted to the base year. For this measure, the Alternative with the lowest net present value (discounted cumulative costs) is the preferred alternative.

In the example below, the Flattest Curve Alternative has the lowest NPV in each scenario, indicating it would be the preferred alternative. This is consistent with the IRR results from above that indicate it is generating a positive IRR in each scenario, and the highest IRR for the Low Cost Scenario.

Net Present Value (Discounted Total Cumulative Costs)

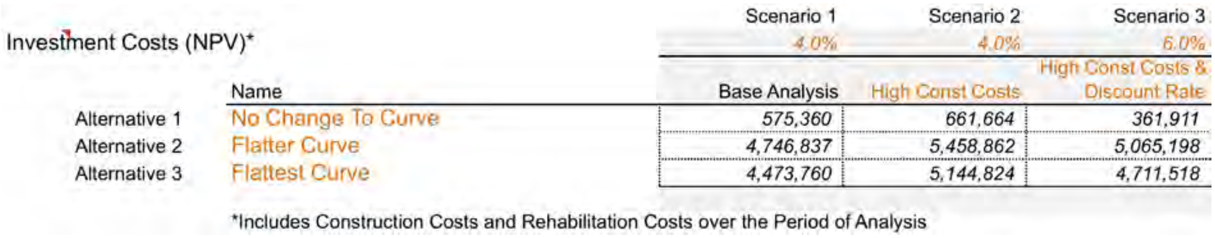
		Scenario 1	Scenario 2	Scenario 3
		4.0%	4.0%	6.0%
	Name	Base Analysis	High Const Costs	High Const Costs & Discount Rate
Alternative 1	No Change To Curve	109,582,973	109,669,277	68,100,041
Alternative 2	Flatter Curve	93,153,165	93,865,190	59,078,093
Alternative 3	Flattest Curve	64,672,695	65,343,759	41,488,147

Lower NPV Reflects Better Option (Lower Total Disc Cost)

Investment Costs (NPV)

Because the Project Benefit Cost Model estimates costs associated with each alternative, benefits are reflected only by a reduction in costs (or cost savings) from one alternative compared to another. To calculate a Benefit/Cost Ratio, these benefits, or cost savings from one alternative to another, need to be compared to an investment.

In this model, Investment Costs are defined as Construction Costs plus any Rehabilitation costs that are invested in the project over the forecast period.[48] As well, the salvage value of the project is estimated at the end of the forecast period (80 years from the Base Year) and deducted from the Investment Costs.[49]


Investment Costs (NPV)*

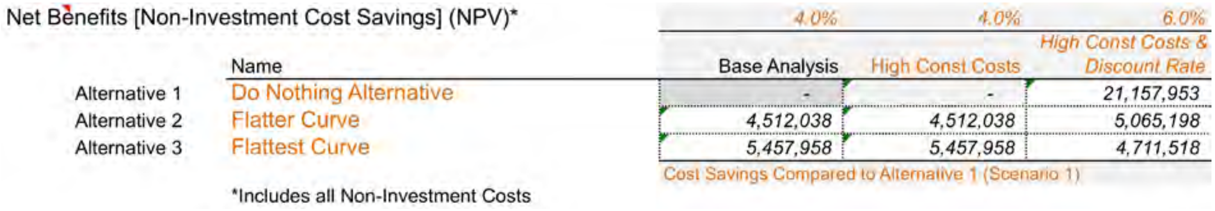
		Scenario 1	Scenario 2	Scenario 3
		4.0%	4.0%	6.0%
	Name	Base Analysis	High Const Costs	High Const Costs & Discount Rate
Alternative 1	No Change To Curve	575,360	661,664	361,911
Alternative 2	Flatter Curve	4,746,837	5,458,862	5,065,198
Alternative 3	Flattest Curve	4,473,760	5,144,824	4,711,518

*Includes Construction Costs and Rehabilitation Costs over the Period of Analysis

The net present value of the stream of Investment Costs is used for the calculation of the Benefit/Cost Ratio, where Investment Costs are the denominator of Benefit Cost calculation.

Net Benefits [Non-Investment Cost Savings] (in NPV)

The Net Benefits associated with each Alternative are equal to the cost savings for that Alternative as compared to the base alternative which in this model is defined as Alternative 1. The Net Benefits are calculated by taking all the Non-Investment Costs for the Alternative considered and subtracting the Non-Investment Costs estimated for Alternative 1. As a result, the Benefits associated with Alternative 1 (Scenario 1) are zero.


Net Benefits [Non-Investment Cost Savings] (NPV)*

		4.0%	4.0%	6.0%
	Name	Base Analysis	High Const Costs	High Const Costs & Discount Rate
Alternative 1	Do Nothing Alternative	-	-	21,157,953
Alternative 2	Flatter Curve	4,512,038	4,512,038	5,065,198
Alternative 3	Flattest Curve	5,457,958	5,457,958	4,711,518

Cost Savings Compared to Alternative 1 (Scenario 1)

*Includes all Non-Investment Costs

As with Investment Costs, the Net Benefits (Non-Investment Cost Savings) are discounted using the Discount Rate for the selected Alternative to calculate the Net Present Value for use in the Benefit/Cost Ratio calculation (see below).

Benefit/Cost Ratio

Typically the results of a benefit/cost analysis are summarized in a Benefit/Cost Ratio. This calculation compares the net present value of a stream of cost savings (Net Benefits) over time compared to the costs, or initial investment in the project.

As described above, the Benefits or Cost Savings (Net Benefits) of each alternative have been estimated by calculating the net present value of Non-Investment costs for each alternative and comparing this against the Non-Investment Costs for Alternative 1. These Net Benefits have been used as the numerator in the Benefit/Cost Ratio calculation. The denominator has been calculated using the same approach, where the net present values of the Investment Costs of each alternative have been compared to the Investment Costs for Alternative 1.

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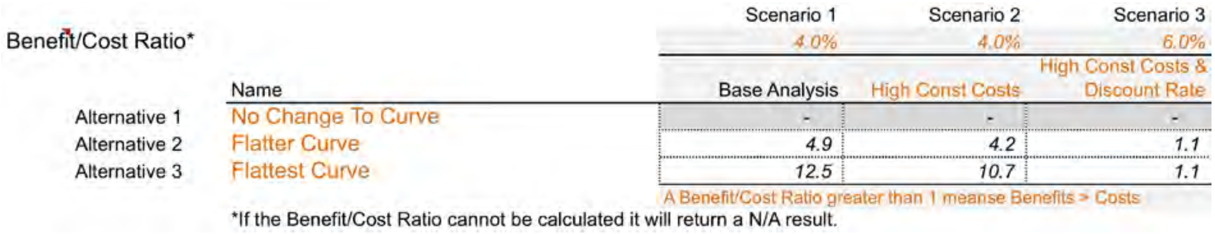
[48] This differs from Net Present Value in that NPV includes all costs.

[49] The salvage value is estimated based on the remaining life of the asset beyond the 80 year forecast timeframe.



Benefit/Cost Ratio*		Scenario 1	Scenario 2	Scenario 3
		4.0%	4.0%	6.0%
	Name	Base Analysis	High Const Costs	High Const Costs & Discount Rate
Alternative 1	No Change To Curve	-	-	-
Alternative 2	Flatter Curve	4.9	4.2	1.1
Alternative 3	Flattest Curve	12.5	10.7	1.1

A Benefit/Cost Ratio greater than 1 meanse Benefits > Costs

*If the Benefit/Cost Ratio cannot be calculated it will return a N/A result.

A Benefit/Cost Ratio greater than 1 indicates that the benefits of the alternative are greater than the costs at the specified time period and that the investment will produce positive results. The greater the Benefit/Cost Ratio, the better the return on the investment for the specified time period.

Section 5: How to Update the Model

Administrator and User Updates

The updates described in this section are intended to be performed by the Administrator of the model. It is expected that all of the variables discussed below will be reviewed and updated on a periodic basis. In some cases, the information will need to be updated on an annual basis to reflect values for the Base Year. In other cases, the values may be updated as either more current, or if better information is available.

The only exception to this is the Scenario & Analysis Definition components. Here it may be the case that the Administrator requires some specified scenarios to always be conducted. Outside of these set Scenarios, it may also be helpful to conduct other sensitivities.

Model Components

The Parameters tab includes the definition of model variables that are applied across each project. Model Parameters should be set to apply to a wide array of projects, and should be updated periodically. It is recommended that this tab be reviewed annually to determine what information may need to be updated.

In several cases, an update to some information in the Parameters tab will require an update to information located elsewhere in the model. The necessary changes are outlined below.

IMPORTANT: Failing to update all the relevant inputs associated with the new or updated categories will lead to erroneous results.[50]

If the information in this tab has been updated, there is no need to review this tab for new analyses. Any individual changes to default values can be made in the Project Definition tab of the model.

An itemized list of the variables found in the Parameters tab, as well as a summary of how to update these variables can be found in Appendix 1.

Base Year

Some of the default values requiring periodic updates include values that were estimated for a particular year. It is important that all these values be brought to current year values (Base Year). In each case discussed below, the Consumer Price Index (CPI) has been used to bring historic values to their estimated 2014 value.

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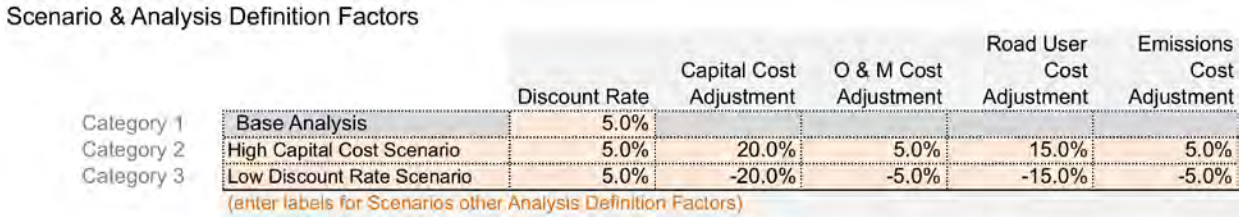
[50] It should be noted that having flexibility to be able to define various categories in the model also creates a burden on the analyst to update relevant information to ensure that the model functions as it is intended.

Scenario & Analysis Definition

It is expected that the Administrator may require that some scenarios be completed for all benefit cost analyses conducted, and the analyst may not be allowed to modify the Scenario and Analysis Definition Factors.

Up to two additional scenarios, in addition to the Base Analysis, can be conducted for each Alternative. In these scenarios, different assumptions can be used for the Discount Rate and costs in each of the following four categories: capital costs, operating & maintenance costs, road user costs and emissions costs. The adjustment entered is applied to the total estimated costs in that category in each year of the analysis.



Scenario & Analysis Definition Factors

		Discount Rate	Capital Cost Adjustment	O & M Cost Adjustment	Road User Cost Adjustment	Emissions Cost Adjustment
Category 1	Base Analysis	5.0%				
Category 2	High Capital Cost Scenario	5.0%	20.0%	5.0%	15.0%	5.0%
Category 3	Low Discount Rate Scenario	5.0%	-20.0%	-5.0%	-15.0%	-5.0%

(enter labels for Scenarios other Analysis Definition Factors)

Discount Rate (4% Default)

The discount rate used to calculate the Net Present Value and Breakeven Point is set by the user for the Base Analysis as well as the other two scenarios. There is no ‘right’ discount rate. However, the rate should reflect the risk and time value of money from the perspective of the provincial government. If there is an official discount rate that the GOA adopts, this should be used for the analysis. At the time of writing (2014) the default discount rate for all Alberta Transportation projects is 4%. Generally, the public sector uses a lower discount rate than the private sector because, it is argued that generally the public sector can be more patient to receive a return on investment than the private sector.

In choosing a discount rate, current economic conditions, inflation and risk of the investment should be considered. At the time of writing (2014), inflation is low reducing the time value of money costs. As a result, a relatively historically low discount rate of 4% could be used for the Base Analysis.

It has long been the practice of Alberta Transportation to use a 4% discount rate for projects. This is in contrast to the Canadian Federal Treasury Board Benefit Cost Guidelines that recommend 10%.[51]

Project Type Categories

The analyst can define up to 10 different project types. For each project type, the default running (or design) speed and asset life should be entered.

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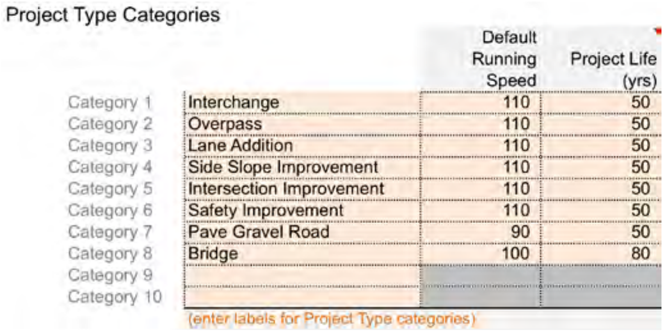
[51] The Treasury Board's 1976 Benefit-Cost Analysis Guide states that the discount rate for federal government projects is 10% in real terms (i.e., when using constant dollars). The Guide also calls for sensitivity analysis (discussed in Section 9.4.1) using real discount rates of 5% and 15%. GUIDE TO BENEFIT-COST ANALYSIS IN TRANSPORT CANADA, Transport Canada, TP11875E, September 1994.

- Rehabilitation Costs tab: Changes to the Project Type definition will require an update to the rehabilitation cost profile data.[52] Rehabilitation costs are calculated as a percent of the historical (original) project investment per year. The Administrator should review the Project Type Categories and update as required.



Project Type Categories

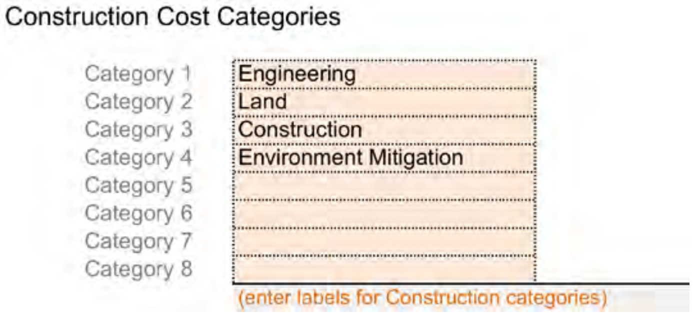
		Default Running Speed	Project Life (yrs)
Category 1	Interchange	110	50
Category 2	Overpass	110	50
Category 3	Lane Addition	110	50
Category 4	Side Slope Improvement	110	50
Category 5	Intersection Improvement	110	50
Category 6	Safety Improvement	110	50
Category 7	Pave Gravel Road	90	50
Category 8	Bridge	100	80
Category 9			
Category 10			

(enter labels for Project Type categories)

Construction Cost Categories

The analyst can define up to 8 different types of construction costs.

The Construction Cost Categories are linked to the Alt # tabs. In the Alt # tabs, the analyst may enter the construction costs for each construction cost category. The Administrator should define Construction Cost categories that will be useful for each analysis.



Construction Cost Categories

Category 1	Engineering
Category 2	Land
Category 3	Construction
Category 4	Environment Mitigation
Category 5	
Category 6	
Category 7	
Category 8	

(enter labels for Construction categories)

Operating & Maintenance Cost Categories (Specified Maintenance)

The user may use these defined categories, the fixed Scheduled Maintenance categories described below, or a combination of the two. Cost category usage is defined in the Alt # tabs. A description of how to define the categories can be found in Section 3: Operating and Maintenance Cost.

The analyst can define up to 5 different types of operating and maintenance costs. The Operating & Maintenance Cost Categories are linked to the Alt # tabs. The analyst will enter the operating and maintenance costs for each category. The Administrator should define Operating and Maintenance Cost categories that will be useful for each analysis.

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[52] In the RehabCosts tab (G14:Z93) the annual cost of rehabilitation of each facility is defined. If the Project Type categories are changed, or the Project Life is changed, the annual cost of rehabilitation (as a percent of project cost) will also need to be updated.

Operating & Maintenance Cost Categories

Category 1	Maintenance
Category 2	Snow
Category 3	Crack Sealing
Category 4	
Category 5	

(enter labels for O&M categories)

Maintenance Cost Categories by Surface Type (Scheduled Maintenance)

There are three fixed Scheduled Maintenance Cost Categories. These cost categories are used to calculate maintenance costs given the surface type.

The Maintenance Cost Categories are linked to the Alt # tabs. The Administrator should check to ensure that the most current values for these Maintenance Cost categories is in the model. These values are contained in the Maintenance tab (G15:I134).[53]

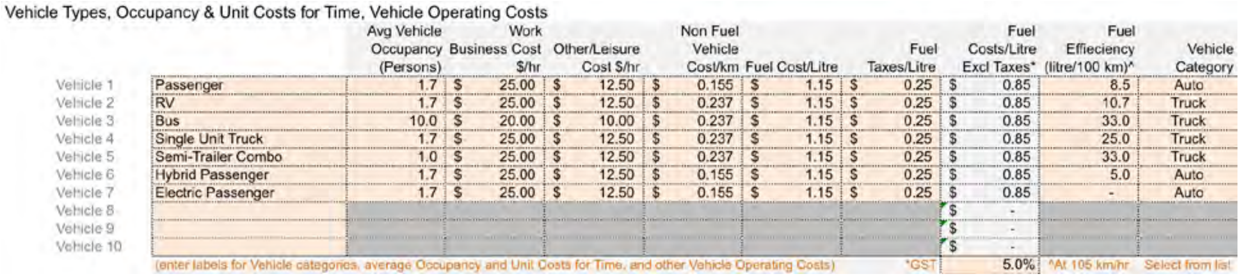
Maintenance Cost Categories (by Surface Type)

Category 1	Gravel
Category 2	Paved Base
Category 3	Paved 2nd

(these are fixed)

Vehicle Default Values

The Administrator can define up to 10 different vehicle types. For each vehicle type, the following information is required: average vehicle occupancy, business and non-business costs/hr, fuel and non-fuel operating costs, fuel efficiency and an assigned vehicle type (auto/truck). The Administrator should define the vehicle types to reflect the mix of vehicles using Alberta roads.



Vehicle Types, Occupancy & Unit Costs for Time, Vehicle Operating Costs

		Avg Vehicle Occupancy (Persons)	Work Business Cost $/hr	Other/Leisure Cost $/hr	Non Fuel Vehicle Cost/km	Fuel Cost/Litre	Fuel Taxes/Litre	Fuel Costs/Litre Excl Taxes*	Fuel Effieciency (litre/100 km)^	Vehicle Category
Vehicle 1	Passenger	1.7	$ 25.00	$ 12.50	$ 0.155	$ 1.15	$ 0.25	$ 0.85	8.5	Auto
Vehicle 2	RV	1.7	$ 25.00	$ 12.50	$ 0.237	$ 1.15	$ 0.25	$ 0.85	10.7	Truck
Vehicle 3	Bus	10.0	$ 20.00	$ 10.00	$ 0.237	$ 1.15	$ 0.25	$ 0.85	33.0	Truck
Vehicle 4	Single Unit Truck	1.7	$ 25.00	$ 12.50	$ 0.237	$ 1.15	$ 0.25	$ 0.85	25.0	Truck
Vehicle 5	Semi-Trailer Combo	1.0	$ 25.00	$ 12.50	$ 0.237	$ 1.15	$ 0.25	$ 0.85	33.0	Truck
Vehicle 6	Hybrid Passenger	1.7	$ 25.00	$ 12.50	$ 0.155	$ 1.15	$ 0.25	$ 0.85	5.0	Auto
Vehicle 7	Electric Passenger	1.7	$ 25.00	$ 12.50	$ 0.155	$ 1.15	$ 0.25	$ 0.85	-	Auto
Vehicle 8								$ -		
Vehicle 9								$ -		
Vehicle 10								$ -		
	(enter labels for Vehicle categories, average Occupancy and Unit Costs for Time, and other Vehicle Operating Costs)						*GST	5.0%	^At 105 km/hr	Select from list

The Traffic Alt # tabs, Project Definition tab, and Alt # tabs use the Vehicle Type definitions to perform various calculations. No updates are required in these tabs as a result of a change in the Vehicle Type definitions.

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[53] It is not expected that the Maintenance Cost categories will change.

Occupancy

- Average occupancy rate for light vehicles as reported by Natural Resources Canada (2009)[54] is 1.68. This has been applied to each of the passenger vehicle, RV, single unit truck vehicles.
- Occupancy information for other vehicle types, including medium and heavy vehicles and buses are 'assumed' values.

Work Business Cost $/hr

- The Work Business Cost per hour reflects the cost of traveller time for work related trips. The average hourly wage rate in Alberta has been used for non-commercial vehicles ($24.84)[55] adjusted for inflation to 2014 ($26.00), the truck driver rate (24.69)[56] adjusted for inflation to 2014 ($26.00) has been used for commercial trucking and bus driver rate ($20.11)[57] adjusted to 2014 ($21.00) for buses.[58] All data has been drawn from Alberta Learning Information Service (ALIS) WageInfo website.[59]

Other/Leisure Cost $/hr

- The travel time costs for non-business travel associated with leisure or other trips is typically lower than for business or work trips. It has been estimated by the US Department of Transport that non-business travel time values range between 50% and 70% of wages (or the business/work value of travel time).[60] The lower end of this range is supported by a more recent study prepared for Transport Canada where the 'overall or base Valuation of Travel Time Savings would be 50% of the average wage rate'.[61] As a result, it has been assumed that 'other'(leisure) travel time costs would be 50% of the rate used for 'business/work' travel time.

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[54] 2009 Canadian Vehicle Survey Summary Report, Natural Resources Canada, Office of Energy Efficiency, page 54. http://oee.rncan.gc.ca/publications/statistics/cvs09/index.cfm

[55] http://alis.alberta.ca/pdf/wageinfo/2011_AWSS_Wages_By_Industry_and_Region.pdf

[56] http://alis.alberta.ca/wageinfo/Content/RequestAction.asp?SearchContent=truck+driver&aspAction=GetWageKeyWordSearchResult&format=html&Page=SearchKeyword&RegionID=20

[57] http://alis.alberta.ca/wageinfo/Content/RequestAction.asp?aspAction=GetWageDetail&format=html&RegionID=20&NOC=7412

[58] All values have been rounded to the nearest dollar.

[59] http://alis.alberta.ca/wageinfo/Content/RequestAction.asp?format=html&aspAction=GetWageHomePage&Page=Home

[60] USDOT (1997), Departmental Guidance on the Evaluation of Travel Time in Economic Analysis, memo, USDOT (www.fhwa.dot.gov); used in STEAM software (www.ota.fhwa.dot.gov/steam).

[61] Anming Zhang, Anthony E. Boardman, David Gillen and W.G. Waters II, *Towards Estimating the Social and Environmental Costs of Transportation in Canada*, Transport Canada, Aug 2004, page 20.

Non Fuel Vehicle Cost/km (California [Fuel & Non-Fuel) Vehicle Operating Cost Calculation)

- The California (Fuel & Non-Fuel) Vehicle Operating Cost calculation is based on the approach used in the CalTrans Benefit Cost Model. In this model vehicle operating costs are broken into fuel and non-fuel operating costs. Non-fuel operating costs include all vehicle operating costs, as measured by the average cost per distance (km).[62] Values are reported for two vehicle classes: autos and trucks. These values reported by the CalTrans model have been modified to reflect metric units and updated to 2012 values.

    - For example, if the non-fuel vehicle cost per mile is 0.239 $/mi for 2007, it is multiplied by 0.621 (1km = 0.621 mi) to get 0.148 $/km. This value is then updated to 2014 by multiplying 0.148 $/km by the inflation index (CPI), yielding a final value of 0.159 $/km.

- The non-fuel costs of heavy vehicles is reported by Barton & Associates to be approximately 0.2154 per tonne-km or passenger-km.[63] While the cost per tonne-km or passenger-km is similar to the converted CalTrans estimate for trucks, it is noted that the units are not an exact match. The Barton & Associates figure has been updated to 2014 using the CPI inflation index yielding a final value of 0.0244 $/km.

Fuel Cost/litre (California [Fuel & Non-Fuel] Vehicle Operating Cost Calculation)

- Gasoline: Fuel costs have been sourced from AlbertaGasPrices.com which provides a compendium of gas prices across Alberta. The current average cost of gasoline is $1.15 per litre and it has average approximately $ 1.15 per litre in 2014 (January to April).[64]

- Diesel: Using the same source, current diesel prices have been tracking above gasoline prices by about 10¢ per litre. As a result, fuel costs for vehicles types that primarily use diesel have been updated to $1.25 per litre.[65]

Calibration to Department Rate

The vehicle operating costs for the California (Fuel and Non-Fuel) approach have been calibrated to the Department's vehicle operating cost pay rate of $0.505/km. Alberta Transportation's Finance Director has advised that the rate is established by the Treasury Board and Finance, and that the factors that went into obtaining the rate include fuel, maintenance, insurance, and amortization cost.

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[62] California Life-Cycle Benefit/Cost Analysis Model (Cal-B/C), Version 4.0, February 2009

[63] Estimation of Costs of Heavy Vehicle Use per Vehicle-Kilometre in Canada, Transport Canada T80808-05-0326, by Barton & Associates in association with Logistics Solution Builders Inc., December 2006, page 61. This cost estimate is for tractor-trailer operations in uncongested conditions. The calculations in Barton include fuel costs which have been taken out of the figures reported here.

[64] http://www.albertagasprices.com/Retail_Price_Chart.aspx

[65] Given that fuel costs can fluctuate dramatically from month to month and season to season, it is recommended that a reasonable estimate be included in the model by the Administrator and this be used for all analysis until the next update. Where the current trend in fuel prices is dramatically different that the base values used in the model, this may be run as a sensitivity to determine what the impact would be on the Benefit Cost Analysis results.

Fuel Taxes/litre (California [Fuel & Non-Fuel] Vehicle Operating Cost Calculation)

- As taxes are a transfer[66] they cannot be included in the benefit cost analysis. Using retail fuel prices thus requires that taxes be deducted. The current tax rates for fuel in Alberta are 24.554 cents per litre plus GST.[67]

Fuel Efficiency (litre/100 km) (California [Fuel & Non-Fuel] Vehicle Operating Cost Calculation)

- Average fuel consumption is reported by Natural Resources Canada (NRCan) (2009)[68] for three vehicle classes[69] (Light Vehicles, Medium Trucks and Heavy Trucks) as follows nationally (and regionally). The Alberta rates are used in the model as follows:
  - Light Vehicles (Gasoline): 10.7 litres/100 km (Alberta Rate 11.3)[70] Light vehicles include: cars, station wagons, vans, SUVs, pickup trucks, and other vehicles (straight trucks, tractor trailers and buses),
  - Medium Trucks[71] (Gasoline): 25.1 litres/100 km. Medium trucks are defined as having a gross vehicle weight between 4.5 and 15 tonnes,
  - Light Vehicles (Diesel): 10.6 litres/100 km (defined as above)
  - Medium Trucks (Diesel): 24.4 litres/100 km (Alberta Rate 22.0)[72] (defined as above)
  - Heavy Trucks[73] (Diesel): 33.4 litres/100 km (Alberta Rate 33.1)[74] Heavy trucks are defined as having a gross vehicle weight of 15 tonnes or more.
- Fuel consumption for new passenger vehicles (2012) has been calculated for 83 vehicles using Natural Resources Canada's Fuel Consumption Ratings.[75] Of these, 10 are hybrid vehicles and have a rated average fuel consumption of 4.93 litres/100 km. The remaining new cars have a rated fuel consumption of 6.59 litres/100 km.

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[66] Taxes can be seen as a transfer from consumers to Government. If they were to be included in the analysis, the taxes would be doubly counted. For this reason, they must be subtracted from the total fuel cost.

[67] http://gasbuddy.com/Can_Tax_Info.aspx

[68] 2009 Canadian Vehicle Survey Summary Report, Natural Resources Canada, Office of Energy Efficiency, page 9. http://oee.rncan.gc.ca/publications/statistics/cvs09/index.cfm

[69] Ibid, page 23.

[70] Ibid, page 19

[71] Ibid, page 31.

[72] Ibid, page 20

[73] Ibid, page 31.

[74] Ibid, page 21

[75] Natural Resources Canada Fuel Consumption Ratings http://oee.nrcan.gc.ca/cars-light-trucks/buying/fuel- comsumption-guide/fuel-consumption-ratings/17771

Because the current fleet of light vehicles as defined by Natural Resources Canada is about half cars and station wagons and half vans, SUVs and pickup trucks, and about only 20% of these vehicles are less than 3 years old, the average fuel consumption for passenger vehicles can be expected to lie between 6.6 (as calculated for new non hybrid vehicles) and 10.7 as reported by NRCan. Without access to the raw data to be able to estimate the actual value, the mid-point of these two estimates is currently reported for non-hybrid passenger vehicles (8.5 litres/100 km).

Other alternative sources of fuel efficiency were also reviewed. Examples of these include the following:

- Using Natural Resources Canada's Fuel Consumption Ratings for new pickup trucks (2012) yielded an average of 9.61 litres/100 km.[76] This is very close to the average report for light vehicles (2009).
- Fuel consumption for intercity buses is reported by Barton & Associates to be 37.5 litres/100 km.[77]

Road User Gradient Factor Categories (Texas [Curvature & Gradient] Road User Costs)

The Texas (Curvature & Gradient) approach to calculating road user costs uses gradient and curvature costs assigned by vehicle type. This approach uses factors that originated in part from data compiled by the Texas Research and Development Foundation in 1982 for the Federal Highway Administration. For the Texas (Curvature & Gradient) Alberta Transportation Benefit-Cost Model, these numbers were converted to 1988 Canadian dollars using Alberta consumer prices for items such as fuel, oil, tires, depreciation, etc. From there further increases were applied to the numbers based on the Transportation Price Index from 1988 to 2012. These 2012 factors are used in the new version of the model.[78]

The calculations associated with the Texas (Curvature & Gradient) approach to estimating road user costs are completed in the RUC Alt# tabs. The data used to perform these calculations (updated to 2012) is in the RUC Alt1 tab as follows:[79]

- Gradient Costs: RUC Alt1 beginning at A294.
- Curvature Costs: RUC Alt1 beginning at AY6.

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[76] Ibid

[77] Estimation of Costs of Heavy Vehicle Use per Vehicle-Kilometre in Canada, Transport Canada T80808-05-0326, by Barton & Associates in association with Logistics Solution Builders Inc., December 2006, page 27.

[78] Benefit Cost Analysis - Vehicle Running Costs, Alberta Transportation & Utilities, Traffic Engineering Branch, January 1989.

[79] The calculations used for the other alternatives are linked to the source data in the RUC Alt1 tab.

Collisions[80]

- Major Injury: 2006-2010 average (Alberta Transportation, Traffic Safety Branch) of Persons Injured divided by the number of Non-Fatal Injury Collisions (Table 1.1 page 2, 2010 Traffic Collision Summary). The proportion of injury collisions that are 'serious' are estimated based on national data (Canadian Motor Vehicle Traffic Collision Statistics: 2009)[81] where the number of seriously injured and total injured is available. This rate has declined steadily from the early 90's from about 10% of all injuries to 6.6% in 2009. Applying this rate to the Alberta non-fatal injury rate the number of people in a collision with a non-fatal injury is 0.09.

- Minor Injury: Same average used for Major Injury as Serious Injury. As above, national data regarding the proportion of injuries that are 'serious' has been used to estimate the number of 'moderate' injuries, estimated to be 93.4% in 2009. Applying this rate to the Alberta non-fatal injury rate, the 2012 base year number of people in a collision with a non-fatal injury is 1.27.

Collision Rates

The collision rate information provided for 2010 was broken down into 6 categories as defined below. The rates reported here are based on 2010 data. In 2011 the Office of Traffic Safety is reporting collision rates for Property Damage Only (PDO) when the value of the damage is $2,000 or more as compared to the previous data which used a threshold of $1,000 for reporting purposes.[82]

- The total number of collisions in Alberta in 2010 was 151,298 (Alberta Transportation, Traffic Safety).[83] The model utilizes collision rates per hundred million vehicle kilometres travelled for highway type and location (urban/rural) where this information is available.

- The model can accept differing collision rates for each of 5 combinations of surface type (gravel/paved) and road type (2 lane, 4 lane undivided, 4 lane divided expressway, 4 lane divided freeway). If collision data is available for a specific road, these rates can be input into the model. Collision rates can be obtained from the graphs included in the collision rates tab; if the rates are unavailable for the scenario in question then the default values may be used. The average collision rates for Alberta in 2010 were as follows[84]:

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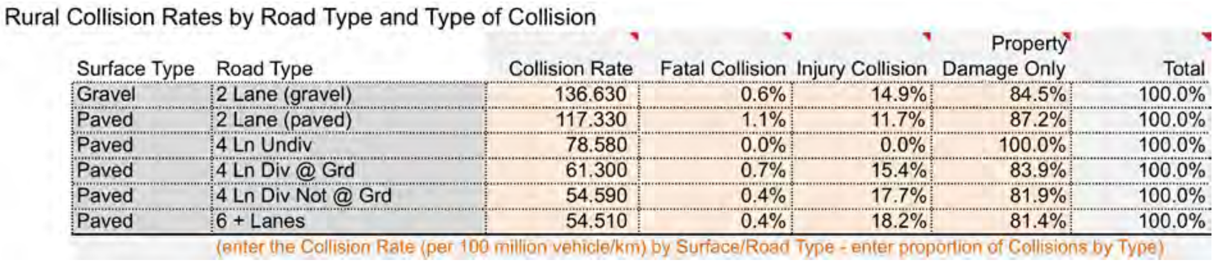
[80] Alberta Traffic Collision Data is contained in Appendix 2.

[81] Transport Canada TP 3322 Cat. T45-3/2009 2011 http://www.tc.gc.ca/eng/roadsafety/tp- tp3322-2009-1173.htm#t6

[82] Note that the threshold for reporting Property Damage Only (PDO) collisions increased from $1,000 to $2,000 January 1, 2011.

[83] Alberta Traffic Collision Statistics 2010, Alberta Transportation, Traffic Safety, page 8.

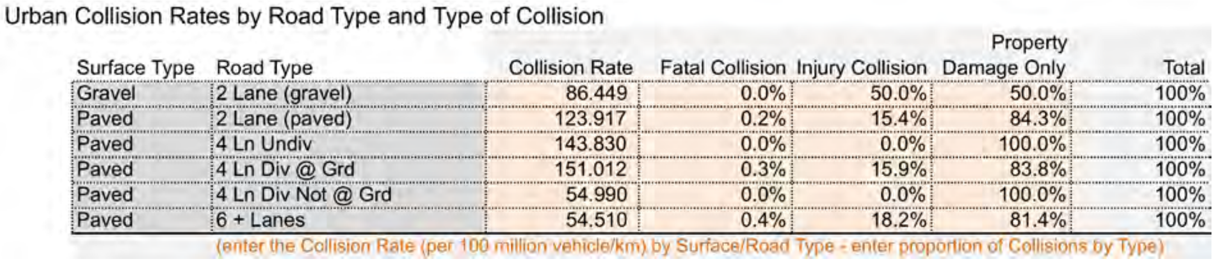
[84] Note that the Urban Collision Rate and proportion of collisions by Type of Collision for 6+ Lanes was not available and the Rural data has been used as a proxy for this data.



Rural Collision Rates by Road Type and Type of Collision

Surface Type	Road Type	Collision Rate	Fatal Collision	Injury Collision	Property Damage Only	Total
Gravel	2 Lane (gravel)	136.630	0.6%	14.9%	84.5%	100.0%
Paved	2 Lane (paved)	117.330	1.1%	11.7%	87.2%	100.0%
Paved	4 Ln Undiv	78.580	0.0%	0.0%	100.0%	100.0%
Paved	4 Ln Div @ Grd	61.300	0.7%	15.4%	83.9%	100.0%
Paved	4 Ln Div Not @ Grd	54.590	0.4%	17.7%	81.9%	100.0%
Paved	6 + Lanes	54.510	0.4%	18.2%	81.4%	100.0%

(enter the Collision Rate (per 100 million vehicle/km) by Surface/Road Type - enter proportion of Collisions by Type)



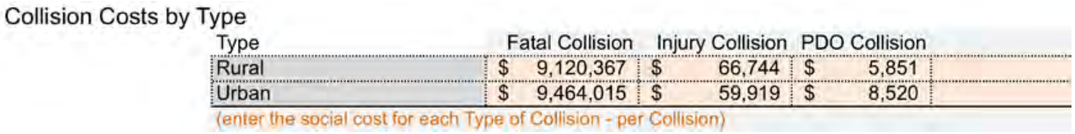
Urban Collision Rates by Road Type and Type of Collision

Surface Type	Road Type	Collision Rate	Fatal Collision	Injury Collision	Property Damage Only	Total
Gravel	2 Lane (gravel)	86.449	0.0%	50.0%	50.0%	100%
Paved	2 Lane (paved)	123.917	0.2%	15.4%	84.3%	100%
Paved	4 Ln Undiv	143.830	0.0%	0.0%	100.0%	100%
Paved	4 Ln Div @ Grd	151.012	0.3%	15.9%	83.8%	100%
Paved	4 Ln Div Not @ Grd	54.990	0.0%	0.0%	100.0%	100%
Paved	6 + Lanes	54.510	0.4%	18.2%	81.4%	100%

(enter the Collision Rate (per 100 million vehicle/km) by Surface/Road Type - enter proportion of Collisions by Type)

Collision Costs

All collision costs used in the model have been provided by the Alberta Transportation Traffic Safety Branch. These estimates are based on work being done across Canada with Transport Canada, which is yet to be finalized. Based on the work to date, the Collision Costs by Type of collision (average for 2006-2011) have been inflated to reflect 2014 values using the CPI inflation index, resulting in values as follows: The social cost values reflect the total cost for each category of collision severity.[85]



Collision Costs by Type

Type	Fatal Collision	Injury Collision	PDO Collision
Rural	$ 9,120,367	$ 66,744	$ 5,851
Urban	$ 9,464,015	$ 59,919	$ 8,520

(enter the social cost for each Type of Collision - per Collision)

Emission Costs by Type

The vehicle emissions component was modelled after the California Life-Cycle Benefit/Cost Analysis Model[86] which incorporates values for six different emission categories. The values for each emissions component were taken from this model, converted from gram/mile to tonne/km, and were updated to 2014 using CPI.

All values are cost per tonne of emissions.

- CO (Carbon Monoxide): $96.50
- CO_2 (Carbon Dioxide): $40.00
- NO_x (Nitrogen Oxides): $30,000.00
- PM_{10} (Particular Matter): $244,000.00
- SO_x (Sulphur Oxides): $102,000.00
- VOC (Volatile Organic Compounds): $2,000.00

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[85] For example, a collision involving a fatality will include the estimate for the fatality, injury and property damage costs.

[86] California Life-Cycle Benefit/Cost Analysis Model (Cal-B/C), Version 4.0, February 2009

Emission costs vary by the average running speed of the vehicle. The Emissions tab uses the emission factors for various vehicle types defined in the California Life-Cycle Benefit/Cost Analysis Model (Cal-B/C). The CalTrans model defines emissions by speed as measured by miles/hr. These units have been converted to km/hr outside the model (emissionsConvV1b.xlsx).

Appendix 1: Summary of Model Variables

Each of the variables in the Parameters tab are itemized in the table below. Values highlighted (red) in this table indicate an external source should be consulted to determine the default value. The source and process for updating these default values is provided for each variable in the section below the table.

Component	Variable	Definition	Information Source	Links
Base Year		Used by the Model as the Base Year for all calculations that are time sensitive.	Current year	All components with a timeline.
Scenario & Analysis Definition Factors	Scenarios	Used to define 3 Scenarios for each Project Alternative.	Base Analysis (fixed) and 2 Alternate Scenarios are user defined.	These scenarios will be applied to each Alternative.
	Discount Rate	Used to determine Present Value and Break Even Point.	User (4% is Alberta Transportation's default value)	Calculation of Net Present Value and Break Even Period.
	Capital Cost Adjustment	Used to determine the change in Capital Costs from the Base Analysis for each of the 2 Scenarios.	User	Applied to both capital costs and rehabilitation costs.
	O & M Cost Adjustment	Used to determine the change in O & M costs from the Base Analysis for each of the 2 Scenarios.	User	Applied to operating and maintenance costs.
	Road User Cost Adjustment	Used to determine the change in Road User Costs from the Base Analysis for each of the 2 Scenarios.	User	Applied to vehicle operating costs and travel time costs.
	Emission Cost Adjustment	Used to determine the change in Emission Costs from the Base Analysis for each of the 2 Scenarios.	User	Applied to vehicle emissions costs.
Project Type Categories	Project Type Categories (up to 10)	Default data for Running Speed and Project Life.	User defined Project Type Categories (up to 10)	RehabCosts tab and Alt# Design Speed (info only)
	Default Running Speed	Provided as a guide when defining the Alternative in Alt#.	User defined for each Project Type	Provided as information in Project Definition.

Component	Variable	Definition	Information Source	Links
	Project Life	Provided as a guide for entering the replacement cost in Rehabilitation Cost profile (RehabCosts tab).	User defined for each Project Type	
Construction Cost Categories	Construction Cost Categories (up to 8)	To separate the costs of the project into logical categories for typical projects.	User defined based typical projects and where necessary project specific categories (e.g. environmental mitigation costs)	Rehabilitation Cost profile (RehabCosts tab) and Project cost summary (Project Costs tab)
Operating Cost Categories	Operating Cost Categories (up to 5)	To separate the operating and maintenance costs of the project into logical categories for typical projects.	User defined based on typical projects and where necessary project specific categories can be defined (e.g. on-going environmental mitigation costs)	Project cost summary (Project Costs tab)
Vehicle Types, Occupancy & Unit Costs for Time	Vehicle Type (up to 10 different vehicle types can be defined)	To separate the costs that are vehicle type specific.	User defined (up to 10 categories)	All vehicle related costs and forecasts of traffic.
	Occupancy	Number of people per vehicle for Travel Time Costs.	Natural Resources Canada (light vehicles)	Travel time costs
	Work/Bus $/hr	Value of Time for Work and Business trips.	WageInfo (Alta) and Transportation Cost and Benefit Analysis II – Travel Time Costs	Travel time costs
	Other $/hr	Value of Time for non-work trips.	WageInfo (Alta) and Transportation Cost and Benefit Analysis II – Travel Time Costs	
Texas [Curvature & Gradient]	Various	The Texas (Curvature & Gradient) Vehicle Operating Costs are based on work completed by AT in 1989.	Benefit Cost Analysis - Vehicle Running Costs, Alberta Transportation & Utilities	Vehicle Values by Road Type: RUC Alt 1 (AY42:BA47)

Component	Variable	Definition	Information Source	Links
California [Fuel & Non-Fuel] Vehicle Operating Cost Estimate	Non Fuel Vehicle Cost $/hr	All user costs (except fuel) associated with operating a vehicle.	Cal-B/C February 2009 advanced to 2011 using CPI	California (Fuel & Non-Fuel) vehicle operating costs.
California [Fuel & Non-Fuel] Vehicle Operating Cost Estimate	Fuel Cost/Litre	Average price of fuel typical for the vehicle type (e.g. gasoline/ diesel).	2012 average Alta fuel costs (AlbertaGasPrices.com)	California (Fuel & Non-Fuel) vehicle operating costs.
California [Fuel & Non-Fuel] Vehicle Operating Cost Estimate	Fuel Efficiency (litre/ 100 km)	The number of litres of fuel consumed per 100 km travelled at an average speed of 105 km/hr (highway driving).	Natural Resources Canada	California (Fuel & Non-Fuel) vehicle operating costs.
California [Fuel & Non-Fuel] Vehicle Operating Cost Estimate	Vehicle Category	The vehicle category will be either Auto or Truck and be used to adjust fuel consumption by average vehicle speed.	User (based on the vehicle type specified by the user)	California (Fuel & Non-Fuel) vehicle operating costs.
Growth Driver Type	Three Growth Driver Categories: Linear, Exponential, Traffic Growth	Categories defined in the Model to project O & M Costs.	Cannot be changed by the Analyst	
Traffic Direction *Texas [Curvature & Gradient] Vehicle Cost Estimate*	Two Direction Categories: 1 Way, 2 Way	Categories defined in the Model used to allocate Gradient costs to traffic on each Road Segment.	Cannot be changed by the Analyst	Used to allocate Gradient costs to traffic on Road Segment
Number of People by Collision Severity	Three Collision Categories: Fatality, Serious Injury, Moderate Injury	Categories defined in the Model.	Cannot be changed by the Analyst	Used to calculate fatality and injury related collision costs.
	Fatality	Average number of people involved in a collision involving a fatality.	Traffic Safety	Used to calculate fatality and injury related collision costs.
	Serious Injury	Average number of people involved in a collision involving a serious injury.	Traffic Safety	Used to calculate fatality and injury related collision costs.

Component	Variable	Definition	Information Source	Links
	Moderate Injury	Average number of people involved in a collision involving a moderate injury.	Traffic Safety	Used to calculate fatality and injury related collision costs.
Collision Rates by Type of Collision	Surface Type/Road Type	The collision rate and distribution of collisions by type can be varied across 5 combinations of surface type and road type.	Categories cannot be changed by the Analyst	Used to calculate fatality and injury related collision costs.
	Collision Rate	Number of collisions per 100 million vehicle kms. See Appendix 2 for collision rate information from 2006-2011.	Traffic Safety	Used to calculate fatality and injury related collision costs.
	Fatality	The proportion of total collisions involving a fatality.	Traffic Safety	Used to calculate fatality and injury related collision costs.
	Injury	The proportion of total collisions involving an injury.	Traffic Safety	Used to calculate fatality and injury related collision costs.
	Property Damage Only	The proportion of total collisions involving only property damage.	Traffic Safety	Used to calculate fatality and injury related collision costs.
Collision Costs by Type	Social costs (fatality/ injury) and property damage costs of collisions.	The average cost per person by collision type.	Categories cannot be changed by the analyst.	Used to calculate fatality and injury related collision costs.
	Fatality	Social cost of each person involved in a fatal collision.	Traffic Safety	Used to calculate fatality and injury related collision costs.
	Serious Injury	Social cost of each person involved in a collision involving a serious injury.	Traffic Safety	Used to calculate fatality and injury related collision costs.
	Moderate Injury	Social cost of each person involved in a collision involving a moderate injury.	Traffic Safety	Used to calculate fatality and injury related collision costs.

Component	Variable	Definition	Information Source	Links
	Property Damage Only	The property damage costs of each collision severity.	Traffic Safety	Used to calculate fatality and injury related collision costs.
Emission Costs by Type	Type of Emission	Label for the type or category of emission.	At Department's discretion	Used to calculate vehicle emission costs.
	Cost per Tonne	The social cost of each emission category.	California Life-Cycle Benefit/Cost Analysis Model (Cal-B/C)	Used to calculate vehicle emission costs.

Appendix 2: Alberta Traffic Collision Data

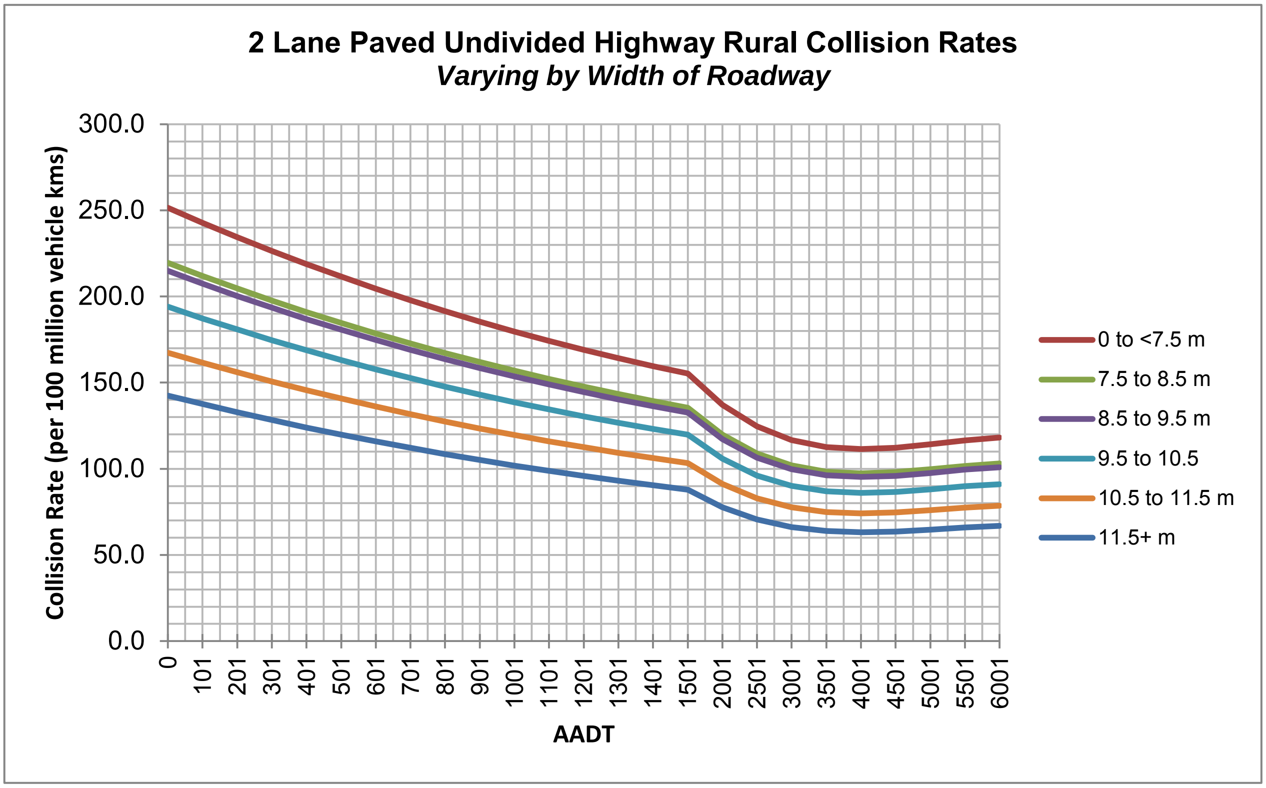
Alberta Traffic Collisions
2006-2011

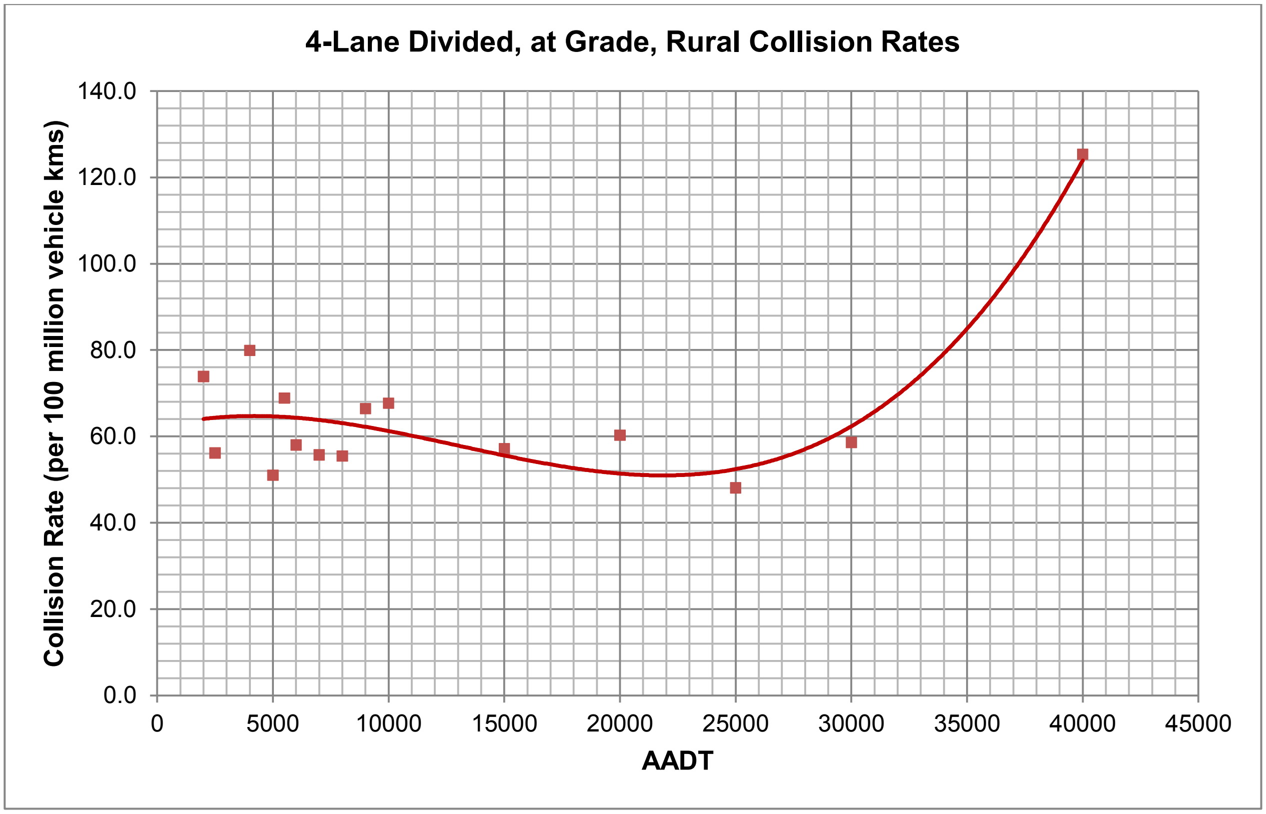
Alberta Total	2011		2010		2009		2008		2007		2006	
	N	%	**N**	%	**N**	%	**N**	%	**N**	%	**N**	%
Fatal Collisions	285	0.2	307	0.2	302	0.2	375	0.2	402	0.3	404	0.3
Non-Fatal Injury Collisions	13909	10.0	13552	9.0	14246	9.1	16153	10.2	17857	11.6	18831	13.2
Property Damage Collisions	124985	89.8	137430	90.8	142678	90.7	141527	89.5	135642	88.1	123357	86.5
Total Reportable Collisions	139179	100.0	151289	100.0	157226	100.0	158055	100.0	153901	100.0	142592	100.0

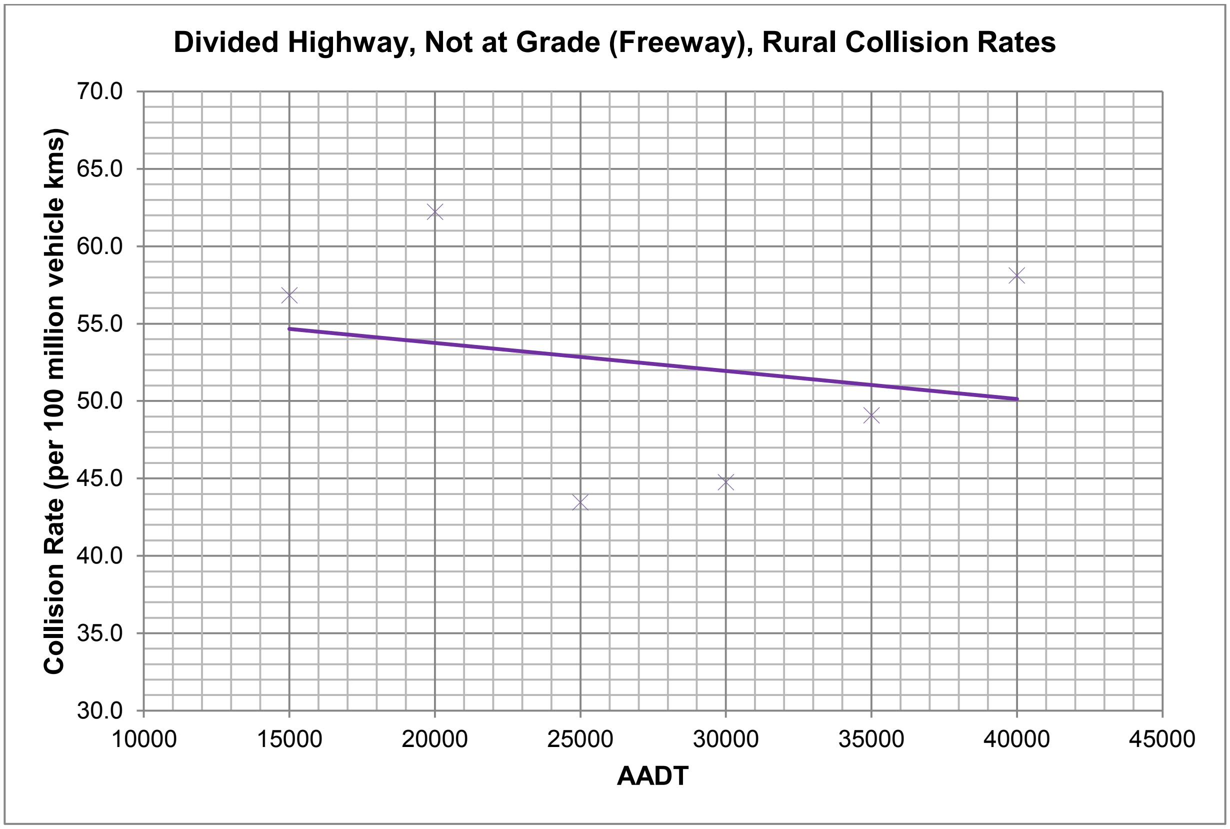
Rural Highways	2011		2010		2009		2008		2007		2006	
	N	%	**N**	%	**N**	%	**N**	%	**N**	%	**N**	%
Fatal Collisions	170	0.9	181	0.9	173	0.9	212	1.0	211	1.0	220	1.0
Non-Fatal Injury Collisions	2937	15.2	2591	13.0	2582	13.3	2834	13.7	3073	14.4	3245	15.3
Property Damage Collisions	16244	83.9	17096	86.0	16708	85.8	17655	85.3	17995	84.6	17766	83.7
Total Rural Highway Collisions	19351	100.0	19868	100.0	19463	100.0	20701	100.0	21279	100.0	21231	100.0

Urban	2011		2010		2009		2008		2007		2006	
	N	%	**N**	%	**N**	%	**N**	%	**N**	%	**N**	%
Fatal Collisions	75	0.1	77	0.1	83	0.0	105	0.08242	130	0.1	119	0.1
Non-Fatal Injury Collisions	9897	8.8	9902	8.1	10534	0.9	12074	9.47768	13638	11.1	14267	12.8
Property Damage Collisions	102064	91.1	112155	91.8	1175579	99.1	115215	90.4399	109395	88.8	96825	87.1
Total Urban Collision	112036	100.0	122134	100.0	1186196	100.0	127394	100.0	123163 ,..	100.0	111211	100.0

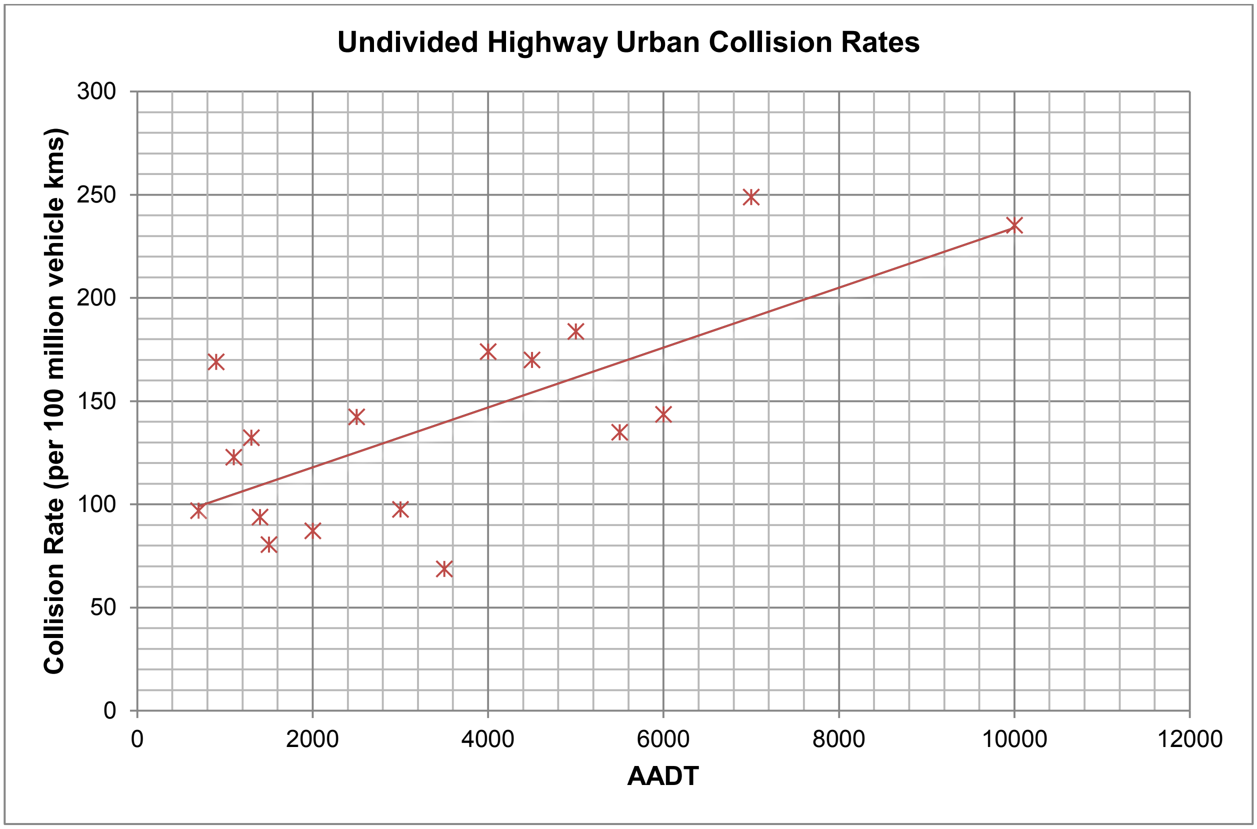
Alberta Transportation
Office of Traffic Safety
August 2013

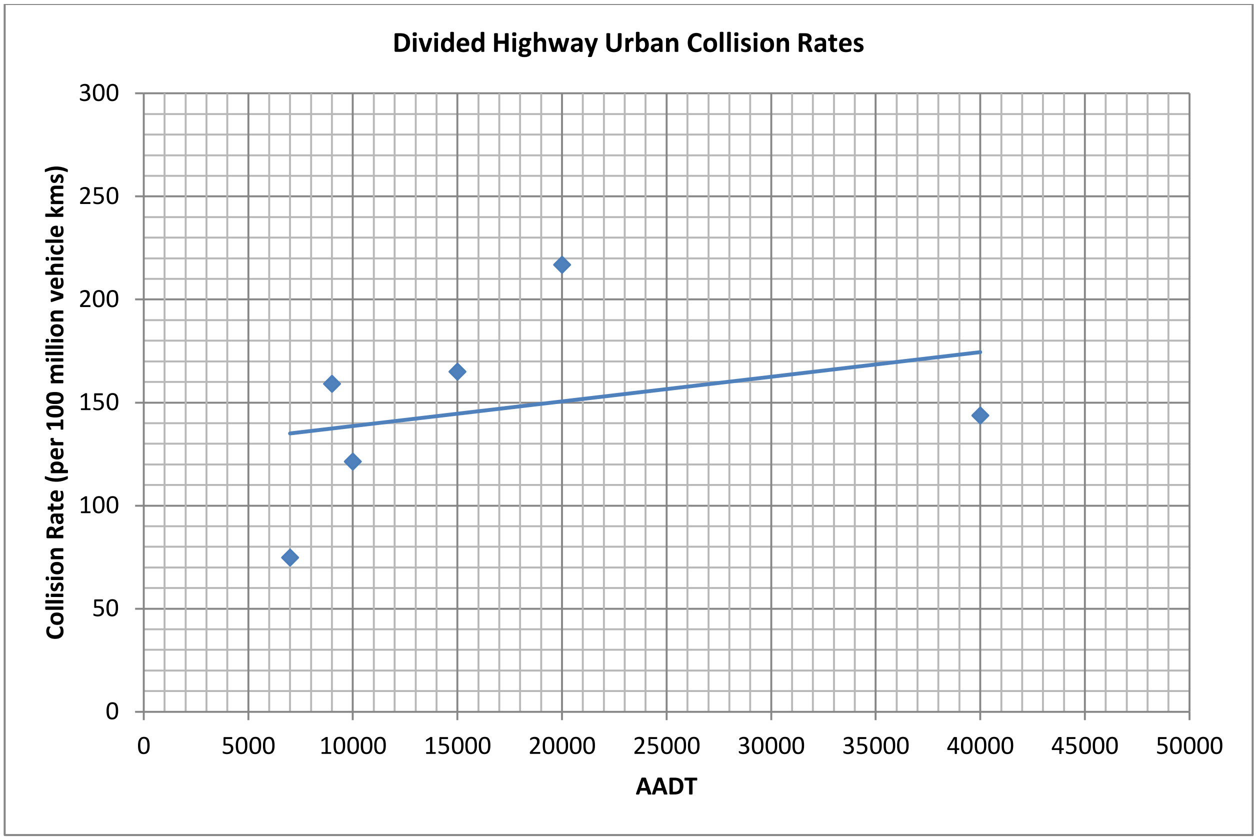

2 Lane Paved Undivided Highway Rural Collision Rates
Varying by Width of Roadway
Collision Rate (per 100 million vehicle kms)
300.0
250.0
200.0
150.0
100.0
50.0
0.0
0
101
201
301
401
501
601
701
801
901
1001
1101
1201
1301
1401
1501
2001
2501
3001
3501
4001
4501
5001
5501
6001
AADT
0 to <7.5 m
7.5 to 8.5 m
8.5 to 9.5 m
9.5 to 10.5
10.5 to 11.5 m
11.5+ m


4-Lane Divided, at Grade, Rural Collision Rates
Collision Rate (per 100 million vehicle kms)
140.0
120.0
100.0
80.0
60.0
40.0
20.0
0.0
0
5000
10000
15000
20000
25000
30000
35000
40000
45000
AADT


Divided Highway, Not at Grade (Freeway), Rural Collision Rates
Collision Rate (per 100 million vehicle kms)
70.0
65.0
60.0
55.0
50.0
45.0
40.0
35.0
30.0
10000
15000
20000
25000
30000
35000
40000
45000
AADT


6+ Lanes (Freeway) Rural Collision Rates
Collision Rate (per 100 million vehicle kms)
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
0
10000
20000
30000
40000
50000
60000
70000
80000
90000
AADT


Undivided Highway Urban Collision Rates
Collision Rate (per 100 million vehicle kms)
300
250
200
150
100
50
0
0
2000
4000
6000
8000
10000
12000
AADT


Divided Highway Urban Collision Rates
Collision Rate (per 100 million vehicle kms)
300
250
200
150
100
50
0
0
5000
10000
15000
20000
25000
30000
35000
40000
45000
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Appendix 3: Benefit Cost Analysis Guide ATU (1991)

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Benefit - Cost Analysis
Guide

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In 1991, Alberta Transportation and Utilities commissioned the documentation of its Benefit-Cost analysis and it was produced in three parts:

The Summary;

The Guide; and

The User Manual.

This is the **Guide** which is the central part of the package that includes the most extensive coverage of the principles and general procedures to be followed when undertaking these kinds of analysis.

The Summary briefly describes the main points made in the Guide and its purpose is to provide a general understanding of what goes into an analysis and how to interpret results and judge their significance.

The User Manual is directed to those involved in the actual preparation of a benefit-cost report and concentrates upon the methods of collecting and processing of data and the preparation and presentation of results.

Those using the manual, particularly, are encouraged to read the Guide for a better understanding of the background to the Department's approach to conducting a benefit - cost analysis and they may also find the Summary helpful in the different ways that things are explained.

Preface

This guide is not intended to be the "last word" on benefit-cost analysis, nor is it a treatise on the subject. Its contents and the procedures outlined have evolved from ideas and expressed views of many staff members in Alberta Transportation and Utilities and the lists of possible applications include those items which came to mind by attendants at meetings held to discuss this subject.

A broad application of this subject is being encouraged and new applications may involve the development of supplementary procedures, particularly in the accumulation and handling of data on an automated basis.

The User Manual describes a procedure for the assembling and handling of information pertaining to roadway projects and parts of that process may be applicable and adaptable to other subjects, however, entirely different applications will require different formats and will introduce variations unique unto themselves.

Although the allocation of costs and assembling of input data may involve new challenges, once arrays of benefits and costs over time are produced, the established methodology for the calculation and presentation of results should apply, regardless of the subject matter.

Even in established applications, the most appropriate approach to all aspects of an analysis will not always follow the recommended procedures and treatment and the analyst is encouraged to question the applicability to the specifics of his project or program and to recommend adjustments when such are necessary to better represent the unique circumstances of his or her case.

That may involve procedures, the analytical process or specific inputs and what to include and what not to include and the imputing of values.

While such adjustment may be important in the specific case, and is also important in the continuing evolvement and improvement of the process, uniformity and consistency of application are also important and the onus rests with the analyst to provide persuasive proof that deviation from the norm is desirable. The analyst will know more about the specific work than anyone else and will be in the best position to know when procedures should be adjusted and will, for the same reason, also be in the best position to explain why a different method is better in that case.

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List of Figures and Tables

NOTE: Figures and Tables are also included with each of the examples included in Section 8 and in the Interest and Formulae, and, Material for Training sections of the Appendices.

about Benefit - Cost Analysis

This arrangement of the words "Benefit - Cost Analysis" portrays benefits as outweighing costs when one is balanced against the other.

When it is not obvious as to which is the greatest is when an analysis is required to determine which outweighs the other.

1. Introduction

1.1 Overview of Benefit-Cost Analysis

Alberta Transportation and Utilities has developed a set of guidelines and a model to conduct benefit-cost analysis in order to provide a common basis for the assessment of Department projects in economic terms.

The analysis procedure is a systematic approach to evaluation and assessment and, for projects or programs undertaken by governments, it compares the benefits which will accrue to society from public funds being expended in the provision of a works or a service.

More specifically, benefit-cost analysis compares the stream of quantifiable benefits generated over the life of a project or program to the cost of initiation and subsequent maintenance. A project is deemed to be economically feasible when the total benefits exceed the total costs or when a satisfactory return is received on the investment.

A benefit-cost analysis deals in dollars and all resources consumed or saved which are used as inputs must be given a dollar value. While, ideally, the purpose and objective of undertaking these analyses is to provide guidance about the efficient allocation of all resources, the procedure has no provision for incorporating "non dollar" factors and the value for anything which cannot be described in dollars must be noted and considered separately along with all of the other non economic factors which will bear upon decisions.

The more items that the decision maker is comfortable in valuing in dollars, the fewer the number of items left for consideration in some other way.

Through a committee process, which will be described in the next section, the Department of Transportation and Utilities has gone a long way towards including items which are difficult to value and for roadway projects, the treatments offered for the value of time and the cost of traffic collisions are noteworthy.

Factors given fair value in the benefit-cost equation should not be given weight along with the other non economic factors when making decisions, otherwise they are being "double accounted". On the other hand, all decision makers will not individually agree with the values reached by consensus and it is not only fair but also a reality of life that some will wish to give further consideration to specific items which are already included in results of the analysis. That is the decision maker's prerogative and is fair in the sense that it is a deliberate and conscious action to give more or less significance to one or more items and that is not "double accounting" as in a case where some item is inadvertently considered twice.

Benefit-cost comparisons are helpful in making decisions and making choices between competing programs, projects and alternatives, however it is only one of several factors which will usually be facing the decision maker.

It is not a substitute for judgement, but for many decisions it is a prerequisite to exercising good judgement and for making good recommendations for ultimate political decisions.[1]

A benefit-cost analysis is an explicit approach to assessing the financial merits of a program or project and the advantage of using this concept lies in the variance which there may be between the results of a detailed analysis and the conclusions which would be reached based solely upon common sense.

The need for such analysis, and the advantage of having its results, increases as they run counter to intuitive judgement.

That does not mean that the results of an analysis must be a surprise to be good - quite the contrary - it will be most comforting when the results of a detailed study match the expected. When the degree of consistency, in that regard, cannot be predicted is when the benefit-cost review is needed the most.

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[1] Treasury Board Secretariat, Benefit-Cost Analysis Guide, Planning Branch, March 1976.

1.2 Committee Process

Various Branches / Sections in Alberta Transportation and Utilities have been undertaking these kinds of analysis for a long time. Typically, they have been done on a 'hit and miss' basis - sometimes an economic analysis is included in support of a recommended procedure or alternative, but in most cases such an analysis has not been done.

In some instances, an area or branch has initiated the procedure and has included an "economic" section in a report but, failing to receive feedback on this particular aspect of the study, has assumed that it was not deemed to be very important, and stopped doing it for further reports.

In May, 1987 the Deputy Minister encouraged a broader and more consistent application of benefit-cost analysis within the Department and over the three months which followed, meetings on this subject were held with over one hundred staff members representing virtually all Branches in Head Office and each of the six Regions.

The findings and results of those meetings were reported to a Task Force made up of Executive Directors which was in existence at that time.

In October, 1987, the Task Force presented the following observations and recommendations to the Executive Committee:

1. Benefit-cost analysis provides information related to the efficient allocation of resources which decision makers should have when assessing and making recommendations about investments or choices between programs, projects or alternatives. While the result of such an analysis is not the decision, nor is it a substitute for good judgment, it is an item which should be weighed and considered along with all other factors which cannot be expressed in dollars and cents.

2. The use and application of economic type of analysis should be expanded within the Department.

   Future applications should not be restricted to the items listed to date but should, instead, cover all work and projects for which good information is available to express both benefits and costs in dollar terms.

3. How quickly the Department can move in this direction will be limited in most cases by the capability of the major suppliers of input information. Roadway related studies depend heavily upon traffic and collision analysis and projections, and Traffic Engineering (now Systems Planning), Systems Planning and Transportation Safety (now Motor Transport Services) will not immediately be capable of supplying the information required on a wholesale basis.

   Studies relating to equipment supply or service, automation, computerization, comparisons of methods, procedures or the choice of materials may involve information essentially available in the initiating area and, in such cases, decisions about the availability of information and other resources necessary to undertake an analysis can be made by the initiating Section or Branch.

4. The benefit-cost analysis should be an integral part of work done in the overall development of any project and the person, unit or section responsible for the project should also undertake the economic analysis.
   Guidelines covering procedures, methodology and format for expressing results should be available to each analyst to provide as much uniformity as possible between studies done in various areas of the Department. A committee including representation from all divisions should oversee the drafting of such guidelines, and that committee might remain in existence to design training programs and give advice to users of the systems. Eventually the training or briefing of some forty staff members would place one "trained" person in each District, Region and Branch who, in turn, would be available as a "close" contact for the analysts.

5. The scope of these analyses should be restricted to including only first or direct costs and benefits. Work requiring the consideration of items such as secondary type of

benefits, distributional or regional effects, the effects on labour, or the redistribution of income are beyond the scope of benefit-cost analysis as included in these recommendations.

6. The Task Force considered several specific items which sometimes receive much debate and reached these conclusions.

   a. **A buck is a buck.**
   The objective of a benefit-cost analysis is to compare the allocative benefits and costs which will result from an activity or the undertaking of a project. Allocative benefits are favourable consequences resulting in opportunities to increase production or consumption. Allocative costs are production or consumption opportunities forgone because the resources used will not be available for some other activity or for some other project.
   For the benefit-cost analysis, it matters not whether the Federal Government will contribute to a provincial project or whether the Province will contribute to a municipal project - the resources to undertake and maintain the work will be the same.

   b. **Market values and consumer prices should sometimes be adjusted.**
   On the theme of allocative benefits and costs and the idea that these are related to resources either saved or used - generally it should be assumed that the dollar values of items, as established in the market place, accurately reflect their importance to society. In other words, the cost of things and the amount which consumers are prepared to pay are good inputs into a benefit-cost analysis.
   However, market values and consumer prices can sometimes be adjusted to more accurately reflect the utilization of resources and the value to society and thus far the Task Force recommends two exceptions to the general market pricing principle.

      i. Federal and Provincial taxes on automobiles, trucks, parts, oil and gasoline should be deducted from the consumer prices when determining road user costs. One reservation about so reducing the cost of vehicle operation by approximately 15% is that this Department would be in an unfair competitive position for budget support if similar analyses were undertaken by other Departments where taxes under similar conditions were not deducted.

      ii. Where aggregates are scarce and higher costs will be incurred in the future in the form of longer hauls, a shadow price should be applied which will reflect the importance of this material and tend to conserve it and delay the day when higher prices must be paid.

      Good agricultural land has also been suggested as a candidate for shadow pricing, however, until proven otherwise it is recommended that the price paid for right-of-way be used as the allocative cost for this item.

   c. **Time for all roadway users is important.**
   Roadway improvement projects will usually result in higher average vehicular running speeds with a corresponding decrease in travel times. It is recommended that average wage rates of $22.00 per hour for bus, truck and transport drivers, $12.00 per hour for working occupants of all vehicles and $5.50 per hour for everyone else, including the occupants of buses and recreational vehicles, be used for all travel time differentials.
   This is a judgment kind of factor and it is most important that those who use the results of these analyses are comfortable with the inputs for items such as the value of time.

   Vehicular operating costs are the lowest in the speed range of 50 to 70 km/hr. and the fact that most drivers, when given the freedom, will choose to operate in the range of 90 to 110 km/hr. suggests that time has value.

d. **Family/community and market losses**
These costs should be included in the analysis.
On average, in 1987 dollars, the societal cost of a fatality including family/community and market losses is $640,000, and excluding these losses is $17,700. Comparatively the cost for a serious injury is $425,000 and for a moderate injury is $1,400. Including property damage and using overall provincial numbers, the average cost per collision is $66,120 if the above losses for fatalities are included and $49,320 if they are not included.
As with the value for time, whether to include or exclude these losses for fatalities is, by and large, a judgment matter and those who make the most important and final decisions on matters using these analyses should also determine the input for this item.

WHEN MAKING DECISIONS ABOUT INPUT FACTORS, IT SHOULD NOT BE ASSUMED THAT THE USE, NON-USE OR VARIATIONS IN ANY FACTOR BECOME RELATIVELY INSIGNIFICANT WHEN COMPARING ONE PROJECT TO ANOTHER. The proportions of influence of the various factors differ from project to project. For example, time or safety will have no bearing on some analysis but will be significant in others.

7. Results

Results can be presented in any manner and format which will be most useful and meaningful to those who review the results of numerous analysis and make comparisons between the results for different programs, projects and alternatives.

For the purpose of assessing what factors should or should not be included in a roadway analysis, the two examples which are included in the report to the Task Force include several combinations of input items. In effect, the various lines on each graph constitute a sensitivity analysis which will not be necessary if it is decided that the same mix of items are to be included in each and every analysis.

The Task Force concluded that decisions should be made about what factors will be included in all analysis and that separate figures and graphs for various combinations of inclusions should not be necessary.

Accumulated net present values discounted at 4% should be included in tabular form as well as shown graphically for all years of the analysis period. Further, separate accumulated present values for capital and maintenance expenditures is useful information for officials in this Department because of the direct responsibility which this Department has for the management of funds for these purposes.

Internal rate of return data should be included for all years for which it is positive. This information is useful in several ways because of these inherent relationships:

- The year in which the internal rate of return is zero corresponds to the year when the accumulated array of undiscounted cash flows totals zero or turns from negative to positive. In other words, the future amounts are discounted at a zero rate of interest.

- The year in which the internal rate of return is equal to the real rate of return (4% in these examples) corresponds to the year when the accumulated discounted net present values equal zero and when the benefit/cost ratio changes from being less than one to being greater than one.

- The latter applies to any discount rate which might be assumed, and the internal rate of return information therefore, in effect, also substitutes for a sensitivity analysis using different discount rates.

Furthermore, many analyses must be taken over quite a long period of time because of the long life of the capital works and, for projects involving a lump sum expenditure at the beginning of the period followed by uniform annual benefits, the long term "rate of return" will approach the rate of return received immediately. For example, if an expenditure of

$1,000.00 yields a net benefit of $100.00 annually, the return on the investment is 10%. The internal rate of return, calculated by the discounting method, would be zero at year 10, 5% at year 15, 8% at year 21, 9% at year 27 and 9.9% at year 50. When applicable, this relationship between immediate rate of return and longer term internal rate of return is good for estimating or checking purposes.

Benefit-Cost ratios are really only meaningful for the years when the ratios change from being less than one to being greater than one and the calculation and inclusions of these ratios in the results should not be necessary because the internal rate of return data gives this information for a range of discount rates.

8. **Long Analysis Periods**
The problems with long analysis periods because of an uncertain future are overcome if the methodology and presentation of results as recommended are acceptable. Those reviewing and using this information can readily determine how the results differ for any period up to fifty years. With computer programs being readily available to analysts, little extra work is required to get results for a long period and for "open ended" analysis as long a period that anyone can conceive being needed should be used. If a sufficiently long period is used, the summary of results, for example, can be shortened easily. On the other hand, to extend the period may involve setting up the entire project again.

9. **Equivalent Uniform Annual Cost (EUAC)**
For cases where different alternatives must have different time periods (usually much shorter periods and may relate to studies involving equipment or other assets having different useful lives), the Equivalent Uniform Annual Cost (EUAC) method of analysis may be superior. As the name of the procedure indicates - the results would be expressed in average costs per year for each alternative with the alternative having the lower average cost being best from a financial point of view. Alternatively, and if desired in order to compare results with other works, a rate of return could usually be calculated for these types of projects also.

Those recommendations were approved by the Executive and a Guidelines Committee was established to further refine the procedures and design training programs for users.

The Guidelines Committee met ten times in the period between February, 1988 and May, 1989 with these results and conclusions:

Principles

Vehicular Traffic Volume Projections

Traffic volumes used over long periods of time into the future should be increased each year for the entire period of the analysis at the rate of 1 % per year for the period following that for which more specific projections can be made. It was noted that the provincial population levels were predicted to increase from 2.38 million in 1986 to 3.28 million in the year 2016. (Source: Alberta Treasury, ABS NEWSTATS - Vol. XI No. 3) That increase slightly exceeds a compound growth rate of 1 % per annum.

Salvage Values

Except for shorter term type of analysis where an item or works will have a recognized market value at the end of the analysis period, salvage values will have a relatively small effect on the results and will be questionable and should not be included in the analysis.

Examples Developed

Each of the examples briefly described here are included in complete detail in Section 8.

Highway 88 Project

A large and complex example determining the financial return which would result from the paving of a long section of Highway 88 between Slave Lake and Loon Lake (85 kilometres).

Life Cycle For Culverts

An example comparing the economic merits of four alternative designs for an 8' diameter culvert.

Guardrail vs Sideslope Improvement

This example compares the benefits and costs for installing guard rail on a hypothetical 9 metre fill with 3:1 sideslopes compared to flattening the slopes to 4:1 on the assumption that guardrail would then not be required.

Other examples were discussed within the committee with some developed to a degree by the individual members but could not be finished due to the lack of time which could be devoted to this subject.

NOTE: In conjunction with the preparation of this Guide, in its present form, in 1991, a hypothetical example involving road user costs associated with changing speeds was developed and that example is included along with the above three examples in Section 8. Obviously, the Committee, who's work is being described here, has not reviewed this example.

Unit Costs For Roadway Projects

Much time by several committee members was devoted to the development of unit prices for a typical roadway project with the following highlights which are most specifically applicable to the Highway 88 project but may have some value for general guidance purposes as well. All cost figures are in 1988 Canadian dollars with taxes excluded.

Capital Costs

Capital costs will usually be available on a project and design specific basis.

The sensitivity of the timing for resurfacing was calculated with the finding that base course and surfacing costs increase by 7 % if a ten year period between resurfacings is used compared to resurfacing each fifteen years and such costs would decrease by 4 % if the period was extended by five years to twenty years. Those relative costs are expressed in terms of real value over a period of fifty years.

Maintenance Costs

For paved two-lane standard
- $4,400 per km per year for five years following new construction or resurfacing; and
- $4,600 per km per year thereafter.

For gravelled roadways
- $6,500 per km per year, plus
- $6,000 per km each three years, for regravelling, plus
- $10,000 per km each twelve years, for regrading.

Those figures are added. For example, in years 3, 6 and 9 the cost would be $12,500 and in year 12 the cost would be $22,500.

Vehicle Operating Costs

- The cost for fuel is the largest single cost for operating all classes of vehicles.
- The costs for depreciation, maintenance and repairs are also significant.
- The cost for oil and tires is, on average, about 4 % of the total cost for passenger vehicle operation and about 11 % of the total cost for truck operation.
- The cost for tires for large trucks increases significantly on steeper grades - up to one-third of the total cost on an 8 % upgrade.
- The greatest efficiency for passenger car operation is on a downgrade of 5 to 6 % and for trucks, a downgrade of 2 to 3 % is most efficient.
- Cost data for operating on gravel varies greatly and the conclusion by members of this committee is that, generally speaking, the operating costs used for passenger vehicles and light trucks on gravel should be about 18 % higher than the cost of operating on a smooth pavement, and that costs for large trucks operating on gravel should be about 30 % higher than the costs used for operating on a smooth pavement.

Collision Costs

No changes in the data or procedures used in the presentations to the Task Force and the Executive are recommended. The costs used for personal injuries and death are based upon a 1980 study done for the British Columbia Ministry of the Attorney General and the costs for property damage are based upon Alberta's Primary Highway Collision Inventory figures.

Costs for Time

The value for time is to be based upon the time for the people involved, again the same as presented to the Task Force and the Executive, including these specific figures:

$ 23.00 per hour for truck and bus drivers;
$ 12.00 per hour for anyone else on business, including truck driver helpers; and
$ 5.00 per hour for everyone else.

Sources of Information for Roadway Projects

Capital Costs - right-of-way, grading and related works
- Program Planning

- base course and surfacing
- Materials Engineering

Maintenance Costs - Operations Branch

Collision Costs - Motor Transport Services

Vehicle Operating Costs - Systems Planning (formerly Traffic Engineering)

Computer Application

A start on handling the large amount of data for a typical roadway project was made with formulae developed to fit the vehicular running cost curves and converting that and other data into annual road user costs.

The problems with the program for generating the internal rate of return were solved.

Training Programs

Programs geared to both users and managers were developed and two courses for users and one for managers was held in the first half of 1989.

The first course for users was held on January 6, 1989 and was advanced to meet an immediate demand by those who were working on these kinds of analysis and required training to reduce the time being taken by one on one instruction. One day was too short to properly cover the material and the next user course which was held on May 18th and 19th, 1989 was designed around two days which worked out well, particularly for those participants who came to the course with very little previous exposure to this subject.

One day was taken for a seminar for more senior managers and that proved to be sufficient time to cover the material in a more general way which seemed to meet the needs of the participants.

Seven of the committee members were resource people for these training sessions and a total of sixteen of the committee members participated in the sessions either as a resource person or as a "student".

A total of forty nine other staff members attended the two user courses and twenty one managers attended the one day seminar held on April 21, 1989.

Samples of some of the material used in these courses and lists of participants and resource staff are included in the appendix.

1.3 Purpose Of The Guide

The Benefit-Cost Analysis Guide has been developed to provide a consistent and uniform approach to conducting benefit-cost analysis for the various areas of the Department. The following report includes information pertaining to:

- the underlying principles of benefit-cost analysis and the benefit-cost model developed by the Department;

- the application of benefit-cost analysis to Department projects;
- the appropriate methodology to conduct benefit-cost analysis, including the general structure of the benefit cost model developed by the Department; and
- the presentation and interpretation of results from a benefit-cost analysis.

The key elements of this guide are summarized in the report Benefit-Cost Analysis Summary. A detailed description of the procedure to follow and the input values required to undertake a benefit-cost analysis, and the documentation of the Department's benefit-cost model, are contained in the report Benefit-Cost Analysis User Manual.

2. Principles of Benefit - Cost Analysis

2.1 Efficiency Criteria

2.1.1 Potential Pareto Improvement

Benefit-Cost analysis is used to assess the merits of a project in terms of economic efficiency. Within the context of economic theory, a project is deemed efficient if the change it brings about leads to a "potential Pareto improvement", a social welfare criteria fulfilled when the total value of the gains produced by a project potentially exceeds the total value of the accompanying losses.[1] This criteria does not take into account distributional considerations, such as who benefits and who bears the costs of a given project. In addition, pecuniary benefits and costs, or the effects of changes in relative prices brought about by a project on other parts of the economy are ignored in the evaluation of economic efficiency.[2]

The "level" of economic analysis which should be undertaken is dictated by the maintenance of efficiency - the efficient use of resources as measured in all areas of the economy.

The procedures outlined here for conducting a benefit-cost analysis limit its scope to considering only the most direct of benefits and costs and this is a common practice for this type of economic study.

To be an appropriate type of assessment, it follows, therefore, that the programs, projects or alternatives to which benefit-cost analysis is applied should not be of the nature or size to materially affect other areas of the economy or general prices or general employment or unemployment levels.

An activity which will have far reaching effects throughout the economy requires a broader base involving econometric models which can trace the effects which a change in one variable will have on all others in the economy and measure the net resulting change.

A limited study may indicate positive results, however, if another area in the economy is adversely affected, the test of efficiency may not have been met and the scope of the study is not appropriate. The adverse effects on the other area of the economy may be greater than the positive effects on the portion reviewed.

A project may be undertaken in an area which has many unemployed and that situation might change and, as well, the local stores may raise their prices during the higher level of local activity, but neither of these events will rule out a benefit cost type of analysis. The changes are on a localized basis and of short duration.

2.1.2 Incrementality

Within the benefit-cost framework of analysis, only

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[1] E. J. Mishan, Economics for Social Decisions, Elements of Cost-Benefit Analysis, New York: Praeger Publishers, p. 14.

[2] Treasury Board Secretariat, Benefit-Cost Analysis Guide, Planning Branch, March 1976, p.11.

the **incremental** benefits and costs associated with a project are considered. The analysis excludes benefits and costs that have already occurred or will occur whether or not the project is implemented.[1]

The incremental costs are calculated on the basis of the "opportunity cost" principle whereby the value of the required resources foregone in the best alternative use is estimated. The incremental benefits generally represent the total willingness to pay by all beneficiaries for the goods or services produced by the project.[2]

As applied to specific projects, the principle of dealing in incremental values takes on a number of different appearances.

At one extreme, an entirely new project or program may have no history of similar activity against which to compare the new and, in such a case, the new activity is compared to doing nothing. The costs of the new are used without deduction as are the benefits and the merits of the project will be presented and judged upon those totals. Those circumstances stretch the concept of incrementality, nonetheless it is well to keep the concept in mind for the majority of the subjects being tested will have deductions to make from both the benefits and the costs before the two are compared.

The Highway 88 example, which was developed by the Guidelines Committee, involved an existing gravel highway and the cost of providing pavement and its maintenance was compared to the cost of maintaining, regravelling and reshaping the existing facility if it were to remain in a gravelled state. Similarly, the benefits which would result from paving the route would be in the form of travel cost savings - the difference between the cost of travelling on gravel and the cost of travelling upon pavement - incremental values.

In a different and new example, assume a number of residents in a rural country residence type of subdivision are tired of paying the high price of trucking in water and would like their local government to test the idea of installing a public water system in the area. In detail this would be a rather complex study, however some simple assumptions will add to the description of incrementality. The net capital cost or incremental capital cost would be the cost of installing the public system less the value of all of the privately owned pumps and pressure systems on the second hand market which would not be required if there was a public water supply system. Annual benefits may take the form of subtracting the cost to the municipality for operating the public system, from the collective cost to all of the residents for their purchase of water and the maintenance costs they incur in running their own systems.

With this simplistic description, the economic test would involve comparing the streams of incremental annual benefits and maintenance costs and the incremental capital costs.

Dealing with incremental values has a further dimension and that relates to the comparison of alternatives, one to another. It is normal when considering more than one way to build a better mouse trap to compare each new way to the old way and this produces two results when two new ways are being considered. If three new ways are being tested, three results will be obtained - each new compared to the old. Comparing each new alternative to a common "do nothing" or "do minimum" choice is sometimes all that is required because one of the alternatives will fall out as clearly being the best or sometimes none may economically stack up to the "base case", suggesting that the status quo should be maintained.

However, sometimes two new alternates will be close contenders with both being better than maintaining the status quo. With the methods developed by the Department, two good alternatives may provide conflicting indications as to which is best. The Net Present Value of one being the highest indicates that is the best, whereas the Internal Rate of Return for a

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[1] National Energy Board and Canadian Energy Research Institute, Workshop on Benefit-Cost Analysis and Export Impact Assessment. Papers presented at a workshop on benefit-cost analysis and export impact assessment, Calgary, November 1989, p. 85.

[2] D. Gillen, M. McMillan and W. Phillips I.M.P.A.C.T. Environomics Ltd., Role of Economics in Transportation Planning, Volume II, Prepared for Alberta Transportation, March, 1979, p. 63.

different alternative may be higher. When that happens, it is necessary to consider the incremental differences in costs and benefits between the two competing alternatives.

Hypothetical examples of needing to deal in incremental values between two competing alternatives are included in both this guide and in the Summary, and the example dealing with culverts in Section 8 considers the incremental differences between three competing alternatives.

2.1.3 Procedure to Measure Economic Efficiency

A project meets the criteria of economic efficiency when the total benefits over the life of the project exceed the total costs. Given that the occurrence of costs and benefits follows different patterns over the life of a project (the majority of costs are incurred initially during the construction phase of the project while benefits arise later as the project becomes operational) and the fact that a dollar today has greater value than a dollar in the future, the streams of costs and benefits must be discounted to a comparable basis in order to enable a meaningful comparison. The present value of the future streams of costs and benefits is calculated by applying the appropriate social discount rate to the project costs and benefits, recognizing the time value of money.

A project can be deemed efficient when the present value of the net benefits (benefits minus costs) is positive, or the ratio of benefits to costs exceeds one, or the rate of return is higher than the acceptable minimum. This is usually referred to as the Minimum Attractive Rate of Return (M A R R) and is typically the rate which is used for discounting purposes.

By and large, the entire contents of this guide are devoted to outlining a procedure for measuring economic efficiency and each of the factors which are mentioned here will be described more thoroughly in later sections.

Determining appropriate values is the first basic step in undertaking an analysis and that will be the subject of the next section.

Having determined streams of benefits and costs over the life of the project, the next step is to convert those streams into meaningful results. The three most common means of expressing results of a benefit cost analysis are in terms of Net Pesent Value (NPV), Benefit / Cost (B/C) ratio and Internal Rate of Return (IRR). Each of those methods will be mentioned from time to time and will be specifically addressed in Section 4.

Time is an important resource and that shows and is illustrated in many ways in our society. Most people have many things they would like to do if time would permit. They must set priorities and choose between competing activities because there is insufficient time to do all of them.

Time is production and time is money - if one had more time, one could make more widgets (production) and receive more money for that greater production. Having more money, one could buy more and "consume" more. A benefit-cost analysis is really a study in production and consumption. If production and consumption is greater with the project than without, the project is economically efficient.

To be used in the analysis, production and consumption must be expressed in dollars and because time is valuable, future expenditures or incomes are not valued as highly as present ones. Future values are discounted and all three of the mentioned means of converting streams of cash flows into results employ the same principles of discounting which principles are identical to those used in the business world for valuing money over time.

If someone is prepared to forego the pleasure of spending (consuming) for a year, he might make a loan to another who wants to consume immediately and who is prepared to pay interest for that privilege. If, after a year, both parties are in respectively the same mood regarding the desire to consume, the loan might be extended and if the interest for the first year is not paid, that, in effect, adds to the amount of the loan and during the second year, interest will be accruing not only on the "principal" but also on the first year's interest. This results in paying interest upon interest and is called compounding or using compound interest. At the time that the loan is made, its amount constitutes the Present Value of the loan, and when it is eventually repaid along with compound interest, the total amount repaid will be the loan's value in the future.

Determining the efficiency of a stream of cash flows, which include some that will not occur until sometime in the future, uses that same process in reverse and reduces the future values to appropriate present values.

Interest and discount rates, coupled with an added featue (inflation), will be dealt with in greater detail in Section 2.4.

2.2 Determination Of Value

2.2.1 Importance

The results of a benefit-cost analysis are a direct reflection of the values given to the input items and therein lies the importance for using good values.

The influence which each of numerous input items will have on one result will, of course, vary and their pure numbers tend to dilute the influence of each, however, even from a confidence view, it is important that all values be credible for one being proved to be shaky casts doubts upon the accuracy of all.

The importance of including as many relevant items as possible in an analysis was mentioned in the introduction, and whether or not to include an item depends upon the ability to give it a value in dollars and the confidence which users of the results will have in the assigned value.

The determination of values, for complex projects particularly, is not only an important task but is also the most difficult and can also constitute the bulk of the work for the analysis, not only involving the analyst's time but the time of others who must be relied upon to supply input data. Whether or not to include an item can, therefore, also depend upon the availability of data in a form which can be used in the analysis. The basic data may be on hand but the time it takes to convert it to a useful form may be prohibitive considering other demands upon the involved staff.

2.2.2 Effect Upon Decisions

The influence which the results of a benefit-cost analysis should rightfully have upon a decision will vary with the degree to which the factors bearing upon the decision are represented in the results of the analysis.

Section 8. includes an example analysing the use of different kinds of culverts. If economics is the sole question in that subject, the results of that analysis should be the decision. Even so, carefully following that example will show that judgement, or some established criteria, regarding the rate of return is finally needed.

On the other hand, the Highway 88 example provides very positive economic results, at least judged by the rate of return in comparison to the discount rate used, however, it should not be expected that the scheduling of the paving of that highway would immediately be done based upon those results. It is a big undertaking and must compete with other highway projects for budgeted dollars and may have social and political factors which are not represented by the items which went into its benefit-cost review. Even economically, the results of the analysis for this project should not, in isolation, be the decision. The return is good, however, if similar reviews of other projects should yield higher returns and the ones with higher returns would use all or more than the established finite roadway budget, the decision based upon economics would be to delay the Highway 88 project.

Good decisions should be based upon the consideration of all relevant factors or items giving to each their proper weight or significance. While that is easy to say, it is difficult to do and one of the difficulties lies in the determination of weights or significances and that leads to an advantage that benefit-cost analysis can provide in the decision making process. That is particularly so when a complex subject is being dealt with which involves numerous items and a number of those items can be given dollar values and grouped into one basket. The benefit-cost analysis determines the net result of all items in the basket, and the decision then rests upon comparing that net result with the factors that could not be valued and put into the basket.

That process not only leads to a fewer number of items which must be mentally juggled, but also provides superior treatment for the items in the basket, if one believes that such items can be assessed better on a consistent and systematic basis than handled mentally each time they or similar groups of factors are involved in a decision.

Obviously, the more items which can be included in the economic basket, the fewer the number remaining to be considered separately. Further, each item added to the basket gives the basket of items collectively more weight relative to the outside items.

A danger which arises with the grouping of some items by one person and consideration being given to the whole by another is double accounting of one or more of the items that have been grouped.

Items which are grouped or included in the basket and fairly represented by the results obtained for the group should not also be considered again along with the other non-economic items. Good documentation and display of the items which are included in a benefit-cost analysis should reduce the likelihood of inadvertently considering items twice.

That should not and cannot prevent a decision maker from intentionally dipping into the basket and giving either more or less weight to an item that he believes has been wrongly valued. Nor should that be considered as double accounting - the decision maker is simply adjusting the significance of that item to his liking.. That should not happen when only one person is reviewing the analysis or using its results - the item can either be valued in accordance with the decision maker's view when used in the analysis or, if that can't be done, it should be left out of the analysis entirely.

In a large organization, the results of a benefit-cost analysis will likely be used by several, and even if the decision makers agree upon the values to be used for input items, dissenting views will be held.

2.2.3 Accounting Stance

The accounting stance selected by the Department for benefit-cost analysis is broad, since it has been decided that the value of all benefits and costs should be considered for a project, regardless of to whom they accrue. This concept of "a buck is a buck" implies that the costs of a project should reflect all expenditures that will be incurred, even if a portion of a provincial project is defrayed by a federal grant, as an example. Similarly, if a municipality's program includes funds from the province or any other source, those contributions should be disregarded as far as this kind of an analysis is concerned. The benefits of a project should encompass all beneficiaries regardless of their origin, and not be confined to residents of the province. More specifically, in the application of the Department's benefit-cost model to roadway projects, a dollar saved in travel costs in Alberta by any motorist has the same value as a dollar allocated and spent by Alberta Transportation and Utilities on improving and maintaining the road system.

2.2.4 Direct Benefits and Costs

The Department has confined the measurement categories for benefit-cost analysis to direct benefits (e.g.. gains accruing to the users of goods and services produced by a project) and direct costs (e.g.. capital and maintenance expenditures). It is possible to estimate indirect or secondary benefits which stem from or are induced by a project by applying appropriate economic multipliers derived from input-output tables. However, given the broad accounting stance adopted by the Department, these spin-off effects are not calculated by the benefit-cost model since it is likely that they would represent merely a transfer of economic activity from one area to another.[1] Typically, secondary benefits are estimated in a benefit-cost analysis when a project is being analyzed from a local or regional perspective.[2]

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1 W.R.D. Sewell, J. Davis, A.D. Scott, D. W. Ross, Guide to Benefit-Cost Analysis, Resources for Tomorrow, p.5.

2 Ibid., p. 18.

2.2.5 Valuation

Where possible, the direct benefits and costs measured in a benefit-cost analysis are estimated on the basis of market prices. The use of market values presupposes that the prices which producers receive and consumers are prepared to pay for goods and services reflect the intrinsic value of those goods and services to society. In cases where the market values diverge from efficient prices, as a result of distortions brought about by taxes, subsidies, regulation, trade barriers, or any other reason, **shadow prices** must be estimated.[1] This involves the adjustment of market prices to reflect more closely the true value of the resources to society.

In the most general of terms, a benefit-cost analysis compares the opportunities for consumption and production with and without the program project or works being tested. Ideally, the analysis is a comparison of the resources which would be used with the benefits which would result and to make that comparison all items which are included in the equation must be given a dollar value.

Imputed Values - Shadow Prices

Some items may not have an established market value and if a price is to be assigned, that action is essentially the same as adjusting one which is either high or low. The difference is in degree and not in kind. The value so adjusted or assigned is an imputed value or a shadow price and the process of assigning or changing the value is known as shadow-pricing.

Benefits or costs not having a directly established market value can sometimes be valued by using information from related markets. For example, the construction of a roadway may generate benefits in terms of improved access into a particular area. These benefits could be imputed by establishing the rise in property values experienced in another area with similar economic characteristics which has benefitted from a comparable project. In the context of the Department's benefit-cost model, imputed values are used for the evaluation of roadway projects to estimate user cost savings pertaining to travel time and collisions.

The items discussed within the Department which might be classified as requiring imputed values or likely candidates for shadow prices all relate to roadway projects and include:

travel time;
fatalities resulting from vehicle collisions;
land; and
aggregates.

The conclusions reached about these items have been outlined in section 1.2 dealing with the committee process and the following provides background for these items.

Travel Time

When discussed in committee, views of different staff covered the complete range of how this item might be treated - from giving no value for any road user's time to giving full value for everyone's time at the going wage rates.

"Middle of the road" views include the charging of truck driver's time, commercial traveller's time and possibly include a rental rate for the vehicles being used but omit other allocations for time. Home makers time might be included because they are continuously "on business". Others believe that the time for some categories of users should be valued if the saving is significant - 5 minutes, 10 minutes, 30 minutes - particularly if an "employee" gets paid for such time, but smaller increments of time such as a minute or two should be forgotten.

The Federal Treasury Board's guide includes travel time in its list of items to be valued and is silent about any exemptions. A recent (1987) Transport Canada report on the Yellowhead Highway Improvement Program includes values of $21.93 per hour for bus, truck and transport drivers, $12.00 per hour (average in Alberta) for occupants of passenger vehicles

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[1] A. Randall, Resource Economics, An Economic Approach to Natural Resource and Environmental Policy, p. 255.

involved in work, and $5.54 per hour for everyone else including the occupants of buses and recreational vehicles (RV's) and the drivers of RV's.

Whether a value for passengers' time should be included depends upon how the increase in available time will be used. If used for increased production or voluntary leisure, time has value. On the other hand, time saving should not be given a value if people already have time on their hands and more time will increase involuntary idleness, as in many developing countries with extensive under employment.[1]

Mr. Adler, in the same reference, relates the value of time savings to the proportion of the time saved compared to the time it takes to make the trip. The saving of twenty minutes in a trip which would otherwise take an hour may be more valuable than that same saving in a trip usually taking four hours. The actual traveling time for the longer trip will vary more (three and one-half to four and one-half hours) and that uncertainty will mean that most passengers will not plan for the use of a twenty minute time saving. That relationship would apply to freight shipment as well as to passenger travel.

Robley Winfrey [2] develops a somewhat different view and generally supports some value for the time of all travelers but suggests that each analyst must find his own answers in this matter.

Within the Department, the following observations and conclusions were reached:

1. Vehicular operating costs are the lowest in the speed range of 50 to 70 km / hr. and the fact that most drivers, when given the freedom, will choose to operate in the range of 90 to 110 km / hr. suggests that time has value;
2. Roadway improvement projects will usually result in higher average vehicular running speeds with a corresponding decrease in travel times;
3. This is a judgment kind of factor and it is most important that those who use the results of these analyses are comfortable with the inputs for items such as the value of time;
4. All intervals of time for all roadway users are important and rates of $22.00 per hour for bus, truck and transport drivers, $12.00 per hour for working occupants of all vehicles and $5.50 per hour for everyone else, including the occupants of buses and recreational vehicles, be used in the analysis;
5. The above rates are in 1987 dollars and should be adjusted over time to reflect general changes in wage rate.

Collision Costs

NOTE:
SOME OF THE PROVINCIAL AVERAGES INCLUDED IN THIS SECTION ARE DATED AND NEW DATA IS AVAILABLE WHICH SHOULD NOW BE USED IN ANALYSIS.

The table on the following page provides a cost breakdown between the various cost factors for collisions.

The Market Losses and Family/Community allocation make up the majority of the charges for fatalities and these items have received the majority of any debate about the cost of crashes. These items in the Serious Injury class are not as contentious because a long lasting injury or disability is an obvious cost to society.

While the market type of losses for fatalities are by far the most significant items in this table, some studies have included much higher figures and, further, the overall significance of including these items is reduced somewhat when the low frequency of fatal type of collisions is considered.

For each crash involving a fatality, on average 1.35 people die, 0.57 are seriously injured and 0.69 are

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[1] Hans A. Adler, Economic Appraisal of Transport Projects.

[2] Robley Winfrey, Economic Analysis For Highways, Library of Congress Catalogue Case Number: 69-16620

moderately injured. Including property damage, the average cost for a fatal collision, using the above figures, is $1,114,000. Similarly, for each non-fatal crash involving an injury, 0.26 victims are seriously injured and 1.43 receive moderate injury for an average cost per crash of $118,831.

Using provincial average of:
- 2 % involving fatalities;
- 35 % involving injuries but no deaths; and
- 63 % property damage only, the average cost per collision is calculated to be $66,120.

The User Manual contains 1990 unit costs and new figures for all of the above statistics.

Giving zero values for Family/Community and Market Losses for fatalities reduces the cost per fatality to $17,671 in 1987 dollars and produces an average cost per collision of $49,320. This figure is about three-quarters of the average cost including all items.

For the usual roadway improvement project, the reduction in collision costs will be only one of several resulting benefits and, consequently, the significance in the final results of including or excluding these items for fatalities is further reduced. Nonetheless, the variations in this factor or any other factor cannot be assumed to be compensating when comparing one project to another - the reason being that the proportions of influence of the various factors are different for each project. For example, in a median widths study for Highway 2, the reduction in numbers and severity of collisions were the only quantifiable benefits, and the difference in results would vary by 25 % depending upon how these two

ALBERTA
SOCIETAL COSTS OF TRAFFIC CRASHES*
PER VICTIM OR CRASH
1985 (with 1987 estimated values)

	FATAL	SERIOUS INJURY	MODERATE INJURY	PROPERT DAMAGE ONLY(per crash basis)
Market Losses	$449,331	$268,629	$ 138	-
Family/Community	134,798	80,597	43	-
Medical	924	23,906	213	-
Rehabilitation	-	12,887	-	-
Funeral	1,962	-	-	-
Legal	4,920	3,488	297	16
Insurance	626	626	142	142
Law Enforcement	170	170	59	14
Public Liability	7,985	8,995	406	233
TOTALS	$600,716	$399,298	$1,298	$ 405
1987 est. values (CPI of 132.0/123.9)	$639,988	$425,402	$1,383	$ 431
Property Damage** per crash	$6,941	$6,249	$6,249	$3,138
		(all injury crashes)		

* Based on data supplied by B.C. Department of the Attorney General.

** Based on Alberta primary highway collisions in 1983 dollars factored by 132.0 / 116.6 to obtain 1987

Table 2 - 1 Societal Costs of Traffic Crashes

items are treated. In a recent study comparing "right angle" corners with an angling alignment, the reduction in collisions made up about 40 % of the benefits, meaning the overall results could be affected by about 10 % because of different treatment for fatalities. Of course, there is no percentage difference for projects where the collision picture will not change.

Hans A. Adler and Robley Winfrey again both express views on this subject and again are on opposite sides of the issue with Adler favoring the consideration of fatalities in non-monetary terms and Winfrey maintaining that most authorities include all costs for fatalities but in so doing, also include the benefits or costs saved because of death. ...."the present worth to society of a living person is the present worth of his future gross earnings (as a measure of his productivity) less the present worth of the cost of maintaining the person in society for the full period up to death."

For analyses in the Department, it has been decided that Family/Community and Market losses shall be included and, for example, using the above figures, the average cost per collision of $66,120 would be used. In accordance with the caveat heading this section, these costs must be updated periodically and new figures for 1990 are included in the User Manual.

Land Values

Although agricultural land was singled out as an item which should be reviewed and considered for imputed values in the future, the subject should be treated more liberally with land and any of its uses being subject to shadow pricing. Market prices for land can fluctuate greatly depending upon the general state of the economy or expectations on a more localized basis, and its true value as a resource cannot change in those degrees. The price actually paid for right-of-way or the estimate of what may be a fair price to pay to an owner, under a specific set of circumstances, may require adjustment to better represent its value as a resource.

One test for the value of land follows a general principle for determining values and that is to consider alternate usage. If the land were not required for a public works, what would its value be in the highest and best alternate use? The highest and best use would, of course, be based upon a use which would meet all approvals and could actually be implemented if the public need was abandoned.

This concept of land valuation is market oriented and the price paid for land will usually be the proper value to use in a benefit-cost analysis. An example of an exception may be a case where land was assembled or purchased many years in advance of actual need and changes in development patterns and zoning, over the years, results in a market value quite different from its "book" value. In such a case, the market value, based upon the highest and best use at the time that the analysis is done, should be used. This subject is again introduced in Section 2.3.1 when dealing with "sunk" costs and that section also includes an example where the value of a remnant piece of right-of-way which is no longer needed for roadway purposes may be assigned a value quite different than its disposal price.

Prices paid or amounts received in any unique or unusual circumstances should be treated as suspect, as far as true value is concerned, and may require an imputed value. Land owned absolutely and not held in fee simple, such as Indian Band lands may require an imputed value quite different than the price actually paid.

Aggregates

Gravel in its natural and economical state is finite and its availability within the province can be scarce or abundant depending upon the geographic location. That, coupled with the fact that it is an essential ingredient in some of the projects and work which the Department manages, as well as for a host of other societal needs, means that its value as a resource depends upon the location of its use or anticipated need. A higher value, in an area where it is still available but will soon be depleted, will encourage, even economically, the use of alternate products for those activities in which a choice is possible and preserve the aggregates for those in which substitute products cannot be used.

The determination of an appropriate shadow price may be as simple as calculating the cost of imported gravel - gravel hauled from a location where an equivalent quality of the product is plentiful. If different qualities are involved, an adjustment in that regard would be in addition to the cost of loading and transporting.

Other Items

While those were the only items which were discussed in any degree of detail in the committee process in the late eighties, there may be other items and circumstances for which and in which shadow prices might be considered.

A project may give rise to benefits and costs which cannot be quantified in any way and can only be reported in a qualitative manner. In particular, there is very little information provided indirectly by the market to establish credible proxy values for some environmental factors. For example, the benefits of modifying the design of a project to preserve a scenic site with aesthetic attributes cannot be quantified in a meaningful way, although determining mitigation costs may be possible. Further, non-market elements, related to the environment might be incorporated into the Department's benefit-cost model in the future as analytical techniques evolve in the establishment of proxies for currently unmeasurable benefits and costs. However, the assignment of dollar values to environmental factors must be both reasonable and supportable to be acceptable to the Department.

In accordance with the **GENERAL PROCEDURES ADOPTED WITHIN THE DEPARTMENT, THE ASSIGNMENT OF DOLLAR VALUES SHALL BE RESTRICTED TO THOSE ITEMS IN WHICH THE VALUES SO ASSIGNED SHALL BE VIEWED WITH CONFIDENCE AS BEING REASONABLE AND SUPPORTABLE AND, IN ACCORDANCE WITH ANOTHER ESTABLISHED PRINCIPLE, THE ONUS OF PROOF LIES WITH THE ANALYST.**

When considering inclusions in the future, the principles of market value and the allocating of amounts based upon intrinsic worth should be the yardsticks of comparison and while the item may not have a market value, with some imagination an equivalency might be established with another item which does have a value in the market place.

An example of enhanced land values resulting from improved access was cited and other projects may have the opposite effect which might also be valued indirectly.

Noise and its detrimental effects has no directly established market value however, in the transportation industry the problems associated with noise from a highway or an airport might be established on the basis of the market value of affected properties compared with the market value of equivalent properties - equivalent in all ways other than having a noise problem. A value so assigned to noise would be an allocative cost to the roadway or airport.

Consumer Surplus

Another circumstance which requires special treatment is when the project or works will change the price or cost of a product or a service and that change results in an increase or decrease in the demand for that product or service. Although stated to cover all circumstances in both the negative and the positive the normal situation will involve an expenditure to make an improvement and as a result of the improvement more people will take advantage of whatever has been improved.

If a new or improved highway or street reduces the cost of travel between two points and more trips are made between the points as a result of the lower cost, the benefits attributed to the additional trips should be treated differently than the benefits calculated for those simply continuing to make the same number of trips.

Assume initially that the reduced travel cost does not change the total travel picture - the benefit to the users would then be the cost saving per trip multiplied by the number of trips. That situation needs no further explanation however to set the stage for considering the additional trips the total travel cost saving with no additional trips could be represented by the area of the shaded rectangle in this diagram.

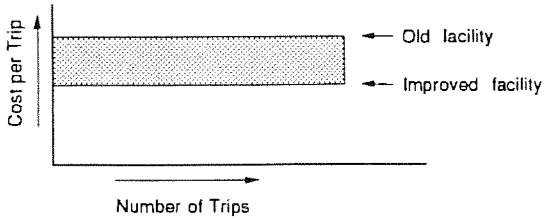

Figure 2 - 1 Reduction in Travel Costs

Now assume that the reduced travel cost causes more people to make the trip or encourages those that were already travelling between the points to make more trips and the above diagram would change to the following one.

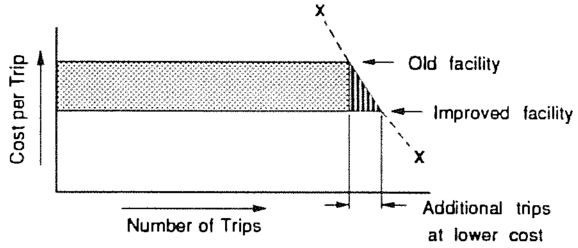

Figure 2 - 2 Reduction in Travel Costs and Consumer Surplus

The benefit resulting from the original trips remains the same - the product of the benefit per trip times the number of trips or the area of the rectangle. The benefit resulting from the additional trips is the area of the triangle - one-half of the cost saving per trip multiplied by the number of new trips.

The benefits attributed to the new trips being only one-half of what they would have been had those same trips been made when the trip was more costly can be traced back to market pricing and the assumption that the benefits of consumption is equal to the satisfaction derived by the user, accepting the fact that the satisfaction of the same thing to different users may vary.

In this case of the additional trips, some contributing to the extra volume would have made the trip had the improvement been very slight - in other words they were just on the verge of making the trip under the old expensive circumstance - they benefit from the improvement virtually the same as the ones originally making the trip. They are represented by the longer vertical lines in the triangle close to those continuing to make the trip. At the other end of the spectrum, some making the trip and contributing to the "new" volume, barely do so now and had the improvement been slightly less they would have chosen to do something else instead. The benefit they receive from the improved facility is virtually nil and they are represented by the short vertical lines near the tip of the triangle. In between are all of the others making the additional trips and if their desires and choices are uniformly distributed over the entire spectrum, the shape of the graphical representation will be a triangle, as shown, and the area within the triangle will be the collective benefit to the users making the additional trips and it is called consumer surplus in economic jargon.

Subsidies, Grants and Taxes

In detail this subject can become complex but the Department has adopted a procedure which is simple and straight forward.

The value for items used in these analyses should reflect the economic resource of the items and, in the absence of subsidies, grants and taxes, the market value should usually be assumed to reflect the resource value. Taxes on gasoline, for example, increase the cost at the pumps but do not change the resource value of the gasoline. Hence, for determining road user costs, taxes for the various costs associated with the operation of a motor vehicle should be subtracted from prices paid by the consumer.

For roadway projects, the elimination of certain taxes will reduce the cost of travel and since the benefits for such projects typically stem from the differences in travel costs, it follows that the benefits will be lower because of the exclusion of those taxes. When comparing the economic merits of one project to another, it is important that input items be treated in a like manner and while this should present no problem when comparing projects within the Department, it is a matter that should receive attention if the Department's projects are being reviewed by others or are being compared, in any way, with those of others.

Subsidies and grants have the opposite effect to that of taxes. Subsidies or grants result in the lowering of the price of goods in the hands of the consumer and, again , they have no effect on the actual amount of resource required to produce the item and such amounts should be added to the consumer's price.

2.3 Excluded Inputs

The problems of including some items or factors in a benefit-cost analysis because of the difficulty in giving them a value have been covered and items which cannot be given a dollar value cannot be included. Further, some apparent economic effects in a local area of the economy should not be included because they do not change the economy as a whole and they do not really reflect any change in resources produced or consumed, and they too have previously been discussed. A local change in prices was one example given for this category of items.

The excluded items referred to here do not relate to either of the above - they are another category of costs or benefits which should be omitted on the grounds that they too have no effect on resources produced or consumed or their effect is so small that they can be forgotten.

2.3.1 Sunk Costs

In economic terms or in engineering evaluations, sunk costs refer to what has been invested or paid in the past and cannot now be recovered. Such costs are said to be "sunk".

A benefit-cost analysis deals with the future and what has been spent in the past is irrelevant except and unless the works which are now being considered can make good use of what was previously done. Even in such a situation, what was spent on the facility in the past is not used directly in the analysis but any advantage of adding to the old is reflected in lower costs (future costs) for that alternative.

Sunk costs and the subject of terminal values are related in the situation where a physical asset is being abandoned and that asset or some components of it still has value. Terminal values are the subject of the next section also, however, there the discussion will be limited to terminal values associated with new work (projects now being analysed for which initial costs are relevant). Here, terminal values or salvage values will apply to works which have been initiated in the past for which their past costs are "sunk".

As an example, assume an urban community has been using lagoons for sanitary sewerage disposal and more capacity must now be planned.

The alternatives might include:

1. expanding the lagoon system;
2. adding preliminary treatment facilities with con tinuing use of the existing lagoons as part of the whole system; or
3. replacing the lagoon treatment entirely with a new mechanical and chemical plant.

The fact that millions may have been spent on the existing system in the capital cost of land, earthmoving, pipes, pumps, fences, etc., and upgrading and maintenance over the years is all irrelevant and has no bearing on the economic merits of what should now be done. That past effort may, however, influence what should be done in the future because the costs which would now go into a benefit-cost equation would be the costs from now onward. The lower future estimated costs for either of the first two alternatives will account for the benefits which the past work on the lagoon system provides.

The third alternative which abandons the lagoons involve terminal values that should be included in the inputs for that choice. Any pumps, fencing materials, etc., which have value in alternate uses should be treated as positive cash flows for this alternative. The value of the land, which will no longer be needed for the lagoons, in its highest, best and acceptable alternate use should be credited to the new treatment plant option. The cost of leveling and any other work required to ready the land for such alternate future use should be a cost against that alternative.

The value of the land which becomes available for other uses poses some interesting prospects in a case such as this. The council and administration of the municipality may decide to retain the land and use it for some municipal purpose, which use and classification may give it a relatively low value in normal land assessment terms.

Alternately, a higher and better use for it may be quite acceptable from a community planning perspective and if that is the case, the higher value should be used in the benefit-cost equations.

Those circumstances may also involve other options for valuing the land. Building upon portions of the background already established, the best use for the land may presently be that which the municipality will be holding it for - a higher use is presently premature. The value presently assigned for the land should be based upon that use. If it can be predicted that there will be a demand for the higher use at some future date. the added value for this land should be credited to the new plant alternative as occurring at the point in time when that event is predicted to happen.

Roadway projects will provide a variety of circumstances involving residual land values and the theme for valuation should be the same - the value should be resource related as opposed to the actual price which might be received for the land. Abandoned right-of-way may be involved with the road bed levelled and topsoil added to make it suitable for agricultural production. The cost of doing that will be a charge against the alternatives which would create the abandonment, however, its agricultural value including the enhancement of adjacent lands through the elimination of severance, if that is the case, should be credited to the same alternative.

The fact that the entire market for the purchase of that abandoned right-of-way is the owner of adjacent lands, which may lead to a token payment for its transfer, should not bear upon the credit value assigned. If the price which the Department would pay for the acquisition of right-of-way and compensation for severance in a similar case is deemed to be the resource value for that item, that same value should be assigned when the procedure is reversed, regardless of the cash amount that actually may change hands.

2.3.2 Depreciation and Salvage Values

Terminal value, residual value and salvage value might be treated as being synonymous and depreciation is a closely related term.

Vehicles, equipment and most physical assets generally depreciate in value with usage and the passage of time and this is relevant in at least two ways in the analysis covered by these guidelines.

Vehicle operation costs are an important item in the determination of roadway user costs and depreciation, being one of the costs of owning and operating a vehicle, is included in those costs. However, only the use related portion of depreciation is important in this case and in the unit operating costs which have been developed for the different classes of vehicles under different operating conditions, the cost of depreciation related to the passage of time has been eliminated.

On the other hand, analyses determining how frequently a vehicle or fleet of vehicles should be "traded in" would make no distinction between causes of depreciation with the relevant data simply being the purchase cost and the receipts when sold.

Short term analyses involving the acquisition and disposal of physical assets must include costs as negative cash flows and the net receipts upon disposal as a positive cash flows with the latter typically being significant and therefore important in the analyses.

For a long term, "open ended" type of analysis where the period being used is stretching the confidence that most may have in the asset continuing to be useful, the asset at that point in time should be given no value unless it can be used in some other way.

The material in a water line may be "good" for 75 years, however, if the decision maker has no confidence in the line being required beyond 50 years, it will be difficult to gain acceptance for a salvage value at year 50 unless there is agreement that a net benefit would result from digging it up and somehow otherwise using it.

For roadways, it has been agreed that the analysis period will usually be 50 years with results shown for each year. The 50 years is a compromise consensus resulting from some believing that a longer period could be used and others not having confidence in roadways being required by that time or, at least, not believing that any specific road or highway would be required in that location at that time.

If there is confidence in any component of the roadway being useful for some other purpose at that time and if the net benefit from that use would be significant, that value could be included, but if included for the last year of the analysis, it should also be included for all years.

The significance of value in the future depends upon the number of compounding periods involved as well as the discount rate with the significance decreasing with an increase in the value for either. For 50 years the discount factor

for 4% is 0.141,
for 6% is 0.0542, and
for 8% is 0.0213.

With a 4% real interest rate being or close to being the minimum attractive rate of return, the significance of value 50 years in the future would be limited to about 14% of their present value, assuming 100% salvage value and if the salvage value is 10%, for example, that significance would be reduced to 1.4%. Considering the significance and other related principles which have been established, salvage values should generally be neglected in the long term analysis and in special cases where they would be included, the analyst should document the case for inclusion.

2.4 Interest, Discount and Inflation Rates

The idea that "time is money" is deep rooted and one of the cornerstones in our monetary and credit system. Interest is a reward or incentive for delaying consumption.

If one has money to invest, payment is expected as compensating for foregoing the pleasure of spending it immediately and after interest is received, payment is expected on the interest which is now also invested - hence the concept of compound interest.

The use of an interest or discount rate has the effect of "watering down" the significance of the future in relation to the present. The significance of future flows of money becomes less significant with increasing interest rates. Using a 2 % discount rate, a dollar 50 years hence has a present value of 37 cents, at a 4 % rate - 23 cents, at a 7 % rate - 3 cents and at a 10 % rate - less than 1 cent. Using a sufficiently high discount rate approaches the same effect as "cutting the project off" at a relatively short analysis period.

2.4.1 Definitions

"Interest" has been given many different definitions by different authorities and might be most simply defined as the price paid for borrowing money. Some different types of interest rates also require definition and their variations are even greater.

Real Interest rate - the rate at which wealth grows over and above price changes (inflation).

Nominal Interest rate - the absolute rate at which invested wealth grows

The distinction between these terms and their relationship to inflation is important and the type of rate used in an analysis depends upon how future expenditures and incomes are expressed.

Future sums expressed in "constant" dollars are the same as their present amounts and are sometimes referred to as "inflation free" dollars. The effects of inflation are ignored.

If the future sums used in the analysis are increased to reflect the effects of anticipated inflation, "current" dollars are being used.

If constant (inflation free) dollars are used, real interest rates must also be used and if results are expressed in interest rate terms, such as when calculating the internal rate of return, the rate produced will be real.

If current dollars are used, nominal interest rates must also be used and results will correspondingly be expressed in nominal rate values.

2.4.2 Interest Rates and Inflation

Real and nominal interest rates and inflation are interrelated and their approximate relationship can be represented by this equation:

Real Interest rate = Nominal Interest rate - Inflation rate
.

Within the bounds of the three documents constituting this Guide, nominal interest rate, prime interest rate and investment interest rate have been used interchangeably, usually in the context of the above formula or a variation of it.

While that formula adequately expresses the principle of the relationships between these different types of interest rates, to be mathematically correct, it must be adjusted slightly resulting with this formula.

$$\text{Real Int. rate} = \frac{\text{Nominal Int. rate - Inflation rate}}{1 + \text{Inflation rate}}$$

2.4.3 Compounding and Discounting

The relationship between present and future values based upon compound interest can be expressed by this formula:

$$F = P(1 + i)^n$$

where:

F = future value
P = present value
i = interest rate
n = the number of periods that interest is paid.

Those relationships also apply in reverse and the reverse order is more often needed and used in the analysis.

Expenditures and receipts are typically made or received at some time in the future and the present value of those future values must be calculated.

The same formula applies and dividing each side by

$$(1 + i)^n$$

gives this rearrangement of terms

$$P = \frac{F}{(1 + i)^n}$$

Reducing the value of future sums to represent present value is called discounting and the value used for i in that formula is called the discount rate. Discount rates are also given different names by some to indicate the principles upon which their magnitudes are more or less based, however, for the purpose of this Guide, it will suffice to leave this term unaltered except to make the distinction between real discount rates and nominal discount rates. Real discount rates corresponding to real interest rates and these are used in conjunction with constant dollars. Nominal discount rates corresponding to nominal interest rates and are used with current dollars.

Financial math tables and computer programs used for discounting purposes are typically based upon "period end" payments with the "n" interval being one year. In other words, interest and discounting steps are on a yearly basis and if, for example, the base year (the year of the first entry) for an analysis is 1991, an expenditure taking place in the year 2000 would be discounted nine periods - "n" would equal nine.

2.4.4 Constant Dollars and Real Interest Rates

While the analysis may be based upon either constant dollars and real interest and discount rates or current dollars and nominal interest and discount rates, the procedure is simplified if constant dollars can be used. This is possible and mathematically correct if inflationary effects on all items will be the same. The inflation rate may vary from year to year with no adverse consequence. A problem arises when using constant dollars only if it is predicted that one or more items will change price(s) differently than the rest.

Usually that will not be predictable which will permit constant dollars to be used with future sums discounted using a real discount rate. How one or a few items, which are predicted to behave abnormally can be handled and still deal in constant dollars will be outlined in the next section.

The following diagrams and calculations, taken from an example in the Summary, illustrate how the formulae work together and produce the same results when using real rates and constant dollars as when using nominal rates and current dollars. They illustrate the discounting of \$ 3,000 for one year and the discounting of \$ 20,000 for ten years - those values being expressed in constant dollars. A real interest rate of 4 % is used and it is assumed that the annual inflation rate is 5 %. Togther, they dictate a nominal rate of 9.2 %.

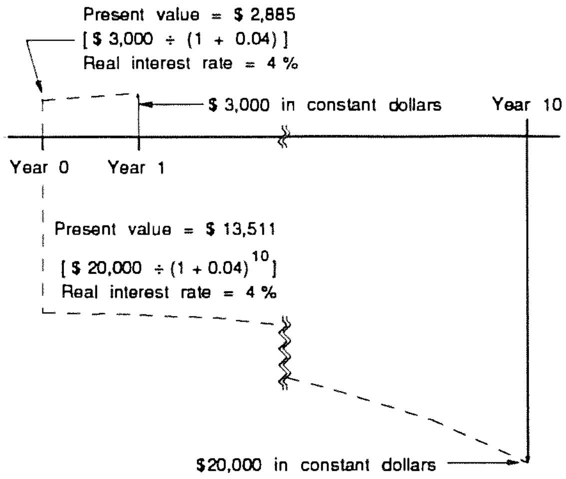

Figure 2 - 3 Discounting Constant Dollars with a Real Discount Rate of 4 %

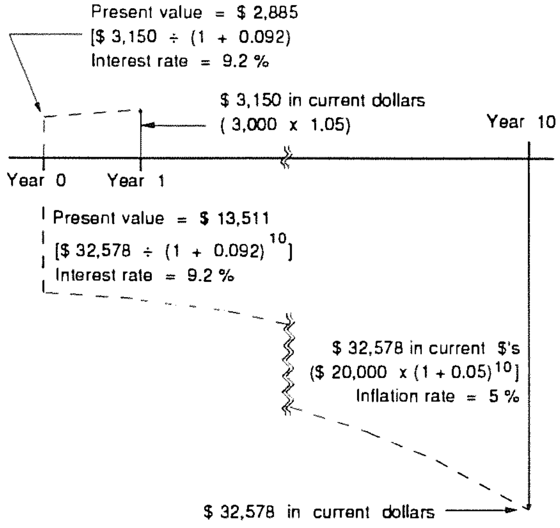

Figure 2 - 4 Discounting Current Dollars
Current dollars have been calculated using an inflation rate of 5 %. A nominal discount rate of 9.2 % has been used for discounting which is equivalent to a real rate of 4 %.

Besides simplifying the procedure, there is further advantage in using constant dollars and a real discount rate in that this rate is more predictable than a nominal rate.

Historically, the real interest rate has been positive and, for the most part, has varied between 2% and 4%. In the eighties, the spread between the prime or nominal interest rate and the rate of inflation was abnormally high for a number of consecutive years, however, that difference is now again down to being below 4%.

The idea of testing the results with three interest rates, usually described as low, medium and high, is recommended by most authorities. An obvious shortcoming of this procedure is that three times as many figures must be included in the results and reviewed and considered compared to a procedure that uses only one rate.

The Department adopting a procedure which includes the calculation of internal rate of return, as explained under the heading Presentation of Results (Section 5.3), eliminates the need to test specific interest rates and for those calculations requiring Present Values, future expenditures or income will be discounted at the rate of four (4) percent, or any other rate which is, from time to time, deemed best within the Department. At the present time the real discount rate is fixed at 4 % [1] and that rate should be used in all studies within the Department until a further review proves that another rate would be better. The model included in the User Manual has been given a default value of four (4) percent for discounting purposes, however the model has provision for conveniently changing that number.

2.4.5 Handling Different Inflation Rates

If numerous future cash flow items will be inflating at rates different than the rest, it may be most expedient to work with current dollars and nominal discount rates and the rate of return values will then also be expressed in nominal rates. If only one item, or even a few items, inflate differently, it may be just as easy and desirable to continue to work with constant dollars and adjust the value of the item or items which

[1] Corporate Planning, Alberta Transportation and Utilities - Eight page document dealing with interest rates. September, 1986.

will not change values as will all of the rest.

The reason that an item will change value differently does not matter; it may be an inflationary aberration or it may be for an entirely different reason - the analytical treatment will be the same.

The present value of the item or items must be adjusted such that if it (they) will change values at the same rate as all of the rest, it will end with the value that is known or assumed. For example, assume that an item with a present value of $ 100,000 will, when it comes onstream in 20 years time, have a value of $200,000 in dollars of that day (current dollars). Further assume that all other involved items will be inflating at the rate of 6% per annum, meaning that this $ 100,000 item would have a future value of $ 320,714 if it was to behave normally.

To be entered as a constant dollar item, its present value must be adjusted such that if it did increase in value at the rate of 6 % per annum, its value 20 years hence would be $ 200,000. The adjusted present value can be calculated by proportioning and using figures already developed - $ 100,000 x 200,000 ÷ 320,714, or, $ 200,000 can simply be discounted at the inflation rate of 6% per year for 20 years. Either way, the present value which would be used would be $ 62,361.

2.5 Period of Analysis

This factor presents a dilemma in that accurate projections for traffic volumes and the price of things over long periods of time are not possible. On the other hand, the benefits for some projects will be severely down played if all calculations are "cut off" at periods of 10, 15 or 20 years in the future which some will say is even too long. Introducing salvage values at the end of any given period will help, however, those who take the position that there may be no traffic in 20 years time should, to be consistent, insist that the salvage value be zero. What is the going price for a roadway which has no users?

There is no right or wrong answer - perhaps the important point is that the people who will use the results of such work to aid in making decisions have confidence in the inputs and, consequently, the results.

Are the assumptions believable? Will the need and demand for roadways diminish or is it more likely that there will be at least as much demand in 20, 30 or 50 years time as there is today? Might it be slightly higher than it is today? Backing into this question, if one believes that the population of Alberta will be at least as great 50 years hence as it is today, and further believes that the human race will continue to like mobility and that the most efficient means of travel for individuals or small groups is a vehicle with at least one wheel travelling on a smooth surface, one may have some confidence in the continuing need for most of our roadways. Might one use technical projections for a 5 or 10 year period and assume zero change or more or less token increases or decreases thereafter?

For long term projects such as roads, bridges, pipelines, structures, etc., it was decided that results shall be calculated over a 50 year period from the time of construction.

Factors requiring projections into the future shall be based upon relatively short term projections by staff experienced in the item being considered and assumed to be either constant or have minimal change thereafter. The long term projection for the population of Alberta is an increase at the rate of approximately one percent per year and volume items related to population levels should be assumed to increase at that rate over the long term.

Traffic volumes, for example, should be projected for five to ten years based upon technical experience and increased at the rate of one (1) percent per annum thereafter.

3. Applications in the Department

3.1 The Need

Benefit-cost analysis can be applied to any activity for which costs and benefits over time can be calculated and is particularly suited towards the evaluation and assessment of capital works or engineering - architectural types of projects.

Alberta Transportation and Utilities is in the business of providing transportation services and assistance towards other utilities within the province and is a large Department within the Alberta Provincial Government with annual budgets approaching one billion dollars.

Being large and in the business of building or helping others (principally municipalities) to build provides a wealth of opportunity for the application of this concept and the use of its results in the decision making process.

While the mandate of this Department is limited to the general fields as described in its title, the possible activities in those fields are diverse requiring choices to be made and priorities established . There are insufficient resources to do everything that is requested and required.

There are choices to be made between competing programs and projects. There are choices to be made between alternate designs and selection of materials. Many capital works projects offer staging opportunities and all require maintenance after constructed. Benefit-cost comparisons will assist in making good decisions in all of those matters as well as in choices which must be made in maintaining an efficient organization and infrastructure to administer the Department's activities.

The results of a benefit-cost analysis are most comprehensive when all competing alternatives have been included in the study, such as when alternate designs or alternate choices for one particular endeavor are being assessed. The differences in the economic merits for all of the alternatives can be weighed against the other factors which cannot be expressed in dollars and cents.

For capital works programming purposes, an analysis will not have been done (initially at least) for all of the individual projects which are possible candidates for the program, and in that case, the application of this analytical process will be only partially helpful. The individual projects which have been analyzed may be ranked, one against another, but that will not show how those projects stack up to all to all of the others which have not been studied. The picture could be completed by undertaking an analysis for all of the individual projects, however, for a large program, the work involved will likely be prohibitive. Over time, with emphasis upon including an economic analysis for each project as part of its development package, more and more projects will have been studied by the time that they are being considered for inclusion in an overall program. The ranking of projects economically will then be more meaningful and complete and with a large majority of the projects already done, it may even be possible to do an analysis for the balance, for the purpose of program planning, to make the economic picture complete.

The Internal Rate of Return being included as one of the ways of expressing results makes these analysis well suited for programming purposes. The return on investment is a common means of expressing financial values and results so expressed not only permits comparisons between similar projects within one program, but also allows a project in one program to be compared with projects in a completely different program - even across departmental lines or to those in other agencies or in the private sector, with some qualification.[1]

Although confidence levels may be higher when making comparisons between projects, results giving an indication of return upon investment permits a project to be judged upon its own merits for its results can be viewed in the light of general market conditions. A project with a real return well above the difference between the "prime" interest rate and the

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[1] With input values being resource orientated, care should be taken when comparing projects with those of others to ensure that all items are being treated in a like manner. For example, the elimination of some taxes will generally lower the return being received and will place projects based upon that procedure in a less competitive position if compared with results of other projects or works wherein those taxes have not been excluded.

rate of inflation might be viewed as being economically good regardless of what the results of other projects might be. What is not known is whether the return for that project is higher or lower than that for a project for which no analysis has been done.

3.2 Application Variations

As outlined in Section 1.2 dealing with the committee process, various areas within the Department have been undertaking these kinds of studies for a long time with specific applications to these subjects:

Equipment replacement analysis

Computer and drafting needs studies

Renting v.s. buying analysis

High Load Corridor choices

Increased Weights. and Dimensions (RTAC)

V.I.S. 5 yr. plan

Stage construction for pavements

Rehab programming and system analysis

Ferry replacement program

Cattle passes

Signalization of intersections

Median width analysis

Pavement v.s. Gravel needs

Rehab of thin full depth pavements

Sewer, water and other utility studies

Comparison of alternate road locations and designs.

It is common practice to prepare cost estimates and comparisons for virtually all of the Department's activities ranging from administrative type of work to capital works projects and all of the various maintenance tasks.

The quantifying of benefits resulting from the activities is not done as a matter of routine and the analysis which have been done in the past have taken initiative on the part of the Branch or Section doing the work to collect and assemble the additional data which is required as inputs for a benefit-cost anaysis.

For one reason or another, it will not be possible nor necessary to apply this concept to all of the Department's activities, however it could be applied on a much broader basis than done to date and the list on the following page includes the applications suggested at the committee meetings held in 1987 and 1988.

For the most part, these would be in addition to those items in the above list which are currently being done. Further, it is the intention that an analysis would be done on each new work in these categories and not on a "hit and miss" selective basis as now done in some of the areas. This does not mean that an analysis would be done in all cases. For example, it may be decided that there is no point in undertaking this part of the work in cases where decisions have already been made and the results of such a study, if done, would have no influence or bearing on future actions.

Each suggestion made is included in this list and the items have been grouped into somewhat related types of activities .

It is recognized that it will not be possible to do an analysis for all of these items immediately, the most common reason being that the necessary data is not readily available at this time.

Doubts. which were discussed at the time the item was introduced, about its suitability, for this kind of analysis, are included in brackets.

Suggestions made at committee meetings in 1987 and 1988:

Equipment lease, buy or privatization
Equipment replacement v.s. maintenance
Equipment systems development
Equipment and supplies inventory

Width of subgrades
Pavement v.s. dust abatement v.s. gravel
Paved shoulders v.s. gravel shoulders
Twinning v.s. passing lanes - higher volume roads
Passing lanes on low volume roads
Channelization of intersections
Interchanges - priority
New facilities - priority
By-passes

Selection of materials for bridges - steel v.s. concrete
Alternate types of structures
Bridge deck type comparisons
Bridge repair v.s. replacement

Rehab staging - 8 to 10 yrs. v.s. 16 to 20 yrs.
Illumination benefits
Pipeline installation and subsequent crossing alternatives
Guard Rail and Guide Posts v.s. alternate designs
Quality of signs - 3 yrs v.s. 10 yrs.
Rate of regravelling - quantity v.s. time until next cycle
Mowing (benefits difficult to quantify)
Gravel inventory
Gravel stockpiling v.s. crushing and hauling directly from pit
Advanced land purchases

New innovations in surveying - total station concept and electronic field book

Public information campaigns
Staff courses (benefits difficult to quantify)

Encourage local taxing authorities to do equivalent studies on equivalent works.

The theme within the Department is to apply this concept of analysis on as broad and as consistent basis as possible and future applications should not be restricted to these lists but should, instead, cover all work and projects for which good information is available to express both benefits and costs in dollar terms.

3.3 Roadway Projects

This application to general roadway type of projects is included as only one item in the list of present applications, however, a large part of the Department's total application of this concept has related to the comparison of highway and roadway alternatives and the comparison of different designs for a specific section of roadway.

These applications date back to the sixties and early seventies when Robley Winfrey, a Consulting Highway Engineer from Arlington, Virginia, was commissioned to lead a seminar on the subject which a number of Department staff attended. While these kinds of applications are judged to have monopolized the Department's total efforts, this application has been spotty with only a small percentage of the total number of projects including an economic section in their covering report. Including an economic analysis as part of a project's review package has been limited to those in which the economics of the case seemed particularly important.

The application to general roadway types of projects continued to take a dominant position in the committee meetings in the late eighties, possibly partly because of the historical significance but likely also because it is by and large the most complex and interesting of all the suggested applications. Further, roadway projects require numerous inputs and a lot of effort at that time was devoted to developing a better system of collecting and handling costs associated with the road user.

For the same reason, a good part of the User Manual of this set of guides concentrates upon the procedures and documentation of the process of handling input items for general roadway projects.

The typical roadway project involves heavy capital cost at the beginning of the period of analysis, routine annual maintenance thereafter and significant periodic rehabilitation work.

For provincial highways or roadways, all of those items are the responsibility of the province as represented by Alberta Transportation and Utilities. The benefit side of the equation stems from the use of the road and to have economic efficiency, the reduction in costs of the road user must match or exceed those costs incurred by the Department.

For any projects under consideration, it is routine procedure to have estimates of initial costs to the Department. For a benefit-cost analysis, maintenance costs, as well as future rehabilitation costs, must also be obtained, and gathering that additional information to complete the expenditure side is relatively easy.

The majority of the work involved in determining the complete cash flow picture is associated with road user costs. Lists of items, sub items and variables are included in the next section and the list of road user items is substantial. The fact that the majority of the basic data for these items is already being collected and used for different reasons within different parts of the Department makes it possible to produce good road user cost figures. Nonetheless, transforming the data into the form needed for these analyses takes time - time which staff cannot always spare for this purpose.

3.3.1 Roadway Project Factors

The following lists include most of the items and sub items which are subject to being important in the makeup of costs and benefits for an economic review. Not all of the items will be relevant for any one project but some projects will involve items not included in these lists.

These lists provide some indication of the number of inputs involved in a roadway study and they (the lists) may serve as a check against which the items actually used in any review may be compared.

General Categories	**Most Significant Items**	**Examples of Sub Items**	**Examples of Variables**
Capital Costs	Grading Base Course Surfacing Structures Right-of-way Engineering Contingencies	Each item has numerous different components of cost.	Location in Province Design standards Availability of materials
Maintenance Costs	Snow & Ice Control Patching Dust abatement Pavement markings Brush & Weed Control Signing Regravelling Crack filling	Some items have a number of sub items	Weather Location Complaints Design

Figure 3 - 1 Roadway Capital and Maintenance Cost Factors.

General Categories	**Items**	**Sub Items**	**Variables**
Operational Costs	Vehicle Classification	Pass. Vehs. Rec. Vehs. Busses SU Truck Tractor Trailers	Load limits Clearances Enforcement
	Traffic Volumes	Annual Daily Hourly variations	Local population Recreation opportunities Tourist route Commuter route Available alt. routes
	Speed Data	Average Hourly variations Accel. - Decel. Stops	Environment Level of Enforcement Passing Opportunities
	Roadway Features	Terrain Surface Type Alignments	Shoulder width Sideslope treatment
	Operational Features	Speed Restrictions Barrier Lines Environment	Posted speed Level of enforcement Rural Semi Urban Urban
	Unit Costs	Fuel Oil Tires Maintenance Use related depreciation	Taxes Local Competition
Travel Time	Trip Purpose	Commercial Business Medical Educational Social Recreational	Increment of time Other uses for time
	Vehicle Occupancy	Trucks Cars Busses Rec. Vehs. Other	
	Unit Costs	Truck Drivers Helpers Comm. Travellers Bus Passengers Passenger Vehs. Tourists	
Safety	Collision History	Total numbers Rates	Driver behavior Weather Road Conditions Roadway design
	Classification	Property damage Moderate injury Serious injury Fatalities	
	Contributing Factors	Driver Roadway Other	
	Predictions	Same as above	
	Unit Costs	Market losses Family/Community Medical Rehabilitation Funeral Legal Insurance Public Liability	

Figure 3 - 2 Input Factors for Road User Costs

4. Analysis Methods

4.1 Overview

When two or more alternatives are being compared, the benefits and costs for each are identified, quantified in money terms and then compared. In most cases "do nothing" will be one of the possible courses of action.

Costs are usually concentrated at the beginning of the project with benefits occurring over an extended period of time, and it is necessary to convert all of these into a common measure for comparative purposes. This is done by using an appropriate interest rate and discounting the future costs and benefits into present value or present worth.

The different alternatives may be compared economically by calculating the net present value for each, by determining the benefit-cost ratio of one compared to another, or by determining the internal rate of return for each.

Finally, any number of tests for sensitivity can be made by simply changing the value of an item and repeating the calculations.

This all sounds quite simple and each component is relatively simple, however, for roadway projects at least, the number of items, sub items and variables affecting each prohibits the changing of many items because of the numbers of combinations of results which would require comparison.

4.2 Analysis Option

Having determined cash flow values for a project, there are several methods for converting those flows into results which provide an indication of the economic efficiency of the project.

As discussed in Section 2.1.2, it is best to deal in incremental values with each new alternative compared to "doing nothing" or more usually compared to "doing a minimum" - whatever would be done if the action being tested is not taken.

As far as the mechanics of these procedures are concerned, it makes no difference whether an alternative is being compared to doing absolutely nothing (no deductions made from any of the entries) or if the cash flows being tested are incremental values wherein at least some of the entries are the differences between what values would be with the project less the values which would apply without the project. These procedures deal with the cash flow entries and it matters not how the entries were calculated or obtained. The descriptions of the results and the interpretation of the results are other matters and both will be influenced by the makeup of the entries.

4.2.1 Net Present Value (NPV)

This method involves the discounting of future cash flows and subtracting expenditures or outward flows from incomes or inward flows. If the result is positive, the activity being tested is good economically in the sense that the return on investment is greater than the interest rate used for discounting. If more than one alternative is being tested, the one with the highest positive result (the highest NPV) is usually the best.

The results of this method are qualified as being judged in terms of the discount rate and that is exactly how the results obtained from this method must be viewed. For example, if testing two alternatives (A & B), Alternate A may provide the higher Net Present Value when future cash flows are discounted at 4% whereas Alternative B may yield the higher positive NPV if a discount rate of 5% is used. The reasons for this and a method of getting a better understanding of the significance of results will be covered when dealing with the methods adopted by the Department that also includes the calculation of the Internal Rate of Return.

The similarity between this method and the Benefit/Cost Ratio method will be illustrated next with further limitations of each discussed.

4.2.2 Benefit/Cost Ratio (B/C Ratio)

This is a popular method of illustrating the results of a benefit-cost analysis and its procedure is closely related to that used in determining Net Present Values - in fact, up to the last mathematical step the procedures are identical. A period of analysis and a discount rate are selected and incomes or positive cash flows are added as are expenditures or outward cash flows. Having those positive and negative totals, the Net Present Value is determined by algebraically adding the two (in effect, subtracting the discounted expenditures from the discounted incomes) and the Benefit/Cost ratio is calculated by dividing the total for discounted incomes by the total for discounted expenditures.

In formula form, the close relationship between the two methods becomes even more obvious.[1]

$$\text{NPV} = \text{Discounted Incomes} - \text{Discounted Expenditures}$$

$$\text{B/C ratio} = \frac{\text{Discounted Incomes}}{\text{Discounted Expenditures}}$$

If the Net Present Value is positive indicating economic efficiency (again with qualification), the B/C ratio will be greater than 1 (one) with the same economic ramification and the same qualification. If the Net Present Value is negative, the B/C ratio will be less than 1 (one) with both results indicating that the project is not efficient economically considering the discount rate and period of analysis used.

To end with one figure - a dollar value for NPV or with a B/C ratio - a specific period of analysis must be chosen and, of course, the results are based upon a specific discount rate. Therein lies a shortcoming of dealing with only one result as provided by either of these methods - knowledge about how sensitive that result is to changes in either of those variables (life of project or the discount rate) is not available. For that reason, many authorities recommend using three discount rates, a low, medium, and high and, collectively, the three results would provide a better picture about the influence of the discount rate.

If the decision maker desires more information about the period of analysis or life given to the project, three different values could also be used for this factor - a short, medium and a long period or life.

A picture which would provide a wealth of information about the effect of both of these variables would be a graph with a family of curves with either NPV's or B/C ratios (or both) plotted continuously for each year for all possible periods with each plot in the family representing different discount rates in steps of 1 or 2 percentage points. While that sounds like a lot of work, and it would be if manually done, with computer programs handling the calculations, the production of the data would be no problem.

Both of these methods will be left for now but will be revisited repeatedly. Present Values are used in the Department's procedures and the inherent relationships between B/C ratios and the other methods will be highlighted.

4.2.3 Internal Rate of Return (IRR)

This method also involves discounting but instead of choosing a discount rate, the discount rate is calculated to make the discounted benefits equal to the discounted costs or, in the same terms as used previously, discounted incomes equal to the discounted expenditures. As in the other two methods, the interest rate or discount rate so calculated will be based upon a specific period of analysis.

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[1] The simple relationships shown here can become somewhat more complicated if the project contains items which can be handled in different ways when calculating the Benefit / Cost ratio. For example, it makes no difference in the magnitude of the NPV whether maintenance costs are included with "expenditures" or whether their annual amounts are subtracted from benefits and, in effect, included with "incomes". Obviously, the magnitude of the B/C ratio would be different for those different treatments. That is not the greatest example in the sense that maintenance costs might have only one rightful location and that would be on the expenditure side. The treatment of land becoming free for other uses with an alternative but continuing to be used with the "do nothing" alternative might be more debatable. Should it be a "charge" against "doing nothing" or should it be a benefit for the alternative? When the B/C ratio is equal to one, rearranging input items, as described here, will not change that result.

Said in another way, if one somehow knew the internal rate of return and used that figure as the discount rate, the Net Present Value would calculate to zero - discounted incomes would add to the same amount as the sum of discounted expenditures. Similarly, if the B/C ratio were calculated with that discount rate, the ratio would be one, regardless of how items might be sorted into "incomes" or "expenditures". The possible variations mentioned in the footnote on the previous page do not apply when the B/C ratio is equal to one.

An advantage of calculating a rate of return is that the results are expressed in a term which is universally known. The business world deals in the return received and the magnitude of the rate of return is meaningful and permits comparisons with other investments with their known rate of return, with the caveats previously mentioned about the treatment of taxes and input values being resource related. See Subsidies, Grants and Taxes - page 18 and the footnote on page 25.

Results expressed in terms of Net Present Value or Benefit/Cost Ratio do not provide a specific rate of return unless the NPV = 0 and the B/C Ratio is equal to one (the rate of return is then equal to the discount rate) - otherwise, if the NPV is positive and the B/C ratio greater than one, it is known that the rate of return is greater than the discount rate used but how much higher is not apparent.

The calculation of the rate of return involves a trial and error process and that is laborsome and tedious if a computer program is not available which will handle the iterations.

The literature dealing with these different analysis methods quite rightfully draws attention to the fact that two or more answers will sometimes satisfy the equations in the rate of return method, however, this should not be a deterrent to using this method for dominant lumpy cash flows in the future are required to set up the multi solution circumstance which does not often occur, and if it does, it may be in a range which is not critical anyway. With continuous plots, as used by the Department, irregularities such as this will be easily recognized and can then be dealt with. See Section 5.4 for a suggested reference for dealing with analytical problems such as this.

4.2.4 Equivalent Uniform Annual Costs (EUAC)

This method also requires the summation of discounted values for each alternative, but instead of comparing totals in some way, the total present values are then converted to equivalent annual amounts using the same discount rate and using the number of annual amounts which correspond to the life of that alternative.

Obviously, if the life of different alternatives is the same, the EUAC of each will be in direct proportion to their total present values and a comparison of totals would be just as revealing as a comparison of other figures which are directly related to the totals.

This method becomes useful, sometimes mandatory, when different analysis periods must be used for the different alternatives, and spreading total discounted amounts over the different length of periods will permit comparison of the annual amounts for different alternatives.

Analysis involving the purchase or lease of vehicles, heavy equipment, office space, office equipment or the like may involve specific, relatively short analysis periods and particularly when different options have different life periods, the EUAC method will be best.

This method may also be applied in cases which involve no benefits or where undiscounted benefits or positive cash flows do not exceed undiscounted costs or negative cash flows and where there is, therefore, no return and the internal rate of return method cannot be used.

Although the name given to this method includes only costs, as just indicated, the activities being reviewed can have benefits and the benefits or incremental benefits can exceed the costs or incremental costs and the Net Present Worths whether positive or negative would simply be converted to equivalent equal annual amounts.

This is one of the applications adopted by the Department and in the section describing the Department's methods, an example using the EUAC method will be given which will also highlight a problem of dealing with short term projects which have different analysis periods.

4.2.5 Other Methods

There are a number of other ways in which results can be expressed and compared and most are some variation of the four basic procedures just described.

Results can, for example, be expressed in Net Future Values in contrast to Net Present Values - a matter of transforming the present values to future values by reversing the discounting process using the same interest rate.

A Capitalized Equivalent amount can be calculated which assumes that a sequence of cash flows which has been developed will repeat forever. Mathematically that amount can be determined by calculating the equivalent uniform annual amount for the period designed and then assume that that annual amount will continue in perpetuity to calculate the Capitalized Equivalent. If comparing one alternative to another, Capitalized Equivalents will provide the same relative answers as the EUAC method - proportions will be identical.

Some agencies favor the Payout Period method when assessing items which may have a very short life - items which may quickly become obsolete, for example. Typically, no interest is used in this method with the Payout Period simply being the time it takes for undiscounted benefits to match undiscounted costs. The method adopted by the Department for calculating all positive values for the Internal Rate of Return automatically provides the Payout Period as described here. The time between the initial expenditure and the time when the IRR changes from negative to positive would meet that definition for a Payout Period.

More complicated procedures involving the use of different interest rates for different classes of cash flows - e.g. the reinvestment rate may be different than the initial investment rate - may be necessary in the consideration of business ventures or private investments, but should not be necessary in the consideration of publically funded endeavors when efficiency is resource orientated.

Income tax would also be an important factor in the private sector but it may be completely ignored in analyses for publically funded projects. With inputs being a measure of resources used or saved, the fact that road user costs entail a mixture of "after tax" and "deductable" dollars is not a complicaton which it may otherwise be.

4.3 Sensitivity Tests - The Significance of Deviations

This subject has been introduced previously in this Guide, most recently in the discussion of the different methods of manipulating streams of cash flows to produce results. The practice of testing the influence which changing discount rates will have upon results is a common procedure when the Benefit/Cost Ratio method is used and the need for sensitivity information about interest rates would be just as great if expressing results in Present Values only.

To more completely paint the whole picture for either of those methods, it is suggested that results for different project life periods might also be required.

Those examples really provide the long and the short of the typical way in which factors are tested for sensitivity - a factor is given a different value and the results after the change are compared with the results before the change and the influence of changing that factor is thus determined.

If a question is raised or anticipated about the unit costs used for the value of time, for example, it is simply a matter of changing those costs and rerunning the program to determine how the results are affected by the change in the time rates.

In the section dealing with the valuation of items, this same process was suggested for determining whether or not a troublesome item deserves the attention which determining an acceptable value may entail. The item may be given high and low values - guessing limits which would undoubtedly include any value which would eventually be assigned and if the results are not significantly affected by the range tested, the valuation for the item could be forgotten.

Rerunning entire programs to determine how results may be affected, as all of the above suggests, should be no problem if data for the whole project is being handled automatically anyway.

If that is not the case or, if for some other reason it is not possible or desirable to determine actual changes in final results, one might revert to the age old means of calculating or estimating the effect or mathematical results which a change in individual entries in the mathematical equation will have.

References dealing with this subject often include it in a discussion about errors.

The possible percentage error in a product or quotient is approximately equal to the sum of the possible percentage errors in the entries being multiplied or divided. In the equation A = B x C, if "B" is subject to a variation of 10 % and "C" to 15 %, "A" may vary as much as, or slightly more than, 25 %. The "slightly more" qualifier draws attention to the fact that this is an approximate relationship but quite adequate if the possible deviations in the individual items are not too large. If the deviations are large, the whole process becomes questionable - the degree to which the approximation might be misleading will be only part of the problem.

In that example, "A" might actually vary between the limits of - 23.5 % to + 26.5 % compared to the approximation of ± 25 %.

When the powers of numbers are involved, the rules for multiplication can be used because, in effect, they entail the same mechanics of calculation.

Roots are powers in reverse and the procedure of summing deviation percentages must also be reversed.

If a number is subject to a deviation of 10 %, the square root of that number may have a deviation of approximately 5 %, the cube root - approximately 3 1/3 %. If the process is reversed and a number is multiplied by itself three times and the accuracy of the number is within 3 1/3 %, the product would be subject to a variation of approximately 10 %.

When adding or subtracting, the numerical deviation in the individual items being added or subtracted is added to determine the possible deviation in the total sum or the resulting difference.

$$(12 \pm 2) + (10 \pm 1) = 22 \pm 3$$

Percentages cannot be used in calculating the deviation in sums or differences, however, in the case of additions, one assumption can be made - the percentage error in the total cannot be greater than the largest percentage error of the individual items making up the total.

That cannot be said about differences which is obvious when the above example of an addition is changed to one of differences.

$$(12 \pm 2) - (10 \pm 1) = 2 \pm 3$$

In the case of differences, small deviations in the individual items can produce deviations larger than the result as that example illustrates.

These methods of determining the influence which a deviation or possible error in input items may have on results will have limited application to the analyst partly because better methods are available to those doing the analysis. In complicated studies particularly, it will usually be easier to simply change values and run the whole program and get accurate results compared to tracing the approximate influence of an item through the system.

However, with some practice and coupled with other tricks of the trade such as the Rule of 72 [1], many things that appear rather complicated can be calculated or checked mentally.

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[1] In compound interest calculations, the interest rate divided into 72 gives the number of periods (years in these analyses) it takes for the factor to grow to two. For example, if interest is received at the rate of 6 % per annum, an investment will double in 12 years (12 periods). Not an exact mathematical relationship but very close over a wide range of interest rates.

For example, the present value of a $ 1,000 item coming on stream in 20 year's time has been determined to be $ 456.39 if discounted using a rate of 4%. If the approximate effect of changing the discount rate from 4% to 5% is desired, one might reason that the difference between dividing a number by 1.05 twenty times and 1.04 twenty times will be about 20 x 1 % = 20 % (the sum of the approximate percentage deviation in each of the divisors. Twenty percent of $ 456.00 is $ 91 and the answer using a 5% discount rate should be in the order of $ 365.

The accurate answer is $ 376.89.

Another example incorporating the Rule of 72: - with compound interest of 6% per annum, how much will an investment of $ 1,000 grow to in 20 year's time ? The investment will double in about 12 years (72 ÷ 6) which leaves eight years not accounted. The error of omitting to multiply $ 2,000 by 1.06 eight times is about 48 % (6 % x 8) and, therefore, in 20 year's time, the investment should be worth about $ 2,000 x 1.48 which is close to $ 3,000.

Working from the other direction, the investment will quadruple in about 24 years which is high by four years of growth which will be equal to approximately 24 % (6 % x 4). $ 4,000 - 24 % x $ 4,000 is just above $ 3,000.

The accurate answer is $ 3,207.14.

In both of the above approximations, the largest cause of discrepancies is that the adding of percentage errors does not take into account the effects of compounding which are inherent in the exact calculations.

5. Departmental Procedures

Analytical methods should be relatively simple and results and variations in results for different projects should be explainable in terms that those with a general knowledge of finances and economics can understand.

Coupled with the standardization of values and procedures, a more or less consistent manner of presenting results will go a long way towards an understanding of the economic reports prepared for different types of work.

For long term "open ended" type of analysis such as for a typical highway or utility project, the Department has adopted a procedure involving the determination of present values and internal rate of return with input data and results summarized on one page (if the project is not too complex) and a graphical plot of present values and internal rate of return on a second page.

For short term analysis, and particularly if different alternatives must have different evaluation periods, expressing the results in terms of Equivalent Uniform Annual Cost (EUAC) may be best. That method or a comparison of Payback Periods might either or both be used in cases comparing alternate purchases or works which have different useful lives.

5.1 Long Term Projects

Virtually all of the activity and efforts of Alberta Transportation and Utilities lead to or are in support of capital work projects which will have a long life, hence the majority of the analysis will fall in this category.

Transportation type of projects or components of those facilities will be used for all of the examples, however, the same principles and procedures can be applied to utility works and for either, as far as the analysis is concerned, it matters not whether the project is under the direct administration and control of the Department or whether the Department is simply supporting a municipality with one of its projects.

Works, when completed, must be operated and maintained and those capital and maintenance costs, together with the benefits which the users of the facility will enjoy, constitute the broad categories of input items.

Showing expenditures or costs as negative and benefits as positive, a cash or resource flow diagram could takethe following form:

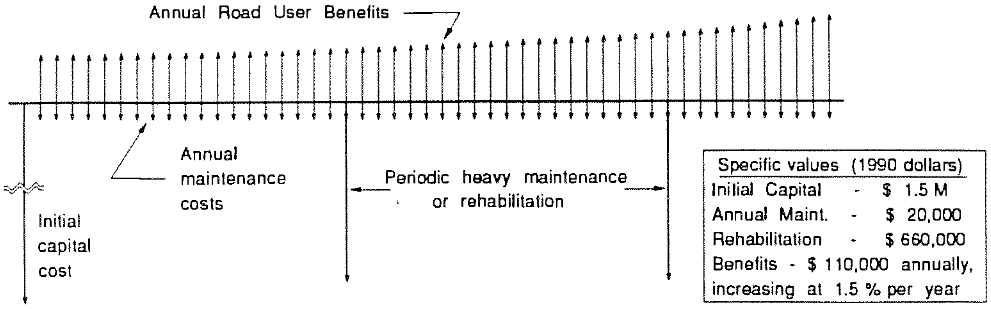

Figure 5 - 1 Cash Flow Diagram for a Typical Roadway Project

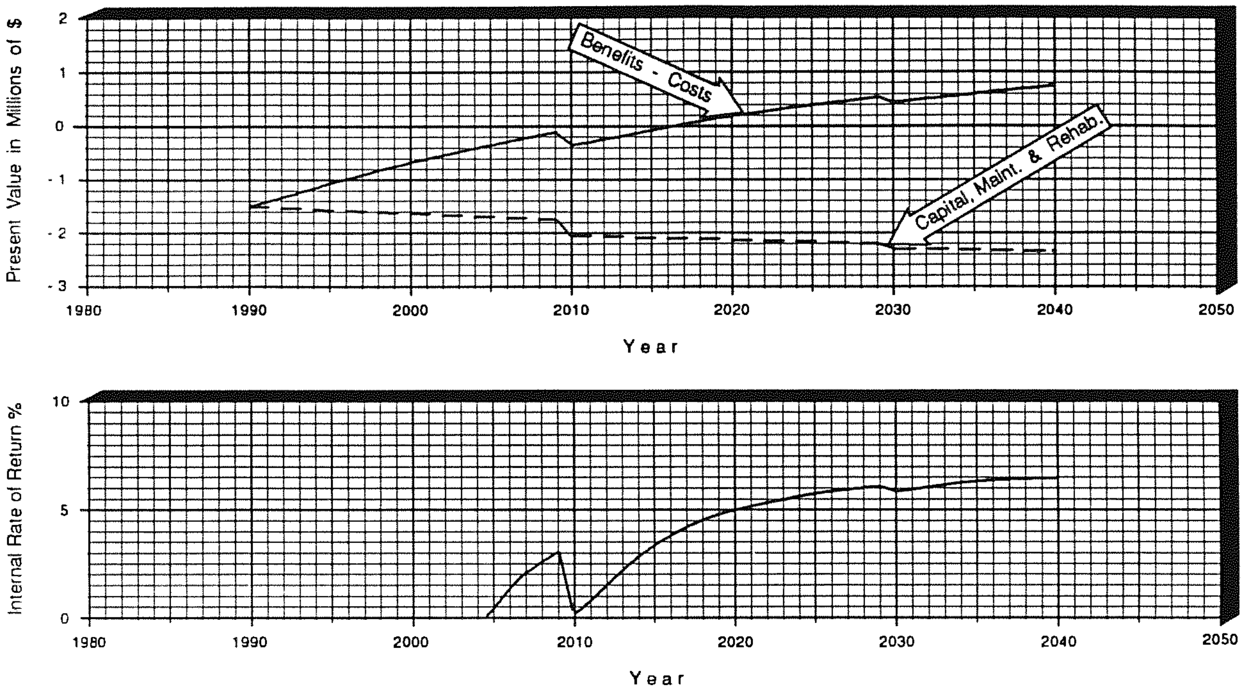

Figure 5 - 2 Graphs Showing Plots of Present Value and Internal Rate of Return - Results correspond with the cash flow diagrram.

5.1.1 Present Values

The lower present value line is a running accumulated sum of discounted capital, maintenance and rehabilitation costs.

The graph starts in 1990 with a capital expenditure of 1.5 million and adding (actually subtracting because expenditures are treated as negative) yearly discounted maintenance costs accumulate to approximately 1.75 million by the year 2009. The major rehabilitation in year 2010 results in a jump in the accumulated figures. The flow diagram shows an equal rehabilitation effort in year 2030, however, on the N P V graph this second major expenditure shows as being relatively small compared to the first being discounted for 40 years compared to 20 years for the first.

The flow diagram shows equal annual maintenance costs over the entire analysis period which illustrates the concept that all costs and benefits can be expressed in "constant" or "inflation free" dollars providing all or most of the items will be inflating at the same rate.[1] If, for example, the project is being estimated in 1990 dollars, the yearly maintenance costs should be estimated based upon 1990 dollars also and providing the level of maintenance activity is not expected to change, that same annual cost can be used for the entire period.

All "constant" dollar values (1990 values) which will not be expended or credited until some time in the future are to be discounted at the rate of 4% - the general average historical difference between the prime interest rate and the rate of inflation.

The present worth of capital, maintenance and rehabilitation costs as shown in that graph therefore represent the amount of money required in the year 1990 to meet all future expenditures up to the year being considered. For example, 2.4 million dollars invested in 1990 and receiving interest (on the balance remaining from year to year) at the rate of inflation plus 4 %[2] would just cover the expenses for this project for 50 years.

The upper line on the present worth graph represented the accumulated discounted benefits being added to the discounted costs. Benefits must also be based upon "constant" dollars and the gradually increasing benefits shown in the flow diagram do not reflect inflationary increases but instead illustrate an increase in the volume of user benefits over time. For roadway projects, user costs will usually be in direct proportion to traffic volumes.

This upper present value plot is commonly referred to as NET PRESENT VALUE (NPV) being the accumulated discounted benefits less the accumulated discounted costs. Projects which have a high NPV are attractive from an investment point of view; those with low NPV are less attractive. When input values are expressed in "constant" dollars and future cash flows discounted at 4%, positive NET PRESENT VALUES mean that the project is yielding above a 4% REAL rate of return (4% above inflation). If one is happy with a 4% REAL return, the project would be considered favourable from a financial point of view. In this example, the NPV changes from negative to positive between years 26 and 27 (mid 2016). This project would be a "go" financially if the decision maker has confidence that this project will be useful to at least the year 2017 and is satisfied with a 4% REAL return.

5.1.2 Internal Rate of Return

By definition, the internal rate of return is the interest rate at which the present worth of the net cash flow is zero.

Except for very simple cases, this interest rate is laboursome to determine manually involving a trial and error process. Examples of manual calculations are included in the Math section of the Appendix. Fortunately, Lotus has an interest package which will calculate internal rate of return and being easy to obtain in this manner, rates for each year over the entire analysis period should be calculated. A graphical plot for the years in which this rate is positive is a very useful and descriptive tool.

Viewing the graph on Page 36, reveals that the internal rate of return becomes positive at year 2005, increases rapidly until the rehabilitation expenditure is entered at year 2010, then recovers rapidly for a few years and gradually flattens to become almost static between 2035 and 2040. With relatively uniform or uniformly changing costs and benefits over the life of the project, the plot of internal rates of interest takes on a shape somewhat like a parabola with a horizontal axis. In this case, the typical shape is interupted with the large rehabilitation entries - nonetheless, the basic form is obvious. Two points on that graph can be readily calculated, determined or checked:

> The zero rate of return will occur at the year when the arithmetic sum of undiscounted costs and benefits equal zero; and
>
> The internal rate of return will be 4 % at the time when the NET PRESENT VALUE is zero.

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[1] Any item not following general inflationary trends must be brought back to the base year by discounting at the rate or rates of inflation anticipated for all of the other items - see Section 2.4.5.

[2] Simply adding the inflation rate and discount rate provides an approximate value. Mathematically, the interest rate which would have to be earned would be equal to i + (1 + i) times the inflation rate - see Section 2.4.4.

The inherent calculations which produce that relationship between Net Present Value and the Internal Rate of Return make the latter a useful indicator. In that example, if costs and benefits were discounted at the rate of 5 %, the Net Present Value would change from negative to positive at year 2020, the same point in time when the Internal Rate of Return is 5 %. Using a 3 % discount rate would result in the Net Present Value just crossing the zero value line in 2009 and would then be negative again until 2015 as the Net Present Value line shifts upward to reflect the effects of the lower discount rate.

The Benefit-Cost Ratio was mentioned as another common method for displaying results and the Internal Rate of Return graph provides insight into what the results of Benefit/Cost (B/C) Ratio calculations would be.[1] If a discount rate of 4 % is used, a B/C ratio of less than one will result for all periods up to 2016 and a ratio greater than one will result if 27 years or longer analysis periods are used. Similarly if 5 % is used as a discount rate, B/C ratios will be less than one for all periods up to 30 years (2020) and greater than one for longer periods. The plot of internal interest rates actually provides "under one" or "over one" results of an infinite number of B/C ratio calculations using different combinations of periods and discount rates both of which must be specific for each B/C ratio calculation.

5.1.3 Testing Two or More Alternatives

If one considers "doing nothing" as one alternative, there would never be a "one alternative" situation involving this kind of an analysis. This section will deal with cases where there are two or more options for doing something. That also requires clarification because if some minimum work has to be done or will be done, should that be one of the options tested along with the more extensive ones or should it be the one to which all others are compared?

An example, - a section of highway must be resurfaced and an alternative to doing that is to replace this section with a better alignment which will result in user benefits. Should the analysis provide the merits of doing either or simply determine the merits of constructing a new highway compared to resurfacing the existing ?

The results will be different, depending upon what procedure is used.

Assume these costs:

Resurfacing existing highway	$ 500,000
Construct new highway	1,000,000
Benefits from resurfacing	- virtually nil
Benefits from a new highway	- $ 50,000 / yr.
Difference in maintenance costs	- negligible

If considered as two options , the results would be:

Resurfacing	- expenditure	500,000
	- return	negligible
New const.	- expenditure	1,000,000
	- return	50,000 / yr.
		= 5 % (REAL)

If incremental values are used (new construction alternative compared with doing minimum)

Incremental costs	500,000
Incremental benefits	50,000 / yr.
- return	= 10 % (REAL)

If the existing highway will be resurfaced providing it is not replaced, the analysis treating the resurfacing as an option provides poor information upon which to base decisions. In this case the expenditure required to gain the 50,000 / yr. return is 500,000 and not 1,000,000.

As a general rule, if some work must be done or will be done, providing a better alternative is not found, that "minimum" work should <u>not</u> be treated as an option. Instead, that should be used as the base case and all other alternatives tested against it. Costs for the "minimum" work which will not be necessary if an alternative is chosen should be credited to the alternative being tested.

When two or more alternatives are being considered,

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[1] The amount above or below one which a B/C ratio calculation will yield depends upon how the input items are sorted. However, for most cases, when the internal rate of return interest rate is used in the B/C ratio calculation, unity results regardless of which method of sorting the input items is used,

the alternative with the highest Internal Rate of Return need not also be the one with the greatest Net Present Value.

Firstly, an example where that is not a problem. Input data is based upon 1990 dollars and all calculations use "CONSTANT" dollars.

ALTERNATIVE	CAPITAL COST (1990)	ANNUAL BENEFITS THEREAFTER	
1	$2.7 Million	$300,000	(benefits will increase with inflation)
2	$5.8 Million	$430,000	
2 minus 1	$3.1 Million	$130,000	

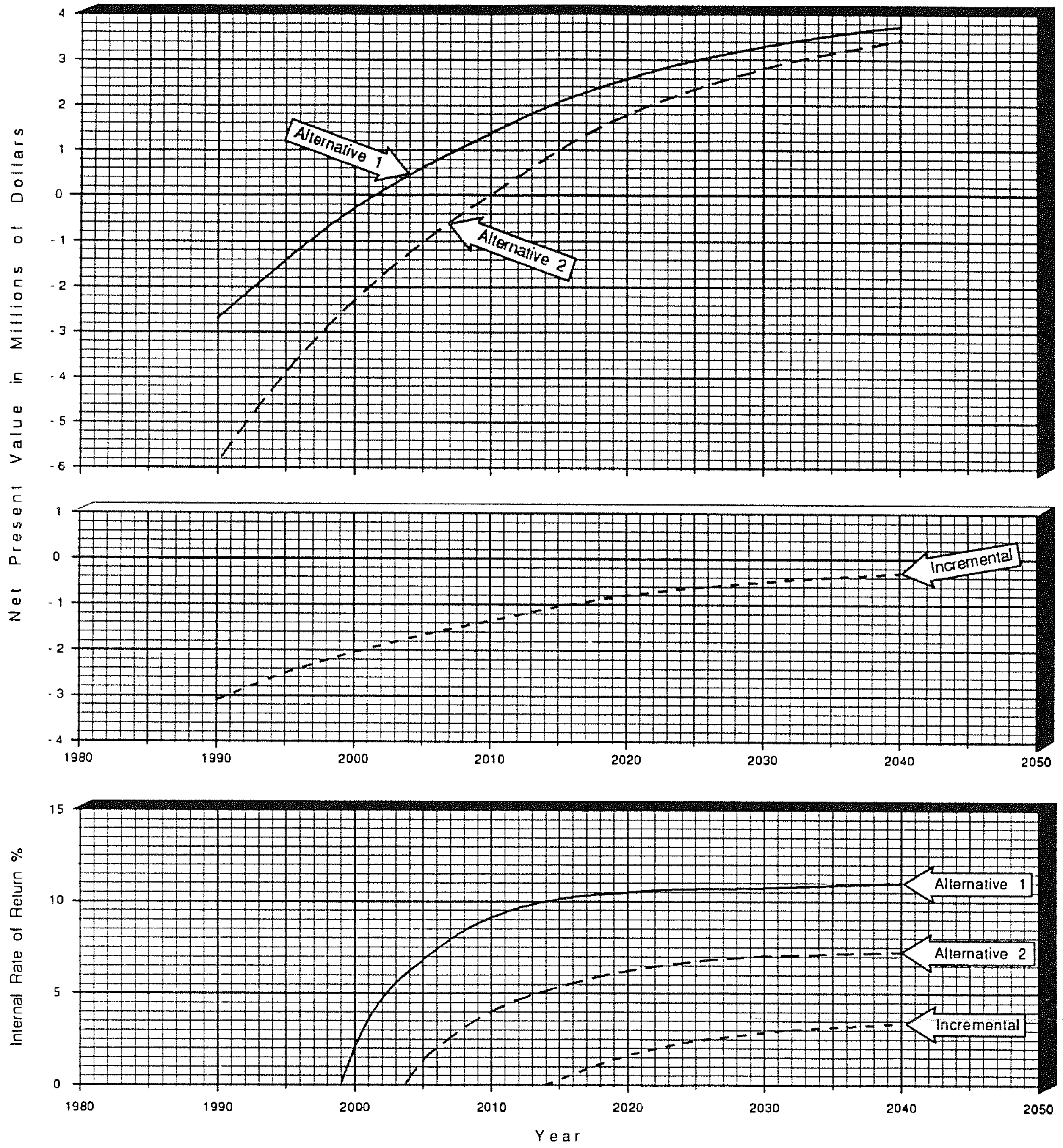

Figure 5 - 3 Graphs Showing NPV, IRR and Incremental Values

In that example, an annual benefit of $300,000 increasing with inflation and resulting from an investment of $2.7 million yields a REAL return of 11.1 % in perpetuity. If benefits stop after 50 years and there is no return of capital (no salvage value in the case of a capital works), the REAL return is approximately 11.05 %, virtually the same as the perpetuity figure.

Discounting future sums at 4 % for this Alternative 1 results in benefits balancing costs after 11 years and the NET PRESENT VALUE is a positive $ 3.7 million at year 50.

Alternative 2 yields a REAL return of 7.4 % in perpetuity, and 7.18 % at year 50. Again discounting future sums at 4 % results in a NET PRESENT VALUE of $3.4 million in 50 years time.

In this example, Alternative 1 yields the greatest return and continuously has a higher NET PRESENT VALUE over time and from these indicators, it would be a better investment than Alternative 2.

The information given about these alternatives may be complete in the sense that they may be "stand alone" choices or they may both be compared to a "do nothing" or a "do little" scenario in which cases the costs and the benefits would be incremental values. In any event, they both have a common base.

A further test would be to compare one to the other with Alternative 2 requiring an additional initial investment of $ 3.1 million and for that incremental additional capital, an incremental annual benefit of $130,000 would be received. The third set of lines on the graphs illustrates the results of that comparison with the NET PRESENT VALUE remaining negative and a REAL internal rate of return of 3.40 % at 50 years which compares with a 4.2 % REAL return in perpetuity.

Those results also indicate that Alternative 2 is not as good an investment as Alternative 1, however, that depends upon the decision maker's view about interest rates.

Had future sums been discounted at the rate of 3 %, the NET PRESENT VALUE of Alternative 2 would overtake that for Alternative 1 in the early 30's and at the end of the analysis period, in 2040, the NET PRESENT VALUE of Alternative 2 would be greater than for Alternative 1.

If the Minimum Attractive Rate of Return (MARR) is deemed to be 4 % (REAL rate), Alternative 1 is best. If working with a MARR of 3 % or less, Alternative 2 would be best from a financial analysis point of view, assuming that confidence in a 50 year analysis period exists.

This topic will be covered further after another example.

It will be noted that most of the figures for this second example (illustated on the following page) are the same as the first. The capital cost for Alternative 2 has been reduced to $ 4.5 compared with a $5.8 which was used previously. Correspondingly, the difference between the cost for these alternatives is less in this example.

Alternative 2 now costing only $1.8 million more than Alternative 1, compared to a difference of $ 3.1 million in the previous example, and with incremental benefits of Alternative 2 over 1 being the same at $130,000 annually obviously increases the attractiveness of Alternative 2.

Discounting at 4% the NET PRESENT VALUE for Alternative 2 overtakes that for Alternative 1 by the year 2011 and at the end of 50 years, has a positive value of $ 4.7 million, a million dollars greater than Alternative 1. Does that mean that Alternative 2 is better than 1 if there is confidence that this investment is good to at least the year 2011 ? Not necessarily.

The internal rate of return is higher for Alternative 1 throughout the entire analysis period leveling off at 11 % after 40 or 50 years. That compares to a REAL rate of return for Alternative 2 of 9.45 % at year 50 which would only rise an additional 0.1 % to 9.55 % in perpetuity.

Does that mean that Alternative 1 is better ? It does providing the difference in cost of $1.8 million can also be invested in something equivalent that will yield a REAL return of about 11 % within 40 or 50 years. Alternative 1 gains a return of $300,000 on $ 2.7 million and an equivalent investment of $1.8 million would yield $ 200,000 for a total of $ 500,000

ALTERNATIVE	CAPITAL COST IN 1990	SUBSEQUENT ANNUAL BENEFITS
1	$2.7 Million	$300,000
2	$4.5 Million	$430,000
2 Minus 1	$1.8 Million	$130,000

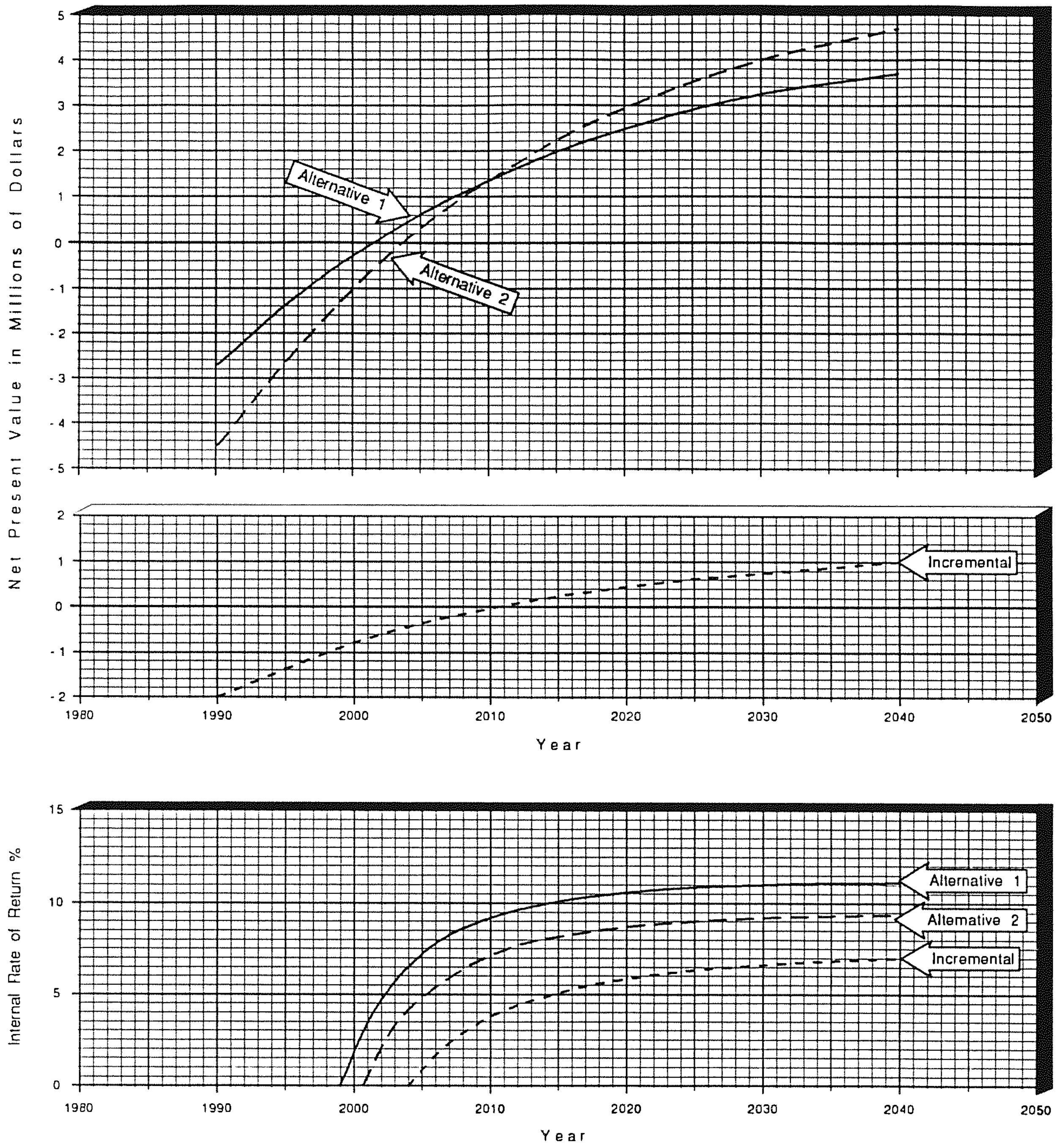

Figure 5 - 4 Results With Conflicting Messages - NPV results indicate that Alternative 2 is best for periods beyond the year 2010, whereas the Internal Rate of Return indicates that Alternative 1 is best.

on $ 4.5 million which is better than receiving $ 430,000 which Alternative 2 provides. In fact, if anything greater than $ 130,000 annually can be gained from that difference of $ 1.8 million in capital, the combination of that and Alternative 1 would be better than putting the entire $ 4.5 million in Alternative 2.

The third set of lines on the graphs illustrate that a 7 % REAL return would be received by year 50 on the incremental cost difference between these alternatives.

In the context of distributing budgets between competing projects this means, from a resource management point of view, that the more expensive Alternative here should be chosen over projects which would yield under 7 %. On the other hand, if all projects which are chosen on the basis of finances are returning over 7 %, then the cheaper alternative here should be chosen permitting the difference to yield a higher return through some other work.

To complete the circle of discussion on this subject, one could return to the "minimum" work example where resurfacing a highway would cost $ 500,000 and constructing a more efficient replacement would cost $ 1,000,000, and add one dimension. Assume that added maintenance and user costs would total $ 100,000 annually if it were neither resurfaced nor replaced. That indeed could be the reason why this highway would at least be surfaced. Now there are benefits to resurfacing being $ 100,000 annually and the return on the $ 500,000 cost would be 20 %.

New construction would still provide $ 50,000 of benefits annually, over resurfacing, due to being shorter, better alignment, etc., and would also save $ 100,000 annually just as resurfacing would. Total annual benefits of $ 150,000 resulting from an expenditure of $1,000,000 would yield a return of 15 %.

If resurfacing and new construction are treated as options, is it better to receive a 20 % return on $ 500,000 or a 15 % return on $ 1,000,000 ? As in the case of the other examples, the answer lies in what would be done with the difference of $ 500,000 if this highway is resurfaced. Comparing the two as options, the incremental additional cost of $ 500,000 for new construction will earn an incremental return of $ 50,000 and it is financially best if competing projects would yield a return less than 10 %.

5.2 Special Cases

In cases which involve no benefits or where undiscounted benefits or positive cash flows do not exceed undiscounted costs or negative cash flows, there is no return and the internal rate of return method cannot be used.

Further, some cases involve alternatives which have distinct and different life periods and for those it is common to express results in terms of Equivalent Uniform Annual Cost (EUAC).

The examples included in Appendix B (Interest Formulae and Examples) include this method of expressing results and a further example with few entries will help illustrate the concept as well as highlight problems with this method.

5.2.1 EUAC and Alternate Methods

The initial cost of a vehicle is $15,000.00 and maintenance costs will be $1000.00 in the first year and increase $1000.00 each year thereafter. Trade in value is based upon depreciation of 30 % per year on the undepreciated value of the previous year. The question is how frequently this class of vehicle should be "traded in" to minimize costs.

This example can be interpreted as one involving different lives and the EUAC method will be tested. The "end-of-year" convention (assuming year end concentration of annual and all costs) will be used and traditionally the EUAC include an amortization of the initial expenditure and current dollars will be used for all entries, based upon an inflation rate of 5.77 % [1].

Based upon the results of calculations, as shown in this table, the minimum EUAC occurs when trading

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[1] This specific rate is used to mathematically agree with an investment rate of 10% and a real interest rate of 4%.

TRADE FREQU.	CONSTANT DOLLARS	CURRENT DOLLARS 5.77 % INT.	PRESENT VALUE 10 % DISC.	TOTAL PRESENT VALUE	SUBTRACT $ 15,000 COST	AMORT. FACTOR FOR 10 %	E U A C
Yearly							
Maint.	- 1,000	- 1,058	- 962				
Trade	+ 10,500	+ 11,106	+ 10,096	+ 9,134	- 5,866	1.100000	6,453
2 Years							
Maint.	- 1,000	- 1,058	- 962				
	- 2,000	- 2,237	- 1,849				
Trade	+ 7,350	+ 8,223	+ 6,796	+ 3,985	- 11,015	0.576190	6,347
3 Years							
Maint.	- 1,000	- 1,058	- 962				
	- 2,000	- 2,237	- 1.849				
	- 3,000	- 3,550	- 2,667				
Trade	+ 5,145	+ 6,088	+ 4,574	- 904	- 15,904	0.402115	6,395
4 Years							
Maint.	- 1,000	- 1,058	- 962				
	- 2,000	- 2,237	- 1,849				
	- 3,000	- 3,550	- 2,667				
	- 4,000	- 5,006	- 3,419				
Trade	+ 3,602	+ 4,508	+ 3,079	- 5,818	- 20,818	0.315471	6,567

Table 5 - 1 Equivalent Uniform Annual Costs for equipment purchase example.

each two years and while that may be the best choice for the immediate future, it MAY NOT BE THE BEST CHOICE IN THE LONG RUN.

For the longer term, what happens after the first term must be considered. With inflation of 5.77 % per year, all costs will be 11.87 % higher in two years time and if the above table were repeated for years three and four, the two year EUAC would again turn out to the the lowest of the four, however, its amount would be $ 7100.00.

The borrowing concept is consistent with the EUAC procedure with the two year $ 6347.00 annual payments coupled with the proceeds from the disposal of the vehicle being just sufficient to pay off a loan of $15,000.00 and meet the maintenance costs.

The question is whether it is best to pay $ 6347.00 in each of the next two years and pay $ 7100.00 in each of the following two years or would it be better to pay, for example, $ 6567.00 in each of the next four years? Another possibility is to get on a three year cycle, paying $ 6395.00 in each of the first three years and $ 7567.00 in the fourth year, the first of the next three year cycle. Perhaps the table stopped short of reaching the best longer range solution, considering all of the possible options.

This kind of a problem can be further tested by using a longer period - as long a period for which there is confidence in the data and assumptions. A 12 year analysis period would accommodate all options if it is assumed or if it is policy that vehicles will not be kept longer than four years. All options having the same life would permit results to be expressed in terms of present worth.

Each option could then be simplified by neglecting inflation and combining, for each sequence, the last year's maintenance, trade in value and purchase of the new replacement.

That has been done in the table on the following page and those results show that a three year cycle is best in the long run and the four year cycle is a close second - more competitive than the two year cycle which the short period EUAC results favoured.

Different circumstances will require different solutions and the best general guidance which can be given is to use as long an analysis period as possible regardless of the method being used.

The procedures and assumptions made in

YEAR	EACH YEAR	TWO YEAR	THREE YEAR	FOUR YEAR
0	15,000	15,000	15,000	15,000
1	5,500	1,000	1,000	1,000
2	5,500	9,650	2,000	2,000
3	5,500	1,000	12,855	3,000
4	5,500	9,650	1,000	15,398
5	5,550	1,000	2,000	1,000
6	5,500	9,650	12,855	2,000
7	5,500	1,000	1,000	3,000
8	5,500	9,650	2,000	15,398
9	5,500	1,000	12,855	1,000
10	5,500	9,650	1,000	2,000
11	5,500	1,000	2,000	3,000
12	+ 9,500	+ 5,350	+ 2,145	398
Present Worth (Discounted @ 4%)	57,249	54,811	53,785	53,824

Table 5 - 2 Cash Flows and Present Values for a 12 year period

reconciling the results obtained from short period EUAC analysis with the longer term are matters for agreement between analysts and decision makers and good solutions may vary with the circumstances of the case.

5.3 Presentation of Results

While the graphs used for long term projects provide a pictorial summary of the results of the analysis, the following types of information and data should also be included to provide the reviewer with knowledge about the major inputs and some insight into the significance of the various factors:

1. Brief description of the project including, in the case of highway work, lengths, between common points, of each alternative tested.
2. The year to which all costs and benefits apply in the case of using "constant" dollars throughout. If "current" dollars are used, the base year should be specified and a description of how future dollars vary from that base year.
3. Capital costs of major components and year of expenditures.
4. Annual maintenance costs.
5. Value and percentage breakdown of components included in the benefits.
6. Notes describing any unusual input and explanation of how any of the components change in volume over time.

In the example data sheet on the next page, the above information is shown in the boxes at the top of the page and a test of the completeness of that data is whether it is sufficient to provide all of the input required for the arrays of figures included in the accompanying table.

The table should include, for each alternative tested, arrays of expenditures and benefits for each year over the entire analysis period and the figures, or at least the "base" or beginning figure in the case of a growth factor, should be directly traceable back to the information heading the page.

Other columns are required to provide the differences between alternatives, the accumulated present worths and internal rate of return values, these being arrays of figures calculated from data in the columns first described. Present worth and rate of return figures are required to plot the graphs.

PROJECT: HIGHWAY "X" BETWEEN A & B

BASE CASE (AGAINST WHICH ALL ALTERNATIVES ARE COMPARED) -
RESURFACE EXISTING HIGHWAY - 10.68 KM BETWEEN COMMON POINTS
ALT. P-1 - BETWEEN COMMON POINTS. CONSTRUCT 7.70 KM OF NEW ALIGNMENT
AND RETAIN 8.7 KM OF OLD HIGHWAY IN SYSTEM

NOTE: CONSTANT DOLLARS USED THROUGHOUT BASED UPON 1989 PRICES

Capital & Maintenance Costs

DESCRIPTION	PER KM	PROJECT	YEAR
ALTERNATIVE P-1			
GRADING	LUMP SUM	$1,850,000	
BASE & PAVE	$218,000	1,680,000	
OTHER COSTS		380,000	
TOTAL		3,910,000	= 1990
MAINTAIN OLD HWY.	3,000	26,000	
+ NEW (1ST 4 YRS.)	4,400	60,000	ANNUAL
SUBSEQUENTLY +	4,600	61,000	ANNUAL
FIRST RECAP	133,000	1,020,000	* 2010
SECOND RECAP	127,000	975,000	* 2025
BASE CASE			
RECAP EXISTING	131,000	1,400,000	* 1990
MAINT. (1ST 4 YRS.)	4,400	47,000	ANNUAL
SUBSEQUENTLY	4,600	49,000	ANNUAL
FIRST RECAP	124,500	1,330,000	* 2005
SECOND RECAP	120,000	1,280,000	* 2020
THIRD RECAP	115,000	1,230,000	* 2035

* DOES NOT INCLUDE YEAR'S MAINTENANCE COST

Road User Costs

Benefits of project would begin in 1991 with values:

DESCRIPTION	AMOUNT	%
Vehicle operation	$ 338,000	58
Collision costs	$ 41,000	7
Time savings	$ 199,000	35
	$ 578,000	100

Besides increasing with inflation, these factors will also increase in direct proportion with increases in traffic volumes which are predicted to be at a rate of 2% per year up to and including 1998 and at a rate of 1% per year thereafter

No.	Year	ANNUAL COSTS				NET ANNUAL UNDISCOUNTED VALUE			SUM OF P W 4% DIS		IRR "REAL"
		ALTERNATIVE P-7		ALTERNATIVE P-1		CAP COST	R U C	COST+R U C			(guess)
		CAP	R U C	CAP	R U C	DIFF	SAVINGS	VALUES	CAPITAL	TOTAL	25.00%
0	1988										
1	1989										ERR
2	1990	1,447		3,970		(2,523)		(2,523)	(2,333)	(2,333)	ERR
3	1991	47	1,874	60	1,296	(13)	578	565	(2,344)	(1,830)	-77.61%
4	1992	47	1,909	60	1,320	(13)	589	576	(2,355)	(1,338)	-39.74%
5	1993	47	1,943	60	1,344	(13)	599	586	(2,366)	(856)	-16.71%
6	1994	47	1,978	60	1,368	(13)	610	597	(2,376)	(384)	-3.18%
7	1995	49	2,013	61	1,392	(12)	621	609	(2,385)	78	5.17%
8	1996	49	2,048	61	1,416	(12)	632	620	(2,394)	531	10.58%
9	1997	49	2,082	61	1,440	(12)	642	630	(2,403)	974	14.19%
10	1998	49	2,103	61	1,454	(12)	649	637	(2,411)	1,404	16.70%
11	1999	49	2,124	61	1,469	(12)	655	643	(2,419)	1,821	18.48%
12	2000	49	2,145	61	1,483	(12)	661	649	(2,426)	2,227	19.78%
13	2001	49	2,165	61	1,498	(12)	668	656	(2,433)	2,621	20.74%
14	2002	49	2,186	61	1,512	(12)	674	662	(2,440)	3,004	21.48%
15	2003	49	2,207	61	1,526	(12)	681	669	(2,447)	3,375	22.00%
16	2004	49	2,228	61	1,541	(12)	687	675	(2,453)	3,735	22.42%
17	2005	1,377	2,249	61	1,555	1,316	694	2,010	(1,778)	4,787	23.33%
18	2006	47	2,270	61	1,570	(14)	700	686	(1,785)	5,106	23.56%
19	2007	47	2,290	61	1,584	(14)	706	692	(1,791)	5,434	23.74%
20	2008	47	2,311	61	1,598	(14)	713	699	(1,798)	5,753	23.88%
21	2009	47	2,332	61	1,613	(14)	719	705	(1,804)	6,063	23.99%
22	2010	49	2,353	1,080	1,627	(1,031)	726	(305)	(2,239)	5,934	23.95%
23	2011	49	2,374	60	1,642	(11)	732	721	(2,243)	6,229	24.03%
24	2012	49	2,395	60	1,656	(11)	739	728	(2,247)	6,510	24.08%
25	2013	49	2,415	60	1,670	(11)	745	734	(2,252)	6,786	24.13%
26	2014	49	2,436	60	1,685	(11)	751	740	(2,256)	7,053	24.17%
27	2015	49	2,457	61	1,699	(12)	758	746	(2,260)	7,311	24.20%
28	2016	49	2,478	61	1,714	(12)	764	752	(2,264)	7,562	24.22%
29	2017	49	2,499	61	1,728	(12)	771	759	(2,268)	7,805	24.24%
30	2018	49	2,519	61	1,742	(12)	777	765	(2,271)	8,041	24.26%
31	2019	49	2,540	61	1,757	(12)	783	771	(2,275)	8,270	24.27%
32	2020	1,327	2,561	61	1,771	1,266	790	2,056	(1,914)	8,856	24.30%
33	2021	47	2,582	61	1,786	(14)	796	782	(1,916)	9,070	24.31%
34	2022	47	2,603	61	1,800	(14)	803	789	(1,921)	9,278	24.31%
35	2023	47	2,624	61	1,814	(14)	809	795	(1,925)	9,480	24.32%
36	2024	47	2,644	61	1,829	(14)	816	802	(1,928)	9,675	24.32%
37	2025	49	2,665	1,035	1,843	(986)	822	(164)	(2,159)	9,637	24.32%
38	2026	49	2,686	60	1,858	(11)	828	817	(2,162)	9,821	24.33%
39	2027	49	2,707	60	1,872	(11)	835	824	(2,164)	9,999	24.33%
40	2028	49	2,728	60	1,886	(11)	841	830	(2,167)	10,172	24.33%
41	2029	49	2,749	60	1,901	(11)	848	837	(2,169)	10,340	24.33%

NOTE: THIS DATA IS NOT THE BASIS FOR THE GRAPHS DISCUSSED EARLIER

Table 5 - 3 Sample Data and Summary for a typical roadway project.

The flow of data and steps in the procedure are thus:

- Information from the data "blocks" goes into the table;
- That year by year data is used to calculate differences, accumulations, present worths and rate of return; and,
- The latter are used to plot yearly points on the graphs over the period of the analysis.

For a relatively simple analysis involving few alternatives, it should be possible to include all of the data on one page and show all of the plots on one graph sheet.

Obviously, if several alternatives are involved and comparisons between alternatives are necessary, more pages will be required and more graphs may also be necessary to separate and distinguish comparisons.

With a process having many applications and each application having different parameters and some requiring extensive input data, there will be circumstances for which the "normal" analysis procedure and ways of presenting results will have to be modified to provide information which will be meaningful and helpful.

Identical results can obviously be presented in a variety of ways and the purpose for outlining a format is to strive for uniformity in this phase of the study also. Those who must review reports prepared in different areas of the Department will appreciate the similarity and familiarity which a common method of illustrating results will provide.

While the analyst should either follow this format or obtain agreement about changes, the number of pages needed to present the results will vary. For even a relatively simple project, the print must be rather small to include input data and the arrays of costs and benefits for each of 50 years on one page. With changes in results being relatively small and uniform in the 30 to 50 year range, the trade-offs between using more pages and showing data and results in 5 year intervals for the last twenty years, as done in an example in the Summary, might b a subject for discussion between the analyst and the decision maker.

5.4 Checks and Balances

There are many opportunities for errors in procedure, methodology and calculations and the analyst, as well as those reviewing the work, should at least check those things which are easy.

The inherent relationship between the NET PRESENT WORTH being zero at the same point in time that the INTERNAL RATE OF RETURN is equal to the discount rate used in determining the present worth is easy to check. Similarly, it is easy to calculate the year or years for which the internal rate of return is zero. With relatively uniform future costs and benefits immediately following a lumpy capital outlay, the internal rate of return in 40 or 50 years will approach the rate of return calculated in perpetuity. The higher the return, the closer the figures will be.

As outlined in Section 5 (Short Cut Methods) of the Summary, an internal rate of return in the order of 10 % or higher for a project life of forty or more years will be very close to the return in perpetuity. The rate of return in perpetuity would be approximately one percent higher than the internal rate of return if that rate is approximately 5 % for a forty or fifty year period.

When comparing alternatives, the plots of the net present values crossing as in Figure 5 - 4 on page 41 (the NPV lines cross near the year 2010) means that the NPV are equal for that period of analysis and consequently a plot of the incremental values cross the zero line at that same point in time. The relationship between net present values and the internal rate of return, described earlier, apply to incremental values also and the IRR for the incremental value, for this example, should therefore be 4 % in the year 2010. Further the same checks, also described earlier, for determining when the IRR should become positive and its approximate value in 40 to 50 years apply to incremental values as well

Therefore, in many cases, there are readily available and easy ways of determining these points on the rate of return graph and knowing its typical shape, a good check on all yearly points on this graph is possible.

Other than that, the checking of results will usually involve working with data which only the analyst may have accumulated.

If a model is used to convert raw data into cash flows, the analyst has two reasons for running some manual checks on the figures being produced:

1. Working with the data will provide insight into the meaning of the results and will assist in providing comments to accompany the report and in preparing to answer questions; and

2. The verification of the correctness of some of the results coupled with making comparisons between the various values produced will uncover larger errors at least.

On the theme of the first point, one basic objective the Department holds for this whole procedure is that it should be as simple and understandable as possible and while the nature or some problems prevent a simple approach, the analyst , at least, should understand what is going on in the analysis.

For analysts unfamiliar with the procedure, it is not a bad idea to initially produce results both manually and with a model and then track down the discrepancies between the two. For a complex project, it is a good bet that there will be errors, likely in both procedures. The manual part of that suggestion is a lot of work but the effort will pay dividends to most in the form of developing a more disciplined approach to handling the data and keeping it straight. The Highway 88 and Speed Change examples are each rather complex projects and the analyst might work from the basic assumptions given for them and compare results with those included in this Guide. Such an exercise may uncover errors in these original works.

For roadway projects, a common source of error relates to the division of traffic and sorting and matching various conditions that apply to the different division or portions of the traffic divisions. The hypothetical Speed Change example includes two block type of diagrams which illustrate the ways in which the traffic must be divided for that project and an example based upon real conditions could be more complicated than that. The example assumes that grades are "flat" throughout for all alternatives with no excess costs for horizontal curvature and typically these features would be involved and would be different for the different alternatives. The Highway 88 project involves the complication of dealing with different grades but the division of traffic for other reasons is relatively simple in that example.

A manual solution is presented for both of those examples and as stated in the Speed Change description, it is easiest, from a calculation point of view to work in incremental values because the traffic which is faced with the same conditions in two alternatives, even for a portion of the route, can be ignored. although easier in that respect, that procedure does not permit a ready check upon the total volume of traffic used.

Using a model and running all traffic through all sections provides an easy check on total traffic and if the total used does not match the annual volume, some has either been missed or used more than once.

Manually working with the data provides more of an opportunity to gain a "feel" for what the magnitude of results in different areas should be and larger errors are likely to be caught but the number of calculations involved provide many opportunities for making mathematical mistakes. A model will provide correct answers, based upon the data it is fed but results are produced quickly and it is easy to keep plugging in new data and give little time to considering whether or not the results are within the realm of being correct.

For both procedures, tabulating results with a relatively fine breakdown into different vehicle classes and different result areas will permit a good check on most figures by comparing one to another. The relative traffic volumes can be the basis for the comparisons with knowledge about the influence of other factors used to judge how the relative values should deviate from being proportional to the traffic volumes. For example, if the volume of single axle trucks is 3 / 4 of the volume of semi-trailer units, the operation costs, for common sections of a roadway, for the single axle units should be a shade over 3 / 4 of the corresponding costs for the semi-trailer trucks. The unit cost for operation of the singles is slightly greater than for the semi-trailers.

The areas in the study containing the most data are the most likely source of errors but that does not mean that the more simple inputs will be immune. All aspects of the results should be scrutinized to spot quantities which do not appear correct. This scrutiny should carry into the checking of discounted values to be satisfied that the present values are believable considering the discount rate and the number of discounting periods involved.

If the present values or the internal rate of return figures are obviously wrong and cannot be explained by finding a mistake in input figures, the analytical process should be questioned. Although rare, some combinations of "lumpy" expenditures or benefits will produce two results for the internal rate of return.

Most references dealing with engineering economy will deal with this subject and, specifically, a book titled "Principles of Engineering Economy" by Eugene L. Grant and W. Grant Ireson published by the Ronald Press Company of New York provides some good solutions. In fact, this book may be helpful in solving most analytical problems encountered which are beyond the coverage of these guidelines and the related mathematical material in Appendix B.

6. Study Design

The User Manual contains a more complete check list of activities which may be involved in an analysis as it progresses through different stages.
The topics which will be discussed here will be confined essentially to those which deal with the viability of a study and its parameters.

6.1 To Study or Not to Study

Prior to embarking upon a Benefit-Cost Analysis, these two questions should be raised and answered:

Is an analysis necessary ?

Is an analysis possible ?

The logical order in which these questions might be addressed will usually be as presented, however, if determining the answer to one may be difficult and the other easy - the easy one might be answered first. For one reason or another, an analysis may not be possible and, if that is the case, there is little point of initiating effort to gain an answer to the first.

The usual need for an analysis is that its results will assist with making a decision about the merits of a program, the ranking of projects within a program, the viability of a project or activity, or the choice between alternatives, equipment, materials or activities. Conversely, an analysis will usually not be needed if all of the decisions about a subject have been made and will not be changed regardless of the results of an analysis. The need for an analysis may be as simple as the boss wanting one.

Whether an analysis can be done or not will usually relate to input items and the ability to value them or the resources available to prepare the information required for valuation. Most analysis will involve numerous input items, and with some items, at least, available, an analysis could be done - it will simply not be as comprehensive as it would be if all items could be included. The answer to the second question will, therefore, rarely be absolute - instead it will be a matter of degree. The results may be helpful even if there are large holes in the data that could be used if it were available. Items which would normally be included but are not included in a particular study should be highlighted and clearly documented along with the results so the users of the results will know that those items are not represented in the results.

In Section 2.1.1, different levels of economic studies were mentioned and if the subject to be studied will materially affect other areas of the economy, a benefit-cost analysis will not be an appropriate type of review and a broader based econometric model should be used instead.

Giving thought initially to data needs and other requirements for the study will pay dividends throughout the review in general scheduling and organization of the work and reduction in delays in receiving the necessary information.

6.2 Establishing Parameters

Setting good limits or establishing the appropriate scope for an analysis can make the difference between good and useful results, and, results which are virtually meaningless and useless.

For example, assume that the paving of a long access type of road is being considered and the benefits for different sections vary greatly. To include all sections in one analysis will mean that one set of results must represent all sections and the good will be somewhat averaged with the "not so good", and the results will not be indicative of how good the good is or how economically inefficient the paving of some of the low benefit sections would be.

6.2.1 Homogeneousness

That example of paving the access road is an example of the lack of homogeneousness, and while the paving of the high benefit sections might yield good returns, the paving of the low benefit sections may yield very poor returns.

An important consideration in establishing the limits or parameters of an analysis is the similarity of the factors which bear upon the results.

Again, there will be all degrees of similarity and where to separate, or whether to separate, will not always be obvious, nor will everyone agree upon the division of studies in cases where close choices are present. The example used where there is a varying degree of benefits is particularly difficult to deal with for it may seem unreasonable to undertake a separate study for each change in benefits and yet one study for all is not adequate either.

In such cases, the needs of the decision maker should be paramount in determining the division of projects. A first step may be to take a high sample and a low sample and the results of those two separate analyses may help in deciding what more might be done. The high and the low samples will, at least, establish outside limits and will indicate if all are viable, none are viable or viability ends somewhere in between.

The needs and views of the decision maker should also be determined regarding divisions based upon factors outside of the framework of the analysis. Just as the result of an analysis is not the decision, the decision about parameters may not depend solely upon the technicalities related to the project.

For example, the decision may be that only 10 km of a long route will not be paved - either at least half of it will be paved or none of it will be paved. If that is the way it is going to be, there is little point of breaking the project into 10 km sections. Divide it in two and study the half containing the greatest benefits. The results of that half, if positive, may lead to further questions about paving part or all of the remaining half.

While some of the problems in determining good limits can be imagined when writing or reading about the subject - the full extent of the complications will not be appreciated until in the midst of an analysis. The complications with undertaking a short cut approach to gaining results will also be complications in predetermining good limits for a project or program. How relevant some factors are will not be known until the data is collected and assessed and, consequently, what were thought to be homogeneous sections at the outset of the study may turn out to have large variations in an influential item.

Therefore, for complex projects the process of establishing good limits and parameters may extend beyond the initial planning and organization stage, and those set initially may have to be adjusted as the study progresses.

While that may be necessary and unavoidable in some cases, giving thought to the subject initially will, in the majority of cases, go a long way towards avoiding the need to make adjustments later.

6.2.2 Applicability and Diminishing Returns

While the coverage in the last section revolved around a single project where geographic cut-off points would be the parameters involved and benefits the variable, the principles involved have a broad application and different subjects will have different kinds of parameters and different variables.

A program to be assessed may have equivalent features. The program may involve a number of mutually exclusive projects or activities, and the question will be whether to study the program as a whole or to break it into any number of smaller more homogeneous parts wherein separate results for each part will provide better information about how the merits of the program vary within itself.

Programs like the supply of telephone service to all Albertans or the burying of all service lines in connection therewith, the similar supply of natural gas, or, the paving of all of one class of roadways in the Province might all include options for the setting of study parameters.

Technically and analytically, the case for separating programs such as that into smaller units for analysis purposes is strong and clear. Even if such an all encompassing program is initiated with the intention of being completely undertaken, the economic forces associated with diminishing returns are strong and the program will usually end up getting reviewed before it is actually completed. The time when good information should be most helful and beneficial is before the program is started - when decisions about it are being made and before significant costs are "sunk".

When alternatives are involved, setting parameters will not only apply to each of the alternatives but also to checking to ensure that all alternatives which have a chance of being viable are included. A side benefits of undertaking an analysis is that a more thorough review of the subject provides another opportunity to uncover omissions - omissions which may even be quite unrelated to the mechanics of the analysis. A final thought about possible additional alternatives might be an example of that.

In the example used initially in this section, the benefit side of the equation was chosen as the variable. That general subject of benefits contains numerous items, each of which may have a bearing upon decisions about homogeneousness. The cost side must also be considered for all other things may be relatively equal but the costs for one part of the whole may be quite different than the balance.

Using a roadway example again, capital costs for one section may be quite different than another due to foundation difficulties or a major river crossing being involved, as examples, and if the benefits for that section are about the same as for another which does not have those costly construction features, the economic merits of the two will vary significantly.

7. Short Cut Methods

This subject is given greater coverage in the Summary than it will be in this Guide.

Those reading this Guide will usually be familiar with the computer models described in the User Manual and will find little use for a manual method - accurate results can be generated easier with the computer programs than approximate results can be produced manually. Nonetheless, some of the "manual" procedures might be helpful in the checking of results produced by the models and, in that regard, the reader is referred to Section 5.2 in the Summary which deals with a perpetuity model.

Analytically producing results involves two basis tasks - developing cash flow data and then transforming that data into meaningful economic indications of efficiency.

For complex projects such as for a roadway, it is anticipated that the absence of adequate cash flow data will prevent an easy and quick approach to the analysis.

Some reading or skimming the Summary may read no further and for those, the message left is clear - for complex projects there is no simple and easy way to simulate the full blown version of an analysis. All of the necessary input data will not be available and the sensitivity of the results to different input factors varies with different circumstances of different cases to the degree that it is hazardous to make assumptions about relevancy. To make assumptions about the value of an item which may well dominate the outcome of an analysis may be no better nor worse than making assumptions about the results directly. Those reading this Guide and the User Manual, in preparation for undertaking an economic analysis, will have reached those same conclusions and will have already covered the underlying reasons.

On the other hand, if cash flow values are available for the subject at hand, their nature and timing will usually permit approximate results to be calculated manually in the form of a rate of return on a perpetuity basis which will be close to results based upon a relatively long analysis period such as 40 or 50 years.

8. Examples

8.1 General Descriptions

This section includes the documentation for the three examples developed or reviewed by the Guidelines Committee in 1988 and 1989 to illustrate concepts and procedures adopted by the Department and described in this Guide.

All three examples are based upon actual data with the Highway 88 Project involving input from many areas within the Department and extensive attention by several members of the Committee.

The Culvert and Guardrail examples were developed within specific Branches with the Committee members providing guidance to ensure consistency with methods adopted by the Department.

In addition to those three examples, the Speed Change example was developed in conjunction with the documentation for the Guide and User Manual and preparation of the Summary in 1991. While the Highway 88 Project illustrates many procedural features involved in a benefit - cost analysis for a roadway project, the nature of that project required only one running speed for each class of vehicle for each alternative and the Speed Change example illustrates the use of many different running speeds which will be necessary in some of the analysis which will be undertaken by the Department.

Project cost (and benefit) data for all four of these examples was handled manually and the step by step process followed is included in each. The objective of the Speed Change example is to illustrate ways and means of calculating road user costs for operation and time, when different speeds must be used for one reason or another, and that example does not include sufficient information (e.g. collision, capital and maintenance costs are not included) to produce economic indicators in the form of Net Present Values or Internal Rate of Return. However, the costs produced in that example could be used as input into the Benefit - Cost Module as described in the User Manual and that automated process was used for determining the NPV and IRR for the Highway 88, Culvert and Guardrail examples.

Categorized in another way, the Highway 88 Project and the Speed Change example are complex projects in the sense that large volumes of data are involved in each with numerous opportunities for going astray in the handling of the data or losing parts of it or using some of it twice. While, by comparison, the Culvert and Guardrail examples have relatively few inputs, they each have other important features to illustrate ways of handling mutually exclusive components of a roadway within the framework of a benefit - cost analysis as adopted by the Department. While these are all roadway related examples, the methods used would be appropriate for other types of work with which the Department is associated.

8.2 Example Features

Many of the features of each of these examples will be appreciated as they are reviewed and what will be outlined here are highlights as well as aspects of each which may not be obvious when wading through the details.

Guarding against errors should be kept in the forefront, particularly in complex projects where the opportunity to make mistakes are so numerous. The Highway 88 example includes quite extensive checks on the calculations and the Speed Change example includes some discussion about how results may vary with different treatment of input data.

Using the Highway 88 project as an example in the User Manual uncovered a procedural error in the manual version which illustrates that such errors will not be caught, in the checking of details, if the same faulty procedure is followed in the checking process.

8.2.1 Highway 88 Example

While not included in the project description, the Guidelines Committee originally considered reviewing the entire section of this highway, which was then a gravel standard (Slave Lake to Ft. Vermilion), but decided that variations in traffic volume for that entire length was too great to include all of it in one project. Deciding to shorten the length to include in one analysis is an example of establishing appropriate parameters as outlined in Section 6.2.

Being done manually, it was easiest to work with incremental values for some of the items and consequently total road user costs for neither the Base Case (retain the gravel standard) nor the Alternative (paving) were produced. It will be noted that the Road User Cost (RUC) columns in the summary data sheet are not needed in this case when done in this manner.

This project has now also been included in the User Manual as an example for the model developed by the Department to handle roadway projects. The model works with total costs from which incremental values are determined and all columns in the summary data sheet are then used.

Variances in results, for the road user costs, between the two methods (manual and model) are discussed in the User Manual and the main points repeated here.

When done manually in 1989, the operation unit costs were read from graphs and the discrepancies in the results for these costs are contributed to inaccuracies in the reading of the graphs.

The calculations for time costs as included here contain a procedural error - the occupants of trucks (average of 1.2 per vehicle) were all given a rate per hour corresponding to the hourly rate for drivers ($23.00 per hour) whereas it should be assumed that there is one driver per vehicle and the balance of the time should be calculated on the basis of the lower working rate ($12.00 per hour).

Collision costs are essentially the same - they should be by the manner in which they were determined. Collision cost data was supplied in 1989 as lump sum figures for each roadway section, however, to illustrate the working of the model, collision rates were calculated to give the same "lump sum" figures, using 1990 societal and property damage unit costs.

Numerous checks were made to test the accuracy of results being produced manually. Similar kinds of manual checks could and should be made even when the calculations are done in a more automated manner. The likely source of errors in an automated procedure may be different than when being done manually, nonetheless the likelihood of error is still high and a few manual calculations and a thorough comparison of results from different areas will go a long way towards eliminating larger errors at least. Moreover, the analyst will have to work a bit with the data to be able to answer questions about where the result figures originate and why the values fall out as they do.

8.2.2 Culvert Example

This example is titled "Life Cycle for Culverts" and compares the economic merits of different treatments for a relatively large culvert installation.

This example is interesting in an analysis sense because it involves very few entries over a long period of time and while the results, in graphical form, take on quite a different appearance than most long term projects, the standardized analysis procedure and method of providing and displaying results can be applied. With the absence of entries after 25 years the NPV and IRR values remain constant for the period 25 years to 50 years and both of these indicators are positive for that period whereas both are negative for the period up to 25 years.

Further, three alternatives are involved (four, including the Base Case) and the NPV and IRR indicators for two of the alternatives are at odds with each other and the incremental values between those two alternatives is assessed.

8.2.3 Guardrail Example

As the more descriptive title given to this example (Guardrail vs Sideslope Improvement) indicates, this project compares the economic advantage of flatening sideslopes instead of installing guardrail. This, as the culvert example, is an analysis of one specific feature of a highway or roadway design which can be treated quite independently of the balance of the components which make up the whole.

With cost differences (benefits) continuing throughout the period of analysis, the results for this project follow the more typical form for long range projects with Net Present Values increasing over time and Internal Rate of Return values leveling off towards the latter part of the project's assumed life.

While the number of input values are relatively few, those that are required for this analysis are not easy to determine and this example illustrates the resourcefulness and knowledge which the analyst, or others supplying input data, must sometimes have about the subject at hand in order to determine values which will produce meaningful results.

Further, as indicated at the end of this example, more work on this subject remains to be done, and such a conclusion is common in the real world where things are complicated and rarely will the analyst feel that the best possible results have been produced. There will usually be room for improvement and refinement in the determination of values or the processing of them.

8.2.4 Speed Change Example

Like the "Highway 88 Project" this example involves working with numerous factors and divisions of traffic and again being done manually, incremental values are used for most of the items.

Being a hypothetical example, little significance should be given to the relative values of results from the different areas except in a very general way (the same might be said about results produced from actual data). Nonetheless, the assumptions should be sufficiently close to reality to permit these general observations to be made and to be expected from an analysis of this nature. Results running counter to these themes or deviating greatly from the proportions given may not be wrong but should be treated as suspect and specifically checked.

- As operating speeds are held down or forced down within the range of 50 to 110 km / hr., operation costs can be expected to decrease and time costs will increase with the difference for time being greater than the difference in operating costs.
- Of all the factors related to speed change as used in this example, the difference of the differences (time costs minus operating costs) as outline above is by far the most significant factor affecting these aspects of road user costs.
- The other items of cost included in this example includes:
  Excess operating costs for slowing down and returning to original speed;
  Time costs for time stopped at a signal; and
  Time costs for the difference in time involved in semi - trailer trucks (this classification only) during acceleration compared to covering the same distance when moving at a uniform speed (the speed they accelerate to).

  While each of these other three items are significant, to the extent that they should not be ignored, collectively they contribute less than 1 / 3 to the final result in this particular example.
- While all proportions for each case will be different, the cost for time stopped at signals could vary greatly from this example. Only one signal is assumed with an average of 1 / 2 minute stop for 15 % of the traffic. With several signals and more traffic on the urban streets (higher percentage of highway traffic would be affected), the influence of this item could increase several fold.

Various methods for specifying the influence of heavier traffic volumes upon running speeds might be used and the basis used in this example has its problems and omissions, and that subject receives some discussion at the end of the coverage for that example. Traffic and the interplay between all of the factors which affect its operation is an extremely complex subject and when the Department settles upon a procedure that can be applied in the majority of cases,with which it deals, additions can be made to the model to incorporate the kinds of factors used in this example.

8.3 Highway 88 Project

"ROADWAY" PROJECT DEVELOPED BY THE GUIDELINES COMMITTEE - 1988

PROJECT - Test the economic merits of paving the remaining gravel portion of Hwy. 88 between Slave Lake and Loon Lake (Peerless Lake Turn-off)

Adjustments - Traffic volumes and other directly related items will be increased at the rate of 3% per year to 1995 and 1% per year thereafter. Prices and costs will be adjusted upwards from 1987 to 1988 by a factor of 1.07 (7%) and from 1988 to 1989 by 1.06 (6%). These adjustments may be made in any order and all at once or in increments. With "operating cost" graphs being based upon 1988 dollars, all inputs will initially be adjusted to 1988 volumes and dollars, and in later steps adjusted to 1989 dollars and, where necessary, to 1991 volumes.

INPUTS AND ASSUMPTIONS

SOURCE OF INFORMATION	DESCRIPTION	VOLUME ADJ.	PRICE ADJ.	1988 VALUES
	LENGTHS (Gravel portion)			
Const. Prog.	C.S. 88:04 - 29.78 km			29.78 km
	88:06 - 26.09 km			26.09 km
	88:08 - 29.67 km			29.67 km
	TOTAL 85.54 km			85.54 km
	CAPITAL COSTS (ALL IN 1988 DOLLARS)			
Const. Prog.	Grading - $1.8 M (Total Project Cost) - Assume Const. in 1989 -			$ 1.8 M
Materials	Base - $ 123,889/km - Assume Const. in 1990			$ 123,889 / km
"	Paving - $ 62,746/km - Assume Const. in 1993			$ 62,746 / km
"	1st Recap - $ 65,692/km - Assume 17 yrs. after paving (2010)			$ 65,692 / km
"	2nd Recap - $ 61,454/km - Assume 15 yrs. after 1st (2025)			$ 61,454 / km
	Maintenance Costs (All in 1988 Dollars)			
Operations Br.	Gravel - $ 6,500/km/yr.			$ 6,500 / km / yr.
	+ 6,000/km/ - Additional cost (Total $ 12,500) each 3 yrs.			12,500 / km /3 yrs.
	+10,000/km/12 yrs. - Additional cost (Total - $22,500) each 12 yrs.			22,500 / km /12 yrs.
	Pavement - 4,400 / km / yr. for 5 years following paving or overlays			
	4,600 / km / yr. after pavement or overlays 5 yrs. old			
	Traffic Volumes & Classification - 1985 Volumes - AADT			
Traffic Eng.	C.S. 88:04 - 580 AADT - PV (66%) - 382.8	1.03^3		418.30
	- SU (18%) - 104.4	"		114.08
	- TRTL (16%) - 92.8	"		101.41
	C.S. 88:06 - 500 AADT - PV (72%) - 360	"		393.38
	& C.S. 88:08 - SU (17%) - 85	"		92.88
	- TRTL (11%) - 55	"		60.10

	GRADES	% OF LENGTH					
		1%	2%	3%	4%	5%	6%
Roadway Pl.	C.S. 88:04	83	11	5			1
	88:06	58	24	15	3		
	88:08	79	19	2			

INPUTS AND ASSUMPTIONS (continued)

SOURCE OF INFORMATION		DESCRIPTION	VOLUME ADJ.	PRICE ADJ.	1988 VALUES
		TRIP PURPOSE & OCCUPANCY RATES			
K.E.H.		Passenger Vehicles - 80 % Pleasure Trips - 1.8 people / veh.			
		- 20 % Business Trips - 1.2 " "			
		All Trucks - 1.2 drivers / vehicle			
K.E.H.	(1)	VALUES FOR TIME - 1988 Dollars			
		Truck Drivers - $23.00 / Person / Hr,			
		Business People - 12.00 / Person / Hr,			
		All Others - 5.00 / Person / Hr,			
		COLLISION COSTS (Reduction after paving) 1987 Dollars, 1985 Traffic			
Motor Transport Services		C.S. 88:04 - $272,000 / yr. Based upon 56.72 km Length			
		= 272,000 / yr. x $\frac{29.78}{56.72}$ = $ 142,810 / yr.	1.03^3	1.07	$ 166,976 / yr.
		C.S. 88:06 - 125,000 / yr.	"	"	146,152 / yr
		C.S. 88:08 - 161,000 / yr.	"	"	188,244 / yr
		TOTAL			$ 501,372 / yr

NOTE: (1) Approved Values for Time Include:
Truck Drivers - $22.00 / hr.
Business People - 12.00 / hr.
All Other - 5.50 / hr. All in **1987 dollars**

ARRAYS OF COSTS & FINAL ADJUSTMENTS

Description	Cost / km 1988 $'s	x 1.06 = 1989 $'s	x 85.54K = Project Cost (1000's)	Total Cost For Year (1000's)	Year
Least Cost (Alt. 1) (Leave as Gravel)					
Maintenance	6,500	6,890	589		1989
	6,500	6,890	589		1990
	12,500	13,250	1133		1991
	6,500	6890	589		1992
	6,500	6890	589		1993
	12,500	13,250	1133		1994
	6,500	6890	589		1995
	6,500	6,890	589		1996
	12,500	13,250	1133		1997
	6,500	6890	589		1998
	6,500	6890	589		1999
	22,500	23,850	2040		2000

CYCLE REPEATS EACH 12 YEARS

ARRAYS OF COSTS & FINAL ADJUSTMENTS (continued)

Description	Cost / km 1988 $'s	x 1.06 = 1989 $'s	x 85.54K = Project Cost (1000's)	Total Cost For Year (1000's)	Year
PAVING (Alternative 2)					
Grading	1,800,000	1,908,000	1,908		
Maintenance same as above			589	2,497	1989
Base	123,889	131,322	11,273		
Maint			589	11,822	1990
Maint.	4,400	4,664	399	399	1991
Maint.	4,400	4,664	399	399	1992
Paving	62,746	66,510	5,689		
Maint.			399	6,088	1993
Maint.				399	1994
↓					
Maint.				399	1998
Maint.	4,600	4,876	417	417	1999
↓					
Maint.				417	2009
1st Overlay	65,692	69,634	5,956		
Maint.			417	6,373	2010
Maint.				399	2011
↓					
Maint.				399	2015
Maint.				417	2016
↓					
Maint.				417	2024
2nd Overlay	61,454	65,141	5,572		
Maint.			417	5,989	2025
Maint.				399	2026
↓					
Maint.				399	2030
Maint.				417	2031
↓					
Maint.				417	2038

ROAD USER COSTS (Benefit from Paving - (Alt. 1 - Alt. 2), All in 1000's

DESCRIPTION	1988 Values	x 1.06 = 1989 $'s	x 1.03^3 = 1991 Volumes	
Vehicle Operation	628.962	666.700	728	(in 1991)
Collision Costs	501.372	531.454	581	(in 1991)
Time Costs	489.023	518.364	566	(in 1991)
Totals	1,619.357	1,716.518	$1,875	(in 1991)

All of these costs (benefits for paving) increase in direct proportion with traffic increases - e.g. 3 % growth per year to 1995 and 1 % / yr. thereafter. e.g. $2,110 in 1995, $2,131 in 1996 and $3,237 in 2038.

TIME SAVINGS

PASSENGER VEHICLES

Total Veh. - km per year (1988) - 12,553,010

Assumed 80 % Pleasure = 10,042,408 x 1.8 / veh. = 18,076,334

Assumed 20 % Business = 2,510,602 x 1.2 / veh. = 3,012,722

PLEASURE

People time travelling @ 85 km / hr. = $\frac{18,076,334}{85}$ = 212,663 hrs.

@ 100 km / hr. = $\frac{18,076,334}{100}$ = 180,763 hrs.

Time Saving 31,900 hrs.

@ 5.00 / hr. = $ 159,500 / yr. (1988)

BUSINESS

People time travelling @ 85 km / hr. = $\frac{3,012,722}{85}$ = 35,444 hrs.

@ 100 km / hr. = $\frac{3,012,722}{100}$ = 30,127 hrs.

Time Saving 5,317 hrs.

@ 12.00 / hr. = $ 63,804 / yr.

TRUCKS (ALL CLASSES)

Total Veh. km = 3,130,340

\+ 2,325,480

5,455,820 x 1.2 / veh. = 6,546,984 driver kms /yr.[1]

Drivers time @ 85 km / hr. = $\frac{6,546,984}{85}$ = 77,023 man hours /yr.

@ 100 km / hr. = $\frac{6,546,984}{100}$ = 65,470 man hours /yr.

NOTE: Error in this procedure is described in the footnote.

TIME SAVING 11,553 hrs. /yr.

@ $23.00 / hr. = $265,719 /yr.[1]

TOTAL (ALL CATEGORIES)

159,500 - Passenger Pleasure

63,804 - Passenger Business

265,719 - Truck

TOTAL $ 489,023 (1988)

Rough Check

Time to travel 1 km @ 85 km / hr. = 0.011765 hrs.

@ 100 km / hr. = 0.010000 hrs.

Diff 0.001765 hrs.

Cost / PV = 0.8 x 1.8 x 5.00 = 7.20

0.2 x 1.2 x 12.00 = 2.88

TOTAL 10.08

P.V. = 12,553,010 x 0.001765 x 10.08 = 223,333

Trucks = 5,455,820 x 0.001765 x 23.00 x 1.2 = 265,775

TOTAL $ 489,108 (checks)

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[1] This figure should be broken into two categories - driver kms/yr (5,455,823) and helper kms/yr (1,091,164). The helper's time should then be valued at $12.00 per hour and the final figure would be $244,538/yr instead of $265,719/yr.

OPERATING COSTS & SAVINGS

0 grade cost

PASSENGER VEHICLES

C.S.	Length (km)	AADT	Veh-km Year (1000)	Breakdown For Grades (1000's) 1 %	2 %	3 %	4 %	6 %	Diff.in Unit Costs	Cost Savings
				(83%)	(11%)	(5%)		(1%)		
:04	29.78	418.30	4546.80	3773.84	500.15	227.34		45.47		
				(58)	(24)	(15)	(3)			
:06	26.09	393.38	3746.09	2172.74	899.06	561.91	112.38			
				(79)	(19)	(2)				
:08	29.67	393.38	4260.12	3365.50	809.42	85.20				
	TOTALS		12553.01							
		1 % →		9312.08					20	186,242
		2 % →			2208.63				21	46,381
		3 % →				874.45			21	18,363
		4 % →					112.38		19	2,135
		6 % →						45.47	32	1,455
					Total					254,576

SU VEHICLES - USE PV PERCENTAGES (above in brackets)

:04	29.78	114.08	1240.01	1029.21	136.40	62.00		12.40		
:06	26.09	92.88	884.48	513.00	212.28	132.67	26.53			
:08	29.67	92.88	1005.85	794.62	191.11	20.12				
	TOTALS		3130.34							
		1 % →		2336.83					64	149,557
		2 % →			539.79				57	30,768
		3 % →				214.79			76	16,324
		4 % →					26.53		88	2,335
		6 % →						12.40	109	1,352
					Total					200,336

TRTL VEHICLES - Use PV Percentages

:04	29.78	161.41	1102.29	914.91	121.25	55.11		11.02		
:06	26.09	60.10	572.33	331.95	137.36	85.85	17.17			
:08	29.67	60.10	650.86	514.18	123.66	13.02				
	TOTALS		2325.48							
		1 % →		1761.04					75	132,078
		2 % →			382.27				66	25,230
		3 % →				153.98			87	13,396
		4 % →					17.17		105	1,803
		6 % →						11.02	140	1,543
					Total					174,050

TOTALS (all classes)	18,008.83 Veh. km (x 1000)	$ 628,962

CHECKS

Total Traffic Volumes
580 x 29.78 x 365 x $(1.03)^3$ = 6,889.02
500 x 26.09 x 365 x "
+ 500 x 29.67 x 365 x " = 11,119.81
Totals = 18,008.83
- checks

Rough check on Annual Costs
12,553 x 21 = 263,613
+ 3,130 x 64 = 200,320
+ 2,325 x 75 = 174,375
638,---	compares with 628,962
- close

DIFFERENCES IN UNIT COSTS (Gravel minus Pavement - 1988 $s per 1000 veh. km)

Note: Input data in these tables has been interpreted from graphs of running costs.

Grades	0 %	1 %	2 %	3 %	4 %	5 %	6 %	7 %
PASSENGER VEHICLES								
Gravel (85 km / hr)								
↑		128	135	143	152	163	174	191
↓		118	114	110	102	102	110	118
Ave.	122	123	125	127	127	132	142	155
Pavement (100 km/hr)								
↑		106	111	118	126	135	145	157
↓		99	96	93	89	80	76	79
Ave.	102	103	104	106	108	108	110	118
Difference in Costs (Average Gravel - Average Pavement)	**20**	**20**	**21**	**21**	**19**	**24**	**32**	**37**
S U VEHICLES								
Gravel (85 km / hr)								
↑		456	530	596	650	708	764	822
↓		290	218	212	238	264	300	340
Ave	362	373	374	404	444	486	532	581
Pavement (100 km / hr)								
↑		388	442	490	530	576	622	664
↓		230	192	166	182	202	225	252
Ave,	304	309	317	328	356	389	423	458
Difference in Costs (Average Gravel - Average Pavement)	**58**	**64**	**57**	**76**	**88**	**97**	**109**	**123**
TRTL VEHICLES								
Gravel (85 km / hr)								
↑		446	560	650	730	810	900	990
↓		230	98	130	174	224	284	354
Ave.	364	338	329	390	452	512	592	672
Pavement (100 km / hr.)								
↑		350	450	522	582	644	718	800
↓		176	76	84	112	145	186	232
Ave.	292	263	263	303	347	394	452	516
Difference in Costs (Average Gravel - Average Pavement)	**72**	**75**	**66**	**87**	**105**	**118**	**140**	**156**

CHECKS ON COMPUTER PRINTOUT

ROAD USER COSTS

3% growth to 1995 - 1991 value x 1.03^4 = 1875 x 1.255 = 2110.3...O K

1% growth thereafter - 1996 value = 1995 value x 1.01 = 2110.3 x 1.01 = 2131.4...O K

2039 value = 1995 value x 1.01^{44} = 2110.3 x 1.5493 = 3269.5...O K

PRESENT WORTHS - CAPITAL & MAINTENANCE

Convert maintenance costs to averages per year

$$\text{Gravel} = \frac{2040 + 3 \times 1133 + 8 \times 589}{12} = \text{average } \$\,846\,/\,\text{yr.}$$

Pavement = (5 x 399 + 12 x 417) ÷ 17 = average 412 / yr.

DIFFERENCE = average 434 / yr.

		Accum.
Present Worth (1989) of Capital Expenditures Discounted @ 4%		
1989 - 1,908 = 1,908		1,908
1990 - 11,233 ÷ 1.04 = 10,801		12,709
1993 - 5,689 ÷ $(1.04)^4$ (or mult. by 0.854804 from tables)	= 4,863	17,572
2010 - 5,956 ÷ $(1.04)^{21}$ (or mult. by 0.438834 from tables)	= 2,614	20,186
2025 - 5,572 ÷ $(1.04)^{36}$ (or mult. by 0.243669 from tables)	= 1,358	21,544
Less savings in maint. between years 1991 & 2039 incl.		
= SPW (50 yrs. - 1 yr.) x 434 = (21.482185 - 0.961538) x 434	= (8,906)	12,638

12,638 compares to actual 12,594 (checks)

PRESENT WORTH - ROAD USER COSTS

3% growth period - use principle - Discount Factor = i (1 + growth factor) + growth factor

for 4% discount & 3% growth $i = \frac{4\text{-}3}{1.03} = 0.9708737\ \% = 0.009708737$

\$1875 cost begins in 1991 (yr. 2) - to use growth (SPW) tables must get 1989 value
= 1875 ÷ 1.03^2 = 1767.3672

Present Value - 1991 to 1995

$$= 1767.3672 \; \frac{(1+i)^6 - 1}{i\,(1+i)^6} - \frac{(1+i) - 1}{i(1+i)} = 1767.3672\,(5.8014886 - 0.9903797) = \quad 8.503$$

1% growth period - $i = \frac{4 - 1}{1.01} = 2.970297\ \% = 0.02970297$

1989 value of 2131 in 1996 = 2131 ÷ $(1.01)^7$ = 1987.62

Present Value - 1996 to 2039

$$= 1987.62\left(\frac{(1.02970297)^{50} - 1}{0.02970297 \times 1.02970297)^{50}} - \frac{(1.0297)^6 - 1}{0.24703 \times (1.0297)^6}\right)$$

= 1987.62 (25.87548 - 5.42252) = 40,653

Accumulated Present Value (Road User) \$ 49,156

From printout 12,594 (Alt. 2 - Alt. 1 Disc.) - (36,570) (Net Discounted Valued) = 49,164 (checks)

CHECKS ON COMPUTER PRINTOUT (continued)

INTERNAL RATE OF RETURN

Two values for the IRR are relatively simple to check - where it is 0 and 4 %

IRR = 0 When undiscounted (0% interest rate) costs = undiscounted benefits.
IRR changes from negative (-2.70 %) in 1997 to positive (1.03 %) in 1998

Net accumulative figures for 1997

Costs (Alt. 2 column) = $\sum \overset{(1989)}{2497} \rightarrow \overset{(1997)}{399}$ = 22,801

Benefits = (Alt. 1)$\sum \overset{(1989)}{589} \rightarrow \overset{(1997)}{1133}$ + $\overset{\text{Road User (1991 to 97)}}{\text{Column 1975 - 2153}}$ = 21,171 (Costs Greater by 1630)

By 1998 - Costs = 22,801 + 399 = 23,200 (Benefits Greater by 734)
Benefits = 21,171 + 589 + 2174 = 23,934

∴ IRR = 0 between years 1997 and 1998 (checks)

IRR = 4%
Net Discounted Values change from negative (2,323) to positive (172) between years 1999 & 2000 and IRR for 1999 is 3.75 % and for 2000 is 6.84 % - looks good.

OTHER CHECKS - difficult - one accurate way is simply to pick an IRR value and equate costs & benefits - same calculations as done above for 4%.

Test for year 2039 - IRR = 14.52 %
Present Worth of Capital Outlays = 1908 + 9809 + 3308 + 345 + 42 = 15,412
Present Worth of Averaged Maint. = SPW (14.52% - 50 yrs. - 1 yr.) x 434
= 2986 - 379 = 2,607
Road User (3% Portion) = SPW (11.1845% - 6 - 1) x 1767.367
= 7437 - 1590 = 5,847
Road User (1% Portion) = SPW (13.3861% - 50 -6) x 1987.62
= 1487.62 = 14821 - 7861 = 6,960
TOTAL BENEFITS 15,414

15,414 very close to 15,412, especially considering that average maintenance costs were used.

Project: Highway 88 - Slave Lake to Loon Lake (85.54 km)

Base Case: Continue to maintain a gravel standard highway
Alternative: Regrade, base and surface the highway
NOTE: Constant dollars used throughout based upon 1989 prices

Capital & Maintenance Costs

Description	Per Km	Project	Year
Alternative		(1,000s)	
Grading	Lump Sum	1,908	1989
Base.	Lump Sum	11,233	1990
Paving	Lump Sum	5,689	1993
First Recap	Lump Sum	5,956	2010
Second Recap	Lump Sum	5,572	2025
Maintenance			
Base Case			
Annually	6,890		
Each 3 Years	13,250	- First in	1991
Each 12 Years	23,850	- First in	2000
Alternative			
First 5 years	4,664 following each surfacing		
Subsequently	4,876		

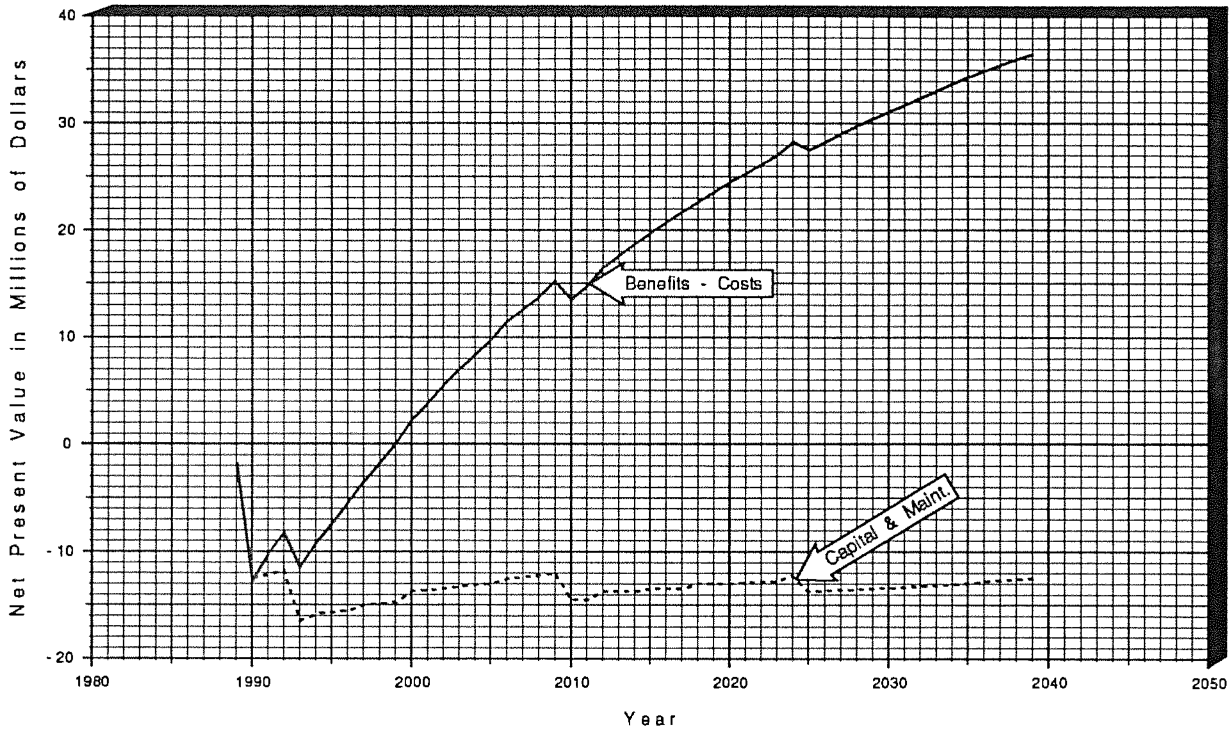
Road User Costs

Benefits of project would begin in 1991 with values:

DESCRIPTION	AMOUNT	%
Vehicle operation	$ 728,000	39
Collision costs	581,000	31
Time savings	566,000	30
Total	$ 1,875,000	100

Besides increasing with inflation, these factors will also increase in direct proportion with increases in traffic volumes which are predicted to be at a rate of 3 % per year up to and including 1995 and at the rate of 1 % per year thereafter.

		Annual Costs				Net Annual Undiscounted Value			Sum pf P V (4 % Disc>)		
		Base Case		Alternative		Cap. Cost	R U C	RUC + Cost			I R R
No.	Year	Cap.	RUC	Cap.	RUC	Diff	Savings	Values	Capital	Total	(Real)
0	1989	589		2,497		- 1,908	-	- 1,908	- 1,908	- 1,908	
1	1990	589		11,822		- 11,233	-	- 11,233	- 12,709	- 12,709	
2	1991	1.133		399		734	1,875	2,609	- 12,030	-10,296	
3	1992	589		399		190	1,931	2,121	- 11,861	- 8,410	
4	1993	589		6,088		- 5,499	1,989	- 3,510	- 16,562	-11,410	
5	1994	1.133		399		734	2,049	2,783	- 15,959	- 9,123	
6	1995	589		399		190	2,110	2,300	- 15,809	- 7,306	- 18.78
7	1996	589		399		190	2,131	2.321	- 15,664	- 5,542	- 9.59
8	1997	1.133		399		734	2,153	2,387	- 15,128	- 3,433	- 2.70
9	1998	589		399		190	2,174	2,364	- 14,994	- 1,772	1.03
10	1999	589		417		172	2,196	2,368	- 14,878	- 172	3.75
11	2000	2,040		417		1623	2,218	3,841	- 13,824	2,323	6.84
12	2001	589		417		172	2,240	2,412	- 13,716	3,830	8.24
13	2002	589		417		172	2,263	2,435	- 13,613	5,292	9.35
14	2003	1.133		417		716	2,285	3,001	- 13,200	7,025	10.42
15	2004	589		417		172	2,308	2,480	- 13,104	8,402	11.11
16	2005	589		417		172	2,331	2,503	- 13,012	9,738	11.68
17	2006	1.133		417		716	2,354	3,070	- 12,645	11,314	12.25
18	2007	589		417		172	2,378	2,550	- 12,560	12,573	12.63
19	2008	589		417		172	2,402	2,574	- 12,478	13,705	12.94
20	2009	1.133		417		716	2,426	3,142	- 12,151	15,229	13.26
21	2010	589		6,373		- 5,784	2,450	- 3,334	- 14,690	13,766	12.96
22	2011	589		399		190	2,475	2,665	- 14,609	14,891	13.17
23	2012	2,040		399		1641	2,499	4,140	- 13,944	16,571	13.45
24	2013	589		399		190	2,524	2,714	- 13,870	17,630	13.60
25	2014	589		399		190	2,550	2,740	- 13,798	18,658	13.72
26	2015	1.133		399		734	2,575	3,309	- 13,534	19,851	13.85
27	2016	589		417		172	2,601	2,773	- 13,474	20,813	13.94
28	2017	589		417		172	2,627	2,799	- 13,417	21,.746	14.02
29	2018	1.133		417		716	2.653	3.369	- 13,187	22,826	14.10
30	2019	589		417		172	2,680	2,852	- 13,134	23,706	14.16
31	2020	589		417		172	2,706	2,878	- 13,083	24,558	14.21
32	2021	1,133		417		716	2,733	3,449	- 12,879	25,541	14.27
33	2022	589		417		172	2,761	2,933	- 12,832	26,345	14.30
34	2023	589		417		172	2,788	2,960	- 12,786	27,125	14.34
35	2024	2,040		417		1,623	2,816	4,439`	- 12,375	28,250	14.38
36	2025	589		5,989		- 5,400	2,844	- 2,556	- 13,691	27,627	14.36
37	2026	589		399		190	2,873	3,063	- 13,646	28,345	14.38
38	2027	1.133		399		734	2.902	3,636	- 13,481	29,164	14.40
39	2028	589		399		190	2.931	3,121	- 13,440	29,840	14.42
40	2029	589		399		190	2,960	3,150	- 13,400	30,496	14.44
41	2030	1.133		399		734	2,989	3,723	- 13,253	31,242	14.45
42	2031	589		417		172	3,019	3,191	- 13,220	31,857	14.46
43	2032	589		417		172	3,050	3,222	- 13,188	32,453	14.47
44	2033	1.133		417		716	3.080	3,796	- 13,061	33,129	14.49
45	2034	589		417		172	3,111	3,283	- 13,031	33,691	14.49
46	2035	589		417		172	3,142	3,314	- 13,003	34,237	14.50
47	2036	2,040		417		1,623	3,173	4,796	- 12,746	34,996	14.50
48	2037	589		417		172	3,205	3,377	- 12,720	35,510	14.51
49	2038	589		417		172	3,237	3,409	- 12,695	36,009	14.51
50	2039	1.133		417		716	3,270	3,986	- 12,594	36,570	14.52



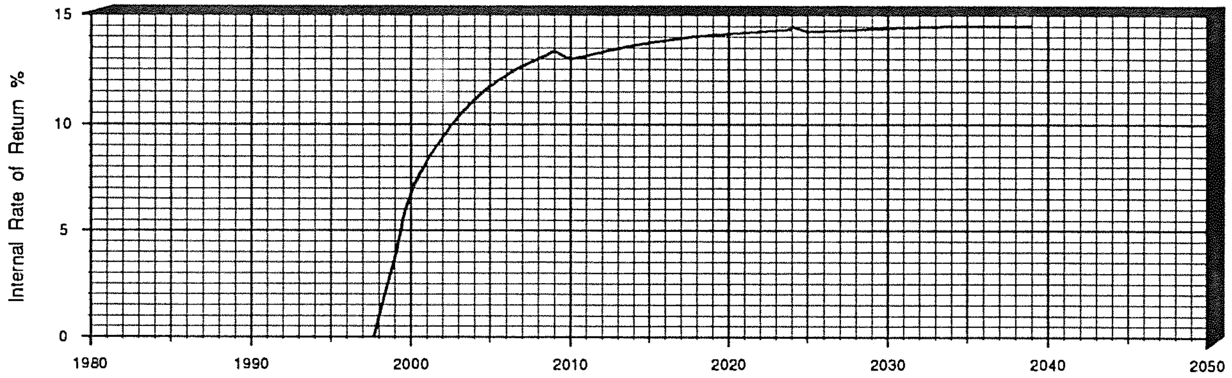


Figure showing Present Values and Internal Rate of Return

8.4 Life Cycle for Culverts

Developed - December 6, 1988
Revised - May 15, 1989

PROJECT - Compare three alternatives to the base case of installing an 8'-0" (2450 mm) diameter x 36 m SPCSP with a plate thickness of 3 mm and replace every 25 years. (Alternatve 1)

Alternative 2 - Install design size and protect for the first 25 years and then allow to rust.
Alternative 3 - Install an oversized pipe initially and add a liner after 25 years.
Alternative 4 - Install a concrete pipe.
At 50 years , the design life of all systems is ended.

ASSUMPTIONS

- The hydraulic conditions will remain unaltered for 50 years.
- No improved technology will become available.
- The in place cost of a culvert is the material cost x 2.5.

Estimated Costs in 1989 Dollars

		Estimated Costs	
		Initial	Future
Alternative 1 Normal SPCSP Installation			
Initial cost - material cost of $429 / m x 2.5 x 36 =		$ 38,500	
Replacement Cost - 25 yrs. hence			
Culvert - same as initial cost	$ 38,500		
Detour -	50,000 =		$ 88,500
Alternative 2 Normal SPCSP with Cathodic Protection for 25 years			
Initial cost - Culvert - same as Alternate 1	$ 38,000		
Cathodic protection -	7,000 =	$ 45,500	
Replace Anodes - 15 years hence			$ 3,000
Power Costs - $200.00 / yr. for 25 years			+ 200.00 / yr.
Alternative 3 Install larger culvert initially (9'0" - 2750 mm)			
Initial cost - material cost of $478 / m x 2.5 x 36 =		$ 43,000	
Cost of Liner - 25 yrs. hence			
Culvert - $578/m x 36 =	$20,800		
Grout - 1.416 x 86 x \$150 / m^3 =	7,650 =		$ 28,450
Alternative 4 Install Concrete Pipe			
Initial cost - Class 4 pipe $800 / m + freight $ 50 / m			
Material - $850 / m x 36 =	$ 30,600		
Installation =	30,000 =	$ 61,000	

Present Worth

One indicator of the relative merits of these four alternatives is the present worth of their costs which, when discounted at a "real" rate of interest of 4%, are:

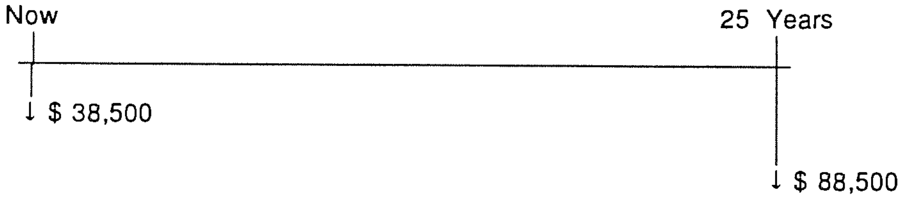
			Present Value (1989)
Alternative 1	Normal SPCSP Installation		
	1989 Cost =	$ 38,500	
	2014 Cost - 88,500 ÷ 104^{25} =	33,198	$ 71,698
Alternative 2	Normal SPCSP with Cathodic Protection		
	1989 Cost =	$ 45,500	
	2004 Cost - 3,000 ÷ 1.04^{15} =	1,666	
	200.00 / yr. for 25 yrs. =	3,124	$ 50,290
Alternative 3	Install Larger Culvert Initially		
	1989 Cost =	$ 43,000	
	2014 Cost - 28,450 ÷ 1.04^{25} =	10,672	$ 53,672
Alternative 4	Install Concrete Pipe		
	1989 Cost =	$ 61,000	$ 61,000

While that information gives the picture for one discount rate, it does not tell the whole story. It does not give the return which is being received on the incremental additional costs of the more expensive alternatives.

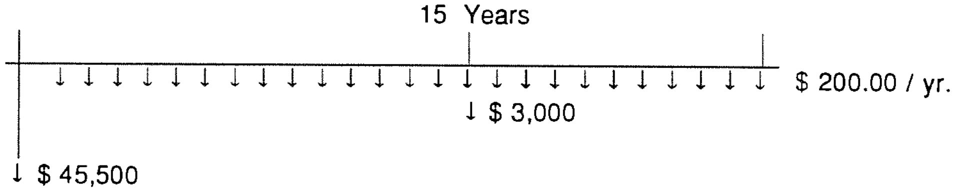
The following three data sheets compare Alternatives 2, 3 & 4 to Alternative 1, the least initial cost alternative. In effect, the flow of costs for Alternative 1 is algebraically subtracted from the flow of costs for the alternative being tested as illustrated for Alternatives 1 and 2 as an example.

CASH FLOW DIAGRAMS

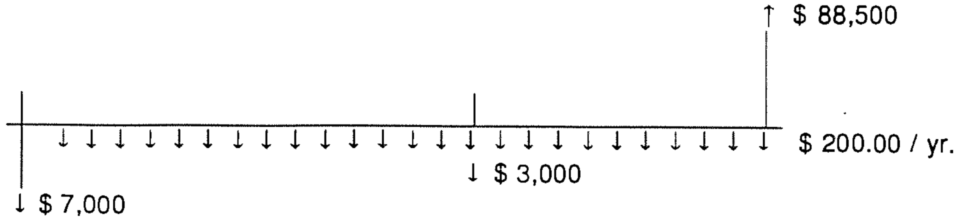
Alternative 1
Normal
Instal.



Alternative 2
Cathodic
Protection



Alternative 2
minus
Alternative 1



Alternative 1 allows the culvert to rust thereby requiring replacement after 25 years.

- culvert costs $38,500 installed
- culvert replacement requires $50,000 for roadway detour

Alternative 2 provides 25 years of cathodic protection such that culvert installation lasts 50 years.

- culvert costs $35,500 installed
- cathodic protection has initial cost of $7,000
- anodes require replacement after 15 years at a cost of $3,000
- electric power to anodes costs $200 per year

		ANNUAL COSTS				NET ANNUAL UNDISCOUNTED VALUES			SUM OF P.W. @ 4% DISCOUNT RATE		IRR (REAL)
No.	Year	OVERSIZE CULVERT		CATHODIC PROTECTION		CAP. COST		COST+SAVINGS			(guess)
		CAP.	BENEFIT	CAP.	BENEFIT	DIFF.	SAVINGS	VALUES	CAPITAL	TOTAL	10.00%
0	1989	38,500		45,500		(7,000)	0	(7,000)	(7,000)	(7,000)	
1	1990			200		(200)	0	(200)	(7,192)	(7,192)	-102.86%
2	1991			200		(200)	0	(200)	(7,377)	(7,377)	ERR
3	1992			200		(200)	0	(200)	(7,555)	(7,555)	-128.34%
4	1993			200		(200)	0	(200)	(7,726)	(7,726)	ERR
5	1994			200		(200)	0	(200)	(7,890)	(7,890)	-145.73%
6	1995			200		(200)	0	(200)	(8,048)	(8,048)	ERR
7	1996			200		(200)	0	(200)	(8,200)	(8,200)	-156.59%
8	1997			200		(200)	0	(200)	(8,347)	(8,347)	ERR
9	1998			200		(200)	0	(200)	(8,487)	(8,487)	-163.89%
10	1999			200		(200)	0	(200)	(8,622)	(8,622)	ERR
11	2000			200		(200)	0	(200)	(8,752)	(8,752)	-169.11%
12	2001			200		(200)	0	(200)	(8,877)	(8,877)	ERR
13	2002			200		(200)	0	(200)	(8,997)	(8,997)	-173.02%
14	2003			200		(200)	0	(200)	(9,113)	(9,113)	ERR
15	2004			3,200		(3,200)	0	(3,200)	(10,889)	(10,889)	ERR
16	2005			200		(200)	0	(200)	(10,996)	(10,996)	-106.27%
17	2006			200		(200)	0	(200)	(11,099)	(11,099)	ERR
18	2007			200		(200)	0	(200)	(11,198)	(11,198)	-136.55%
19	2008			200		(200)	0	(200)	(11,293)	(11,293)	-194.86%
20	2009			200		(200)	0	(200)	(11,384)	(11,384)	-194.30%
21	2010			200		(200)	0	(200)	(11,472)	(11,472)	-194.89%
22	2011			200		(200)	0	(200)	(11,556)	(11,556)	-163.34%
23	2012			200		(200)	0	(200)	(11,637)	(11,637)	ERR
24	2013			200		(200)	0	(200)	(11,715)	(11,715)	ERR
25	2014	88,500		200		88,300	0	88,300	21,408	21,408	9.24%
26	2015					0	0	0	21,408	21,408	9.24%
27	2016					0	0	0	21,408	21,408	9.24%
28	2017					0	0	0	21,408	21,408	9.24%
29	2018					0	0	0	21,408	21,408	9.24%
30	2019					0	0	0	21,408	21,408	9.24%
31	2020					0	0	0	21,408	21,408	9.24%
32	2021					0	0	0	21,408	21,408	9.24%
33	2022					0	0	0	21,408	21,408	9.24%
34	2023					0	0	0	21,408	21,408	9.24%
35	2024					0	0	0	21,408	21,408	9.24%
36	2025					0	0	0	21,408	21,408	9.24%
37	2026					0	0	0	21,408	21,408	9.24%
38	2027					0	0	0	21,408	21,408	9.24%
39	2028					0	0	0	21,408	21,408	9.24%
40	2029					0	0	0	21,408	21,408	9.24%
41	2030					0	0	0	21,408	21,408	9.24%
42	2031					0	0	0	21,408	21,408	9.24%
43	2032					0	0	0	21,408	21,408	9.24%
44	2033					0	0	0	21,408	21,408	9.24%
45	2034					0	0	0	21,408	21,408	9.24%
46	2035					0	0	0	21,408	21,408	9.24%
47	2036					0	0	0	21,408	21,408	9.24%
48	2037					0	0	0	21,408	21,408	9.24%
49	2038					0	0	0	21,408	21,408	9.24%
50	2039					0	0	0	21,408	21,408	9.24%

Table - Comparison of Alt. 2 to Alt. 1

Alternative 1 allows the culvert to rust thereby requiring replacement after 25 years.

- culvert costs $38,500 installed
- culvert replacement requires $50,000 for roadway detour.

Alternative 3 provides an oversized culvert initially with a liner installed after 25 years.

- oversized culvert costs $43,000 installed
- liner costs $20,800 and requires $7,650 worth of grout to seal.

		ANNUAL COSTS				NET ANNUAL UNDISCOUNTED VALUES			SUM OF P.W. @ 4% DISCOUNT RATE		IRR (REAL)
No.	Year	REPLACE CULVERT		OVERSIZED CULVERT		CAP. COST		COST+SAVINGS			(guess)
		CAP.	BENEFIT	CAP.	BENEFIT	DIFF.	SAVINGS	VALUES	CAPITAL	TOTAL	10.00%
0	1989	38,500		43,000		(4,500)	0	(4,500)	(4,500)	(4,500)	
1	1990					0	0	0	(4,500)	(4,500)	-100.00%
2	1991					0	0	0	(4,500)	(4,500)	ERR
3	1992					0	0	0	(4,500)	(4,500)	ERR
4	1993					0	0	0	(4,500)	(4,500)	ERR
5	1994					0	0	0	(4,500)	(4,500)	ERR
6	1995					0	0	0	(4,500)	(4,500)	ERR
7	1996					0	0	0	(4,500)	(4,500)	ERR
8	1997					0	0	0	(4,500)	(4,500)	ERR
9	1998					0	0	0	(4,500)	(4,500)	ERR
10	1999					0	0	0	(4,500)	(4,500)	ERR
11	2000					0	0	0	(4,500)	(4,500)	ERR
12	2001					0	0	0	(4,500)	(4,500)	ERR
13	2002					0	0	0	(4,500)	(4,500)	ERR
14	2003					0	0	0	(4,500)	(4,500)	ERR
15	2004					0	0	0	(4,500)	(4,500)	ERR
16	2005					0	0	0	(4,500)	(4,500)	ERR
17	2006					0	0	0	(4,500)	(4,500)	ERR
18	2007					0	0	0	(4,500)	(4,500)	ERR
19	2008					0	0	0	(4,500)	(4,500)	ERR
20	2009					0	0	0	(4,500)	(4,500)	ERR
21	2010					0	0	0	(4,500)	(4,500)	ERR
22	2011					0	0	0	(4,500)	(4,500)	ERR
23	2012					0	0	0	(4,500)	(4,500)	ERR
24	2013					0	0	0	(4,500)	(4,500)	ERR
25	2014	88,500		28,450		60,050	0	60,050	18,026	18,026	10.92%
26	2015					0	0	0	18,026	18,026	10.92%
27	2016					0	0	0	18,026	18,026	10.92%
28	2017					0	0	0	18,026	18,026	10.92%
29	2018					0	0	0	18,026	18,026	10.92%
30	2019					0	0	0	18,026	18,026	10.92%
31	2020					0	0	0	18,026	18,026	10.92%
32	2021					0	0	0	18,026	18,026	10.92%
33	2022					0	0	0	18,026	18,026	10.92%
34	2023					0	0	0	18,026	18,026	10.92%
35	2024					0	0	0	18,026	18,026	10.92%
36	2025					0	0	0	18,026	18,026	10.92%
37	2026					0	0	0	18,026	18,026	10.92%
38	2027					0	0	0	18,026	18,026	10.92%
39	2028					0	0	0	18,026	18,026	10.92%
40	2029					0	0	0	18,026	18,026	10.92%
41	2030					0	0	0	18,026	18,026	10.92%
42	2031					0	0	0	18,026	18,026	10.92%
43	2032					0	0	0	18,026	18,026	10.92%
44	2033					0	0	0	18,026	18,026	10.92%
45	2034					0	0	0	18,026	18,026	10.92%
46	2035					0	0	0	18,026	18,026	10.92%
47	2036					0	0	0	18,026	18,026	10.92%
48	2037					0	0	0	18,026	18,026	10.92%
49	2038					0	0	0	18,026	18,026	10.92%
50	2039					0	0	0	18,026	18,026	10.92%

Table - Comparison of Alt. 3 to Alt. 1

Alternative 1 allows the culvert to rust thereby requiring replacement after 25 years.

- culvert costs $38,500 installed
- culvert replacement requires $50,000 for roadway detour.

Alternative 4 provides a concrete pipe culvert with a 50 + year design life

- concrete culvert costs $61,000 installed

		ANNUAL COSTS				NET ANNUAL UNDISCOUNTED VALUES			SUM OF P.W. @ 4% DISCOUNT RATE		IRR (REAL)
		REPLACE CULVERT		CONCRETE CULVERT		CAP. COST		COST+SAVINGS			(guess)
No.	Year	CAP.	BENEFIT	CAP.	BENEFIT	DIFF.	SAVINGS	VALUES	CAPITAL	TOTAL	10.00%
0	1989	38,500		61,000		(22,500)	0	(22,500)	(22,500)	(22,500)	
1	1990					0	0	0	(22,500)	(22,500)	-100.00%
2	1991					0	0	0	(22,500)	(22,500)	ERR
3	1992					0	0	0	(22,500)	(22,500)	ERR
4	1993					0	0	0	(22,500)	(22,500)	ERR
5	1994					0	0	0	(22,500)	(22,500)	ERR
6	1995					0	0	0	(22,500)	(22,500)	ERR
7	1996					0	0	0	(22,500)	(22,500)	ERR
8	1997					0	0	0	(22,500)	(22,500)	ERR
9	1998					0	0	0	(22,500)	(22,500)	ERR
10	1999					0	0	0	(22,500)	(22,500)	ERR
11	2000					0	0	0	(22,500)	(22,500)	ERR
12	2001					0	0	0	(22,500)	(22,500)	ERR
13	2002					0	0	0	(22,500)	(22,500)	ERR
14	2003					0	0	0	(22,500)	(22,500)	ERR
15	2004					0	0	0	(22,500)	(22,500)	ERR
16	2005					0	0	0	(22,500)	(22,500)	ERR
17	2006					0	0	0	(22,500)	(22,500)	ERR
18	2007					0	0	0	(22,500)	(22,500)	ERR
19	2008					0	0	0	(22,500)	(22,500)	ERR
20	2009					0	0	0	(22,500)	(22,500)	ERR
21	2010					0	0	0	(22,500)	(22,500)	ERR
22	2011					0	0	0	(22,500)	(22,500)	ERR
23	2012					0	0	0	(22,500)	(22,500)	ERR
24	2013					0	0	0	(22,500)	(22,500)	ERR
25	2014	88,500				88,500	0	88,500	10,698	10,698	5.63%
26	2015					0	0	0	10,698	10,698	5.63%
27	2016					0	0	0	10,698	10,698	5.63%
28	2017					0	0	0	10,698	10,698	5.63%
29	2018					0	0	0	10,698	10,698	5.63%
30	2019					0	0	0	10,698	10,698	5.63%
31	2020					0	0	0	10,698	10,698	5.63%
32	2021					0	0	0	10,698	10,698	5.63%
33	2022					0	0	0	10,698	10,698	5.63%
34	2023					0	0	0	10,698	10,698	5.63%
35	2024					0	0	0	10,698	10,698	5.63%
36	2025					0	0	0	10,698	10,698	5.63%
37	2026					0	0	0	10,698	10,698	5.63%
38	2027					0	0	0	10,698	10,698	5.63%
39	2028					0	0	0	10,698	10,698	5.63%
40	2029					0	0	0	10,698	10,698	5.63%
41	2030					0	0	0	10,698	10,698	5.63%
42	2031					0	0	0	10,698	10,698	5.63%
43	2032					0	0	0	10,698	10,698	5.63%
44	2033					0	0	0	10,698	10,698	5.63%
45	2034					0	0	0	10,698	10,698	5.63%
46	2035					0	0	0	10,698	10,698	5.63%
47	2036					0	0	0	10,698	10,698	5.63%
48	2037					0	0	0	10,698	10,698	5.63%
49	2038					0	0	0	10,698	10,698	5.63%
50	2039					0	0	0	10,698	10,698	5.63%

Table - Comparison of Alt. 4 to Alt. 1

Because there are no cash flows between 25 and 50 years in the futures, the results at year 2014 remain constant to the end of the period (2039).

Results of Year 2014 and Beyond

	Present Worth (4 % Real Disc. Rate)	I.R.R. (REAL)
Alt.. 2 - Alt. 1	$ 21,408	9.24
Alt. 3 - Alt. 1	18,026	10.92
Alt. 4 - Alt. 1	10,698	5.63

The real rate of return which would be received on the additional $4,500 to install the larger pipe in Alternative 3 is greater than the internal rate of return for Alternative 2 which indicates that Alt. 3 is better than Alt. 2, the opposite to that indicated by the present worths based upon a 4% real discount rate. In principle, this is a similar situation to the results illustrated in Figure 5 - 4 on page 40 with an explanation on page 41.

Comparing ALT. 2 to ALT. 3, the internal rate of return is 6.29%, meaning that if a rate higher than that is desired, Alt. 3 is best. If generally a lower rate of return is being received on other investment choices, it would be best to spend the additional money required initially and over the first 25 year period for Alt. 2.

The graphs of Present Worths and I.R.R.'s and the following Summary of Present Worths for all of the different interest rates mentioned may further aid in the explanation.

Present Worths for Costs for Various Real Discount Rates

	0 %	4 %	5.63 %	6.29 %	9.235 %	10.92 %
ALT. 1	127,000	71,698	61,000	57,759	48,225	45,133
ALT. 2	53,500	50,290	49,468	49,189	48,225	47,828
ALT. 3	71,450	53,672	50,234	49,191	46,126	45,132
ALT. 4	61,000	61,000	61,000	61,000	61,000	61,000

If better than 10.92% real rate of return can be obtained elsewhere, Alternative 1 is best. If that high a rate is not available but 6.29% or greater is, Alternative 3 is best and below 6.29%, Alternative 2 is best.

Although beyond the alternatives mentioned, the cathodic protection could be extended beyond 25 years, thereby giving more flexibility to that option. If one assumed a continuing power bill of $200 annually and that anodes would be replaced each 15 years, that alternative when compared to Alternate 1 would yield an internal rate of return of 9.50% at year 50 and beyond. That, of course, requires an analysis period beyond 50 years and into the range of 75 years which is contrary to the guidelines. Nonetheless the flexibility of being able to make a further decision 25 years hence, when 50 years from then is 75 years from now, is an important consideration.

Assuming the concrete pipe option might also be good for 75 years without further expenditure, it should also be considered, however, this alternative does not have the flexibility of making further decisions at a later date and, in any event, its' 50 year and beyond I.R.R. is only 6.44% which is not competitive with cathodic protection.

Alternative 3 provides an oversized culvert initially with a liner installed after 25 years.

- oversized culvert costs $43,000 installed
- liner costs $20,800 and requires $7,650 worth of grout to seal

Alternative 2 provides 25 years of cathodic protection such that culvert installation lasts 50 years.

- culvert costs $35,500 installed
- cathodic protection has initial cost of $7,000
- anodes require replacement after 15 years at a cost of $3,000
- electric power to anodes costs $200 per year

		ANNUAL COSTS				NET ANNUAL UNDISCOUNTED VALUES			SUM OF P.W. @ 4% DISCOUNT RATE		IRR (REAL)
		OVERSIZE CULVERT		CATHODIC PROTECTION		CAP. COST		COST+SAVINGS			(guess)
No.	Year	CAP.	BENEFIT	CAP.	BENEFIT	DIFF.	SAVINGS	VALUES	CAPITAL	TOTAL	10.00%
0	1989	43,000		45,500		(2,500)	0	(2,500)	(2,500)	(2,500)	
1	1990			200		(200)	0	(200)	(2,692)	(2,692)	-108.00%
2	1991			200		(200)	0	(200)	(2,877)	(2,877)	ERR
3	1992			200		(200)	0	(200)	(3,055)	(3,055)	-139.35%
4	1993			200		(200)	0	(200)	(3,226)	(3,226)	ERR
5	1994			200		(200)	0	(200)	(3,390)	(3,390)	-155.81%
6	1995			200		(200)	0	(200)	(3,548)	(3,548)	ERR
7	1996			200		(200)	0	(200)	(3,700)	(3,700)	-165.34%
8	1997			200		(200)	0	(200)	(3,847)	(3,847)	ERR
9	1998			200		(200)	0	(200)	(3,987)	(3,987)	-171.51%
10	1999			200		(200)	0	(200)	(4,122)	(4,122)	ERR
11	2000			200		(200)	0	(200)	(4,252)	(4,252)	-175.83%
12	2001			200		(200)	0	(200)	(4,377)	(4,377)	ERR
13	2002			200		(200)	0	(200)	(4,497)	(4,497)	-179.01%
14	2003			200		(200)	0	(200)	(4,813)	(4,613)	ERR
15	2004			3,200		(3,200)	0	(3,200)	(6,389)	(6,389)	ERR
16	2005			200		(200)	0	(200)	(6,496)	(6,496)	-106.27%
17	2006			200		(200)	0	(200)	(6,599)	(6,599)	ERR
18	2007			200		(200)	0	(200)	(6,698)	(6,698)	-201.28%
19	2008			200		(200)	0	(200)	(6,793)	(6,793)	-201.70%
20	2009			200		(200)	0	(200)	(6,884)	(6,884)	-153.41%
21	2010			200		(200)	0	(200)	(6,972)	(6,972)	ERR
22	2011			200		(200)	0	(200)	(7,056)	(7,056)	-201.29%
23	2012			200		(200)	0	(200)	(7,137)	(7,137)	ERR
24	2013			200		(200)	0	(200)	(7,215)	(7,215)	ERR
25	2014	28,450		200		28,250	0	28,250	3,382	3,382	6.29%
26	2015					0	0	0	3,382	3,382	6.29%
27	2016					0	0	0	3,382	3,382	6.29%
28	2017					0	0	0	3,382	3,382	6.29%
29	2018					0	0	0	3,382	3,382	6.29%
30	2019					0	0	0	3,382	3,382	6.29%
31	2020					0	0	0	3,382	3,382	6.29%
32	2021					0	0	0	3,382	3,382	6.29%
33	2022					0	0	0	3,382	3,382	6.29%
34	2023					0	0	0	3,382	3,382	6.29%
35	2024					0	0	0	3,382	3,382	6.29%
36	2025					0	0	0	3,382	3,382	6.29%
37	2026					0	0	0	3,382	3,382	6.29%
38	2027					0	0	0	3,382	3,382	6.29%
39	2028					0	0	0	3,382	3,382	6.29%
40	2029					0	0	0	3,382	3,382	6.29%
41	2030					0	0	0	3,382	3,382	6.29%
42	2031					0	0	0	3,382	3,382	6.29%
43	2032					0	0	0	3,382	3,382	6.29%
44	2033					0	0	0	3,382	3,382	6.29%
45	2034					0	0	0	3,382	3,382	6.29%
46	2035					0	0	0	3,382	3,382	6.29%
47	2036					0	0	0	3,382	3,382	6.29%
48	2037					0	0	0	3,382	3,382	6.29%
49	2038					0	0	0	3,382	3,382	6.29%
50	2039					0	0	0	3,382	3,382	6.29%

Table - showing results from a comparison of Alt. 2 and Alt. 3 (incremental values).

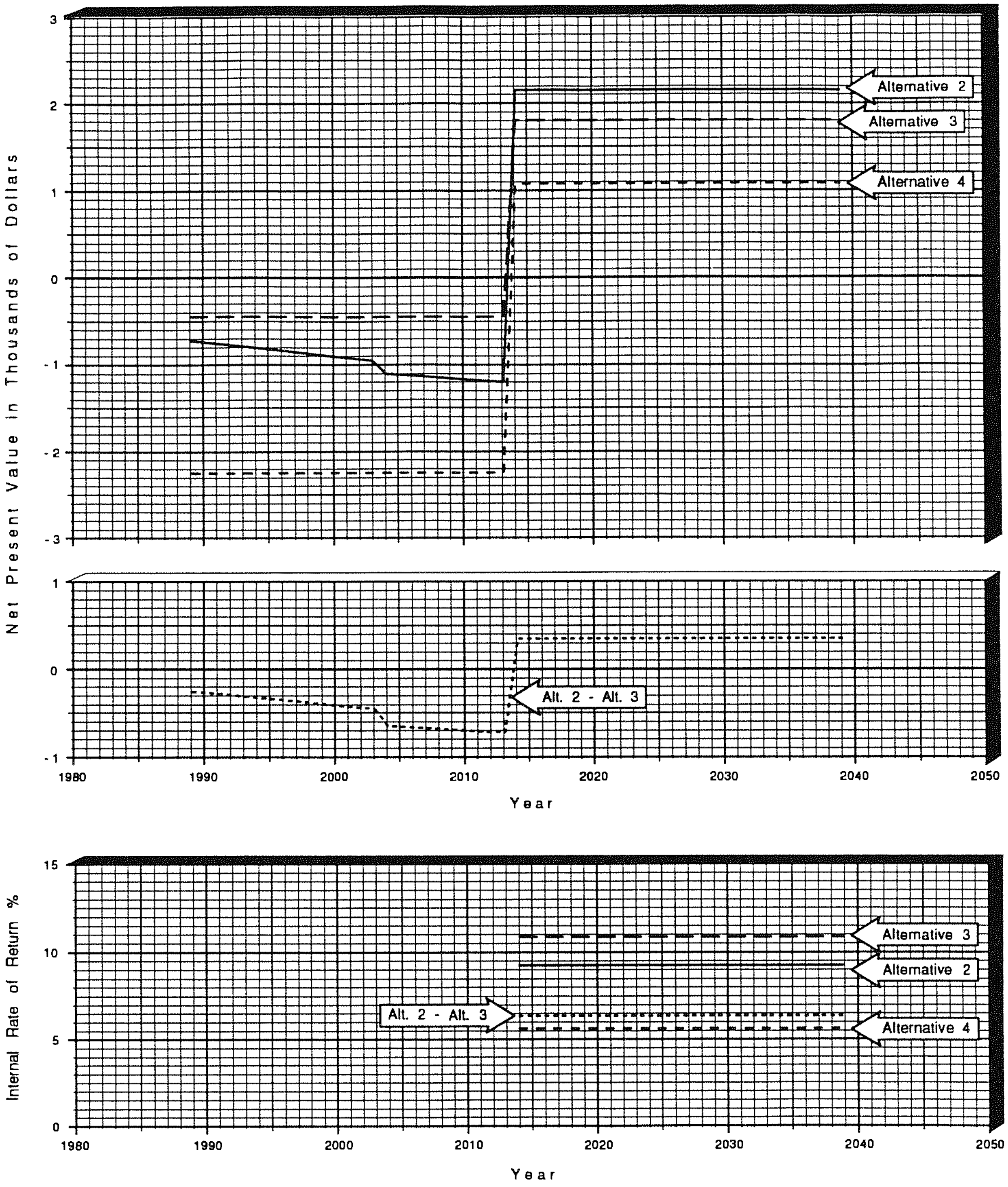


Figure - Showing Net Present Values and Internal Rate of Return for all Alternatives and and for incremental values comparing Alt. 2 with Alt, 3

8.5 Guardrail vs Sideslope Improvement

PROJECT - To test the economic feasibility of flattening sideslopes as an alternative to the installation of guardrail.

ASSUSMPTIONS:

Standard	- RAU-211-110
Embankment Height	- 9 m
Length of Embankment	- 500 m
Cost of Guardrail	- 26 $ / m initial installation
	- 13 $ / m reinstallation every 18 years
Guardrail Maintenance	- 500 $ / km-yr.
Additional Fill Material	- 2 $ / cu. m
Right-of-way	- 2500 $ / ha (1000 $ / ac)
Traffic Volume	- 1000 AADT

COSTS:

Capital and Maintenance

3:1 Sideslope Guardrail	- 2 x 500 x 26 =	$ 26,000 /18 yrs.
Maintenance	- 2 x 0.5 x 500 =	$ 500 / yr.
4:1 Sideslope Earthwork	- 2 x 500 x 1/2 (36 x 8 - 27 x 8) x 2 =	$ 81,000
Right-of-way	- 2 x 500 x (36 - 27) x $\frac{2,500}{10,000}$ =	$ 2,250

Operating (Collision costs)

Encroachment Rate:

From RTAC table F.2.2C the expected encroachment rate for a rural arterial is (.00045 events/km/yr. x AADT)

Probability of Encroachment:

From RTAC Figure F.2.3b the probability of an errant vehicle travelling 2+ metres (shoulder width) is 92%.

Number of Encroachments Per Year:

With 1,000 AADT the expected number of collisions with a guardrail or number of run-off roads is:

Encroachments x probability of encroachment x AADT

= .00045 x 0.92 x 1000 = 0.414 events per km per year.

Severity Index And Collision Severity:

From RTAC Tables F.2.4a and F.2.4b a 4:1 sideslope has a severity index of 2.6

Resulting in 61 % P.D.O. Collisions
39 % Injury Collisions

A W-Beam Guardrail has a severity index of 3.7 (RTAC Table F.2.2b)

Resulting in 44.5 % P.D.O. Collisions
54.8 % Injury Collisions
0.7 % Fatal Collisions

Collision Costs (continued):

Using provincial average collision cost data of:
$ 1,105,000 / Fatal Collision
112,000 / Injury Collision
3,500 / P.D.O. Collision

4:1 sideslopes yield an average collision cost of:
(0.61 x 3550 + 0.39 x 112,000) = $ 45,850

Guardrail yields an average collision cost of:
(0.445 x 3550 + 0.548 x 112,000 + 0.007 x 1,105,000) = $ 70,690

RESULTS:

With 1,000 AADT and 500 m of guardrail/embankment, the expected collision costs are:
Length x Events x Cost
(Guardrail (0.5 x 0.414 x 70,690) = $ 14,635 / yr.
4:1 sideslopes (0.5 x 0.414 x 45,850) = $ 9,490 / yr.

CONCLUSIONS:

- With a 9 m embankment height 500 m in length, the internal rate of return is 11.51 % with 1,000 AADT.
- Lower embankment heights or increased traffic volumes would result in greater returns.
- Narrower shoulders would increase the probability of encroachment into the hazard (guardrail or sideslope) and should, therefore, increase the cost effectiveness of sideslope improvements vs guardrail placement.
- Higher embankment heights would result in lower returns due to increased earthwork quantities and right-of-way requirements but could still be cost effective depending on the traffic volumes.

FURTHER WORK REQUIRED:

- Determination of collision severity indices for 5:1 and 6:1 sideslope.
- Determination of other maintenance costs associated with guardrails (increased snow removal costs, increased grass cutting costs, etc.).
- Determination of sideslope maintenance costs for 3:1, 4:1, 5:1 and 6:1 sideslopes.

RAU - 211 - 110 design standard 1000 AADT 9 m embankment height

Installation of guardrail assumes a 3:1 sideslope
Guardrail costs 26,000 $/km installed and has an 18 yr. life
Guardrail replacement cost is 13,000 $/km every 18 years
Annual guardrail maintenance is approx. 500 $/km

Improving sideslopes requires additional fill @ 2 $/cu.m.
and additional right-of-way @ 2500 $/ha

Benefits accrued are reduction in collision costs and increase annually at the same rate as traffic (2% for first 10 years and 1% thereafter)

		ANNUAL COSTS				NET ANNUAL UNDISCOUNTED VALUE			SUM OF P.W @ 4% DISCOUNT RATE		IRR
No	Year	GUARDRAIL		4:1 SIDESLOPE		CAP COST	R.U.C	COST+R.U.C			(guess)
		CAP	COLL $	CAP	COLL $	DIFF	SAVINGS	VALUES	CAPITAL	TOTAL	10.00%
0	1989	26,000		83,250		(57,250)	0	(57,250)	(57,250)	(57,250)	
1	1990	500	14,635		9,490	500	5,145	5,645	(56,769)	(51,822)	-90.14%
2	1991	500	14,928		9,680	500	5,248	5,748	(56,307)	(46,508)	-63.00%
3	1992	500	15,220		9,870	500	5,351	5,851	(55,862)	(41,307)	-42.19%
4	1993	500	15,513		10,059	500	5,454	5,954	(55,435)	(36,217)	-28.21%
5	1994	500	15,806		10,249	500	5,557	6,057	(55,024)	(31,239)	-18.72%
6	1995	500	16,099		10,439	500	5,660	6,160	(54,629)	(26,371)	-12.06%
7	1996	500	16,391		10,629	500	5,762	6,262	(54,249)	(21,612)	-7.25%
8	1997	500	16,684		10,819	500	5,865	6,365	(53,884)	(16,961)	-3.67%
9	1998	500	16,977		11,008	500	5,968	6,468	(53,532)	(12,417)	-0.95%
10	1999	500	17,269		11,198	500	6,071	6,571	(53,195)	(7,978)	1.17%
11	2000	500	17,442		11,310	500	6,132	6,632	(52,870)	(3,670)	2.82%
12	2001	500	17,615		11,422	500	6,193	6,693	(52,557)	510	4.15%
13	2002	500	17,787		11,534	500	6,253	6,753	(52,257)	4,566	5.22%
14	2003	500	17,960		11,646	500	6,314	6,814	(51,968)	8,501	6.09%
15	2004	500	18,133		11,758	500	6,375	6,875	(51,691)	12,318	6.82%
16	2005	500	18,305		11,870	500	6,435	6,935	(51,424)	16,021	7.42%
17	2006	500	18,478		11,982	500	6,496	6,996	(51,167)	19,613	7.92%
18	2007	13,000	18,651		12,094	13,000	6,557	19,557	(44,750)	29,267	9.02%
19	2008	500	18,824		12,206	500	6,617	7,117	(44,513)	32,645	9.33%
20	2009	500	18,996		12,318	500	6,678	7,178	(44,284)	35,921	9.60%
21	2010	500	19,169		12,430	500	6,739	7,239	(44,065)	39,098	9.83%
22	2011	500	19,342		12,542	500	6,800	7,300	(43,854)	42,178	10.04%
23	2012	500	19,514		12,654	500	6,860	7,360	(43,651)	45,164	10.21%
24	2013	500	19,687		12,766	500	6,921	7,421	(43,456)	48,059	10.38%
25	2014	500	19,860		12,878	500	6,982	7,482	(43,269)	50,866	10.50%
26	2015	500	20,032		12,990	500	7,042	7,542	(43,088)	53,586	10.61%
27	2016	500	20,205		13,102	500	7,103	7,603	(42,915)	56,223	10.72%
28	2017	500	20,378		13,214	500	7,164	7,664	(42,748)	58,779	10.81%
29	2018	500	20,550		13,326	500	7,225	7,725	(42,588)	61,256	10.89%
30	2019	500	20,723		13,438	500	7,285	7,785	(42,434)	63,656	10.96%
31	2020	500	20,896		13,550	500	7,346	7,846	(42,285)	65,982	11.02%
32	2021	500	21,069		13,662	500	7,407	7,907	(42,143)	68,236	11.07%
33	2022	500	21,241		13,774	500	7,467	7,967	(42,006)	70,420	11.12%
34	2023	500	21,414		13,886	500	7,528	8,028	(41,874)	72,536	11.17%
35	2024	500	21,587		13,998	500	7,589	8,089	(41,747)	74,585	11.20%
36	2025	13,000	21,759		14,110	13,000	7,650	20,650	(38,580)	79,617	11.29%
37	2026	500	21,932		14,222	500	7,710	8,210	(38,463)	81,541	11.32%
38	2027	500	22,105		14,334	500	7,771	8,271	(38,350)	83,404	11.35%
39	2028	500	22,277		14,446	500	7,832	8,332	(38,242)	85,209	11.37%
40	2029	500	22,450		14,558	500	7,892	8,392	(38,137)	86,957	11.39%
41	2030	500	22,623		14,670	500	7,953	8,453	(38,037)	88,650	11.41%
42	2031	500	22,795		14,782	500	8,014	8,514	(37,941)	90,290	11.43%
43	2032	500	22,968		14,894	500	8,075	8,575	(37,848)	91,877	11.44%
44	2033	500	23,141		15,006	500	8,135	8,635	(37,759)	93,415	11.46%
45	2034	500	23,314		15,118	500	8,196	8,696	(37,674)	94,903	11.47%
46	2035	500	23,486		15,230	500	8,257	8,757	(37,591)	96,345	11.48%
47	2036	500	23,659		15,342	500	8,317	8,817	(37,512)	97,741	11.49%
48	2037	500	23,832		15,454	500	8,378	8,878	(37,436)	99,092	11.50%
49	2038	500	24,004		15,565	500	8,439	8,939	(37,363)	100,400	11.51%
50	2039	500	24,177		15,677	500	8,500	9,000	(37,293)	101,686	11.51%

Table - showing results for the comparison of guardrail and sideslope improvement.

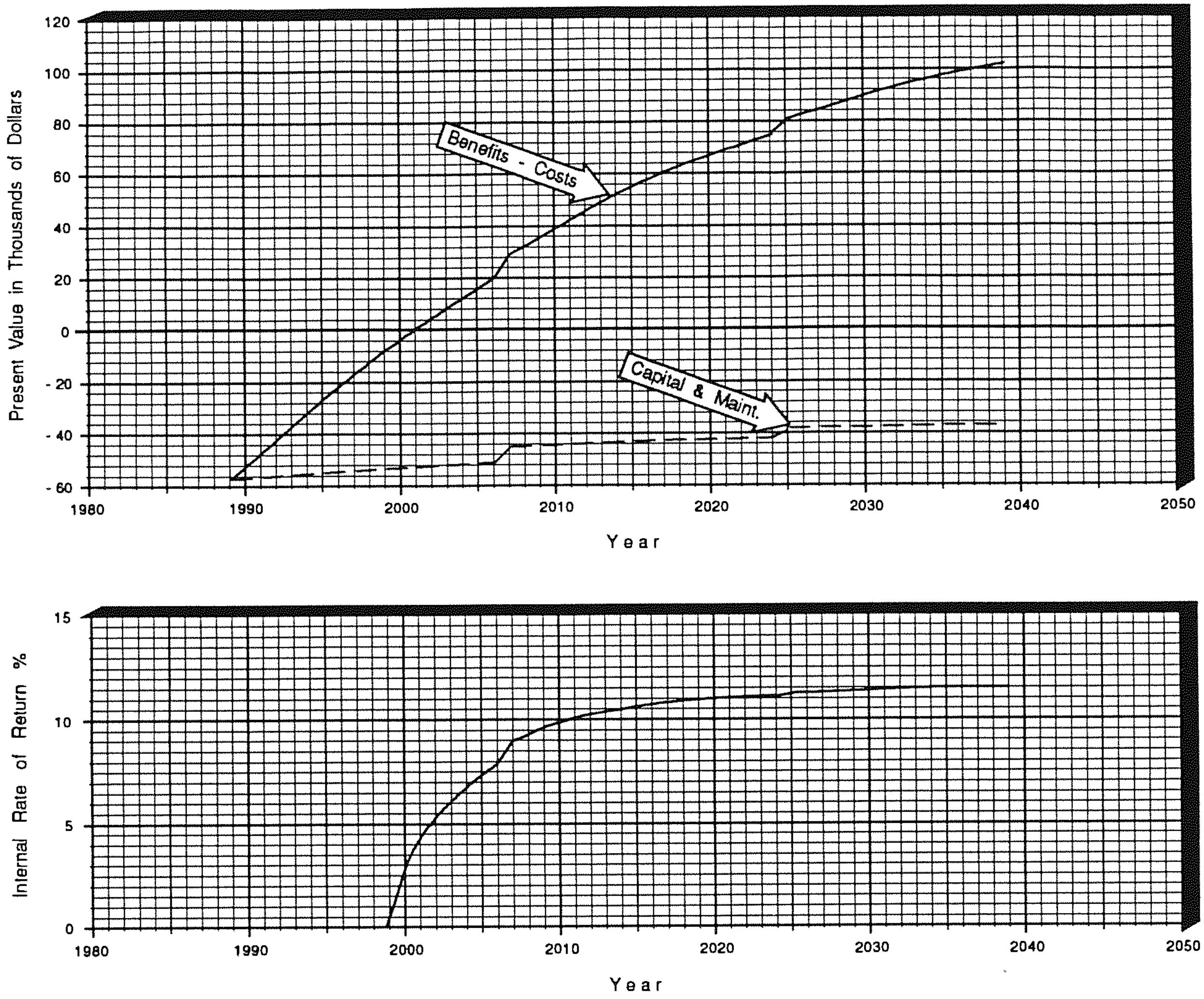


Figure - illustrating Net Present Values and Internal Rate of Return for guardrail compared with sideslope improvement.

8.6 Speed Change Example

This is a hypothetical example concentrating upon road user costs associated with speed change and time delays. Other items will either be ignored or made more simple than they would be in an actual case.

This involves two aspects of impeded traffic flow - one because of an urban setting with speed restrictions, and, the other involves forced lower speeds due to heavy traffic and the absence of passing opportunities. When traffic flows directly from one of these circumstances into the other, in some respects one affects the other. Each of these situations may occur separately and when that is the case, it will be obvious how the procedures used in this example must be adjusted to handle the independent situation.

All unit prices which will be used will be in Canadian dollars for 1988. All other numbers used (mostly traffic related) are assumed numbers - chosen simply to illustrate methods and procedures. It should not be assumed that any are provincial averages or default values. Systems Planning should be consulted for data for specific cases.

Assumptions

General

A two lane highway passes through an urban community which presently has a 3.2 km, - 50 km per hour speed zone with one traffic actuated signal.

Options

The rural sections of this highway are being converted to four lane divided standards and the options being considered include:

1. Do nothing to a 10.2 km section of the highway which includes this urban zone and about three and one-half kms of rural section on each end. Doing nothing now, or at most, resurfacing the existing highway within a few years is an option, assuming that a new route around the community will be constructed sometime;
2. Divide the existing highway up to the 3.2 km restricted zone as well as make certain improvements to the urban section which are reasonable, considering the restricted right-of-way. This option may not rule out a new route someday, but will delay it beyond the timing associated with the first option; and
3. Construct a new route around the community now which would be 11 km in length as measured between the same points which are 10.2 km apart via the existing route.

Obviously, if conclusions (economically) were to be reached, capital, maintenance and rehabilitation costs would have to be obtained for each of those options and the timing for future events would also have to be assumed. Further, road user costs would have to include the incremental costs for collisions. However, all of that will be neglected as the objective of this example is to concentrate upon operational and time costs associated with variations in running speeds. Further, flat grades and curves will be assumed requiring no adjusments in the operational costs for those items.

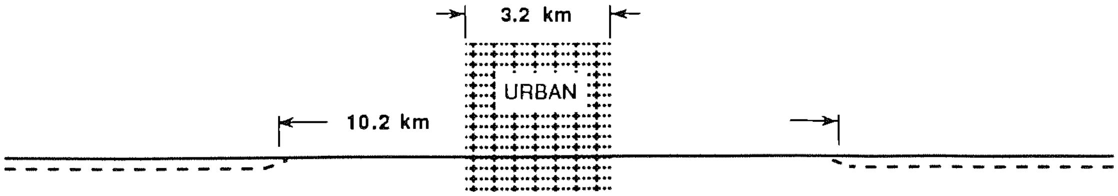
Traffic

Rural Sections

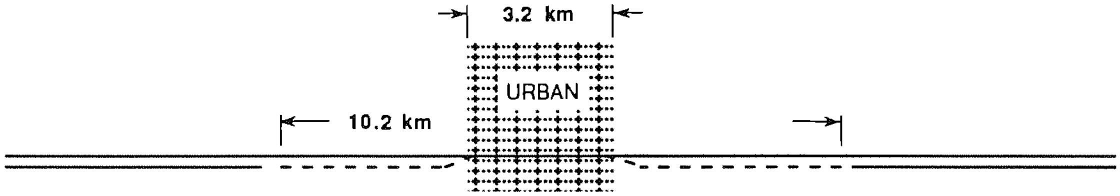
7,000 AADT with this breakdown in classification and occupancy

8 %	Tractor Trailer trucks- 1.2 persons / unit
6 %	Single Axel trucks- 1.2 persons / unit
1 %	Busses- 1 driver and twenty passengers / unit
10 %	Autos (business)- 1.5 persons / unit
75 %	Autos and R Vs- 2.5 persons / unit

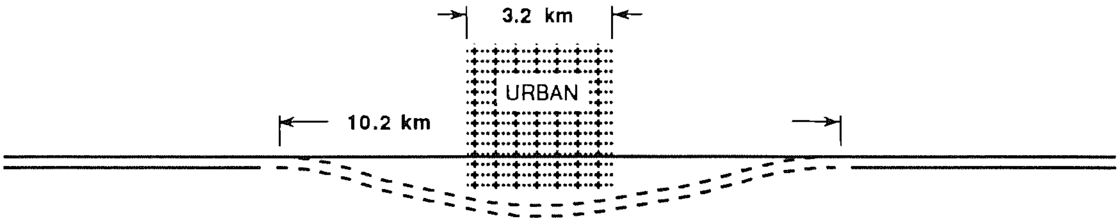
The Three Alternatives



"Do Nothing" Alternative - Leave 10.2 km section as a two lane highway when rural sections are divided.



Widening Alternative - Twin a further 7 km of highway, to the urban limits



New Route - 11 km long between common points

New Route Alternative - Provide a new route around the urban area

Average running speed for all vehicles for most of the time is 103 km / hr. with these exceptions due to slower vehicles and lack of passing opportunities -

	Volume	Restricted Speed
Highest 20 hrs	1,200 vph	70 km / hr.
Next 100 hrs.	950 vph	80 km / hr.
Next 200 hrs.	750 vph	88 km / hr.
Next 400 hrs	600 vph	95 km / hr.
Next 800 hrs	400 vph	100 km / hr.
Remaining 7,246 hrs.	< 350 vph	103 Km / hr.

On average, 10 % of the vehicles (mostly R Vs) in each of these groupings are the numbers restricting the speed.

Assume that same number of vehicles now restricting the speed will continue to travel the same speed after the highway is divided, and all classes of trucks and busses will continue to average 103 km / hr. but the balance will increase speed an average of 8 km / hr. to 111 km / hr.

After multi-laneing both sides of the 10.2 km section being tested, traffic will have the opportunity to pass before and after this relatively short restriction and the numbers of vehicles affected on these short sections are assumed to be only 20 % of those now impeded on the long section. That 20 % applies to the entire 7 km outside of the signed speed zone. More than 20 % of the numbers of vehicles will be impeded but most will be restricted for only a portion of the entire length - e.g. 40 % may be impeded an average of half of the distance.

Urban Section

Good conformance with the 50 Km / hr. posted speed.

On average, 15 % of each class of vehicle on the highway are stopped by the signal.

The red signal phase for highway traffic is one minute.

No highway traffic waits through more than one signal.

For the purpose of calculating travel times, assume deceleration occurs instantaneously for all classes of vehicles, as does acceleration except for tractor trailer units (TRK) For those assume a uniform acceleration rate of 4,000 km / hr / hr when going from a stop to 50 km / hr., and, a uniform rate of 2,000 km / hr / hr when going from 50 km / hr. to 103 km / hr.
NOTE: 4,000 km / hr / hr = 0.309 m / sec / sec.

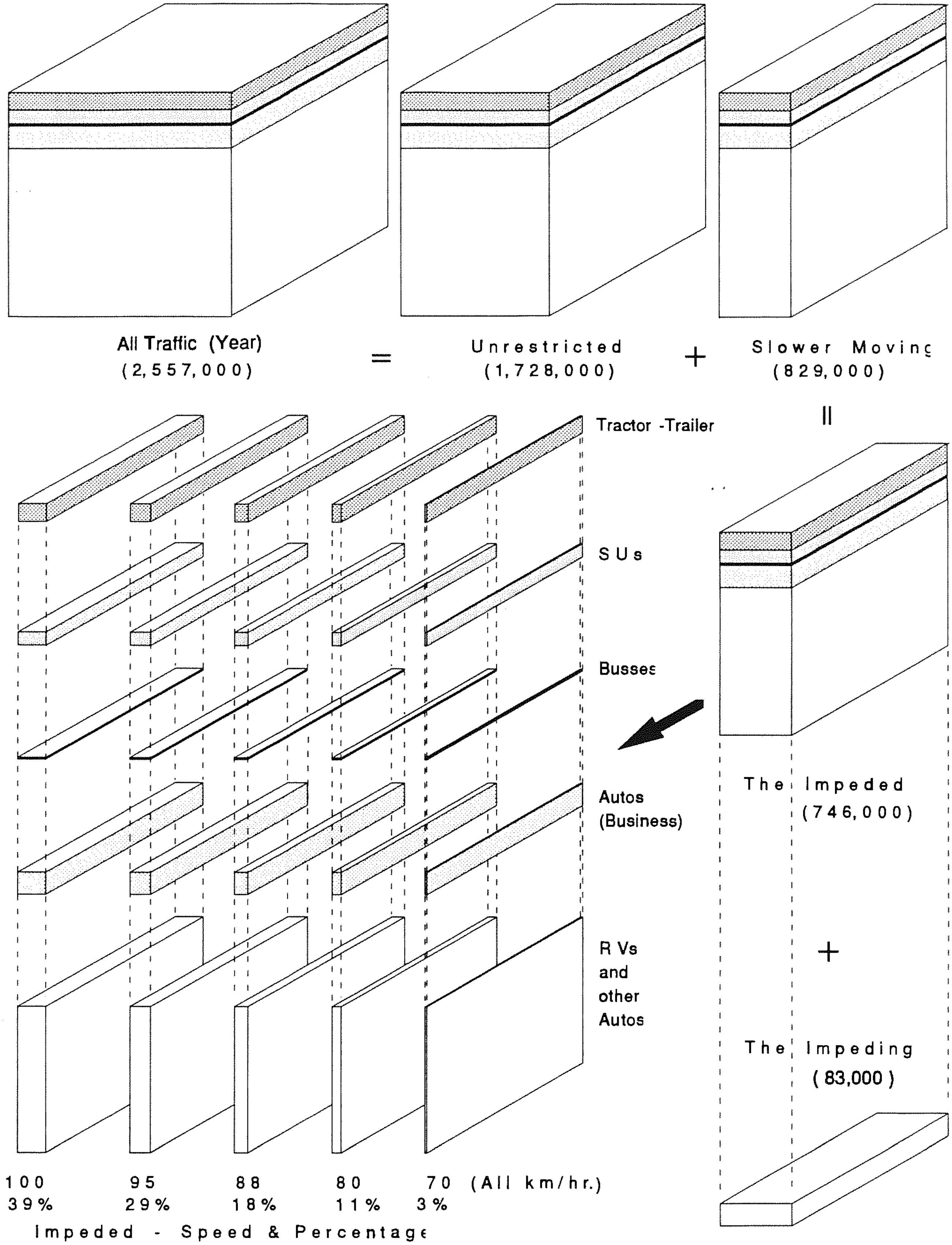
Origin-Destination Data

Thirty percent of all classes of vehicles are destined for or have some reason for entering the community - e.g. 70 % of each class would use a new route, if provided.

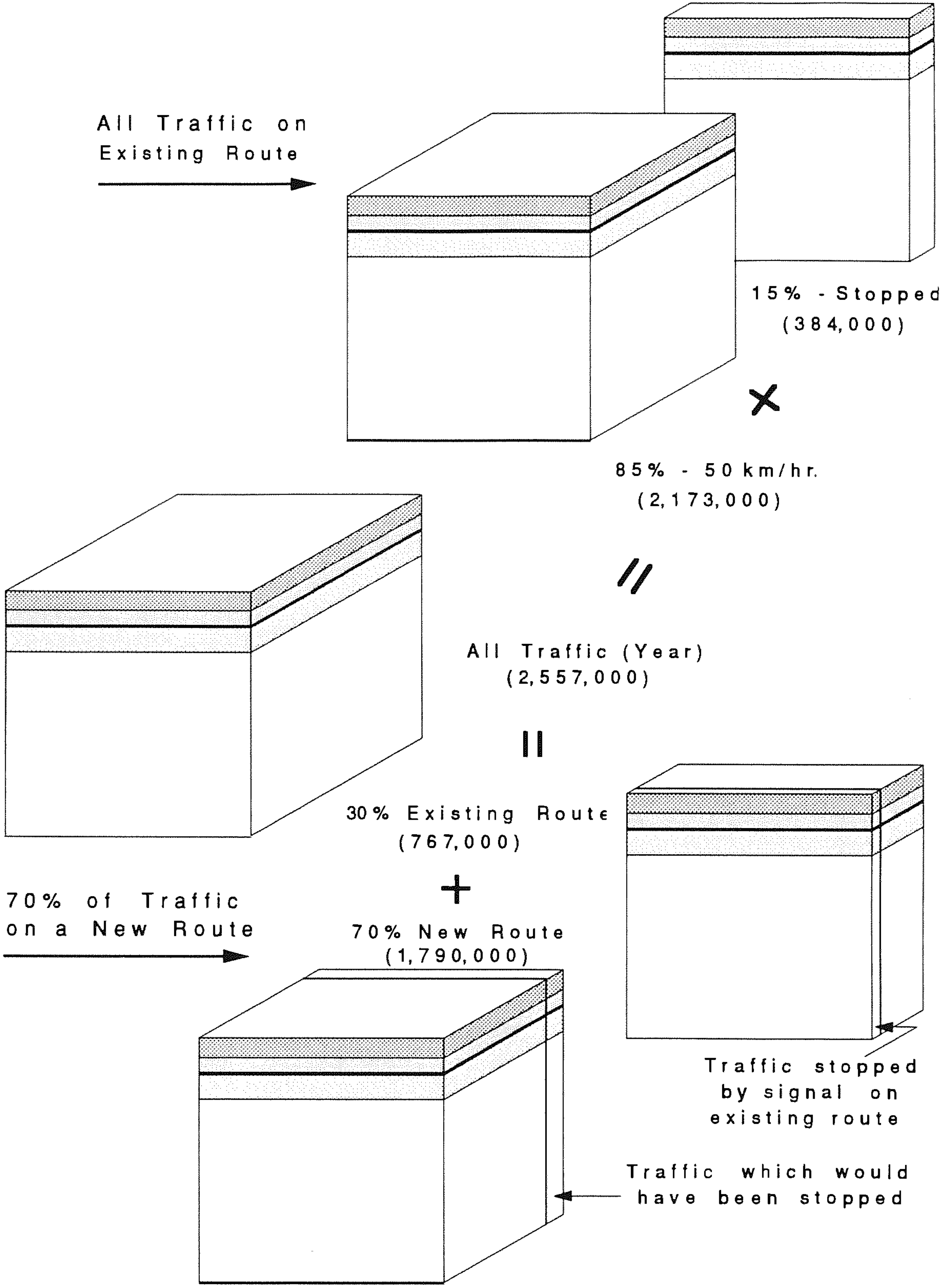
The Future

Again, for simplicity purposes, the calculations included here will be for the base year only (1988 - corresponding to the dollars used). In an actual case, besides recognizing volume adjustments, changes in many other items might be predicted - e.g. the length of speed zone, number of signals and red time for each and changing traffic characteristics with changing volume

The "Rural" Traffic Picture



The "Urban" Traffic Picture



The Solution

For input into the three options outlined, operation and time costs are required for:

1. The existing route with all traffic on it- as it now exists over the 10.2 km section;

2. The existing route, with 7.0 km of it divided with no change which would affect these user costs for the remaining 3.2 km. Again, this alternative would see all traffic on the existing route; and

3. An option in which 70 % of the total traffic is diverted to a free flowing new facility 11 km in length with the assumption that the remaining 30 % would then also operate unimpeded on the 7.0 km rural section (2 lanes with an average running speed of 103 km / hr.) of the old highway but that its operation on the 3.2 km section would be the same as if all of the traffic was still there.

If a more automated procedure was being employed, it may be best to separate the traffic into sufficiently small categories to handle all of the different situations for the entire trip and run total costs to agree with each of those three descriptions.

Here, the procedure is being done manually and it is easier, for some of the items, to work in incremental costs where those that are common to two or all three alternatives can be omitted as cancelling each other when comparisons are made. Rather than following each of the different classes of traffic completely through the different circumstances, the project will be analyzed by different sections with results obtained for the 7.0 km section and the 3.2 km section separately before adding the two. This procedure has the added advantage of illustrating more clearly how each could be handled independently if one did not flow into the other.

More specifically,these steps and procedures will be followed:

The 7.0 km Rural Section

1. The operation and time costs will be calculated for increasing the speed for traffic slowed on this section (20 % of the traffic which is held up on the long two lane sections) to 103 km / hr. That difference in user costs will apply to either widening the existing highway or constructing a new route.

2. The difference in user costs for operating at 111 km /hr. rather than at 103 km / hr.for all auto and R V traffic (except that which is now impeding traffic) will be determined. 100 % of such costs will apply to the widening alternative, and, 70 % will apply to the new route alternative.

3. The costs for added time for tractor trailer (TRK) units due to their slower acceleration (from 50 km / hr. to 103 km / hr.)will be included as an advantage for the new route alternative (70 % of number applies).

4. Excess cost for decel and accel will not be included with these steps but will instead all be included in the calculations for the 3.2 km urban section.

The 3.2 km Urban Section (Used for the new route alternative only)

1. The difference in costs for 70 % of the total traffic will be calculated comparing 50 km / hr. operation on this 3.2 km section to 4.0 km (the new route is 0.8 km longer than the existing) of free flow operation (up to 111 km / hr.)

2. The extra time costs associated with 15 % of 70 % of the total traffic being stopped by the signal will be added.

3. The extra time costs for acceleration (from stop to 50 km / hr.) of the tractor trailer (TRK) units stopped by the signal (15 % of 70 % of the total TRK traffic) will be added.

4. The excess costs for decel and accel. from rural speeds (111 and 103 km / hr.) to either 50 km / hr (85 % of 70 %) or to zero (15 % of 70 %) will be added. No reduction for the numbers slowed by other traffic will be made because the excess costs should apply regardless of the reason for the change in speed.

Preliminary Calculations

Procedural Notes:

1. Some units of cost and time are expressed in amounts per 1,000 vehicles. When that is the case the traffic volumes will be expressed in 1,000 s - e.g. 25,567 might be shown as 25.57.

2. Rounding, except for final result figures will be kept to a minimum - not because all of the figures may be significant (some of the items are just not that accurate), but rather to eliminate confusion as to where the figure may have originated. The more numerals included in a number the less likely that another number will be the same.

3. Some of the final results will be reached only after several intermediate steps with the figures obtained in one calulation being used again in a later step which may be taken several pages later. In order to help track the steps and determine where figures originate, all results which will be used again as input into another calculation will be enclosed in a box. Some steps will produce more than one result and sometimes, for illustrative purposes, those results will be added or subtracted as a final part of that step. Often, the sum or difference will not be used again whereas the figures making up that total will be used later. The boxes will be particularly helpful in keeping the data straight in those cases.

Most of the calculated figures in this section (Preliminary Calculations) will be used and no boxes will be used in this section.

Annual traffic = 365.25 x 7,000 = 2,556,750 vehicles per year
By class - TRK units - 8 % = 204,540
- SUs - 6 % = 153,405
- Busses - 1 % = 25,567
- Autos (business)- 10 % = 255,675
- Autos & R Vs - 75 % = 1,917,562
Total 2,556,749 (checks)

Unit Operating Costs (taken and interpolated from tables produced by Systems Planning)

	1988 operating costs per 1,000 km							
Km / hr. →	50	70	80	88	95	100	103	111
TRKs	243.9	254.4	262.0	267.6	273.3	277.6	282.4	N/A
'103' costs - others	38.5	28.0	20.4	14.8	9.1	4.8		
SUs & Busses	311.4	282.1	280.3	285.8	294.9	302.7	309.9	N/A
'103' costs - others	-1.5	27.8	29.6	24.1	15.0	7.2		
Autos & R Vs	95.6	91.1	92.4	95.3	99.0	102.0	104.5	111.4
'111' costs - others	15.8	20.3	19.0	16.1	12.4	9.4	6.9	
'103' costs - others	8.9	13.4	12.1	9.2	5.5	2.5		

Excess Costs for Speed Change (Formulae based upon 1988 data produced by Systems Planning)

TRK units

Excess Costs / 1,000 units = $(0.327 \times S1 + 2.8)^{1.74} - (0.327 \times S2 + 2.8)^{1.74}]$

Where: S1 = Speed in km / hr. reduced from and returned to; and
S2 = Speed in km / hr reduced to.

SUs & Busses

Excess Costs / 1,000 units = $(0.1936 \times S1 + 1.8)^{1.9} - (0.1936 \times S2 + 1.8)^{1.9}$

Autos & R Vs

Excess Costs / 1,000 units = $(0.0588 \times S1 + 1.4)^{1.9} - (0.0588 \times S2 + 1.4)^{1.9}$

Table of Excess Costs / 1,000 units or occurences

	111 km / hr. to 50 and back to 111	103 km / hr. to 50 and back to 103 .	50 km / hr to stop, and back to 50	Both Ranges Combined
TRKs	N/A	352	164	516
SUs and Busses	N/A	244	100	344
Autos & R Vs	34.8	N/A	14.4	49.2

Extra Time Taken by Tractor Trailer Units for Acceleration / 1,000 units

Stop to 50 km / hr.

Time taken = $t = v \div a$ = 50 km / hr ÷ 4,000 km / hr / hr = 0.0125 hours (per unit)
Distance = $d = 1/2\ a\ t^2 = 1/2 \times 4{,}000 \times 0.0125 \times 0.0125 = 0.3125$ km
Time at 50 km / hr = $d \div v = 0.3125 \div 50 = 0.00625$ hours.
Difference = $0.0125 - 0.00625 = 0.00625$ hours per unit
= 6.25 hours per 1,000 units or occurences

50 km / hr. to 103 km. / hr.

Time = $t = v \div a = 53 \div 2{,}000 = 0.0265$ hours
Distance = $d = v\ t + 1/2\ a\ t^2 = 50 \times 0.0265 + 1/2 \times 2{,}000 \times 0.0265 \times 0.0265$
$= 1.325 + 0.702 = 2.027$ km.
Time at 103 km / hr. = $2.027 \div 103 = 0.0197$ hours
Difference = $0.0265 - 0.0197 = 0.0068$ hours per unit
= 6.8 hours per 1,000 units or occurences.

Summary

Extra time - Stop to 50 km / hr. = 6.25 hours / 1,000
50 to 103 km / hr. = 6.8 hours / 1,000
Stop to 103 km / hr = 13.05 hours / 1,000 (This figure not used again)

Extra Time Required to Travel 1 Kilometre (Hours / 1,000 vehicles)

Compared with -	50	70	80	88	95	100	103
- 111 km / hr.	10.99	5.28	3.49	2.35	1.52	0.991	0.700
- 103 km / hr.	10.29	4.577	2.791	1.655	0.818	0.291	

Average time stopped for the 15 % of traffic facing a red signal - 1 / 2 minute
= 1 / 2 ÷ 60 x 1,000 hrs. / 1,000 veh. = 8.33 hrs. / 1,000 vehicles

Calculations For 7 km Section

1. Operation and Time Costs (Existing compared with 103 km / hr.)

Volumes by hours in a year (All Vehicles)

	Annual Volume	% of Total
20 highest - 20 x 1,200	= 24,000	2.895
next 100 - 100 x 950	= 95,000	11.460
next 200 - 200 x 750	= 150,000	18.094
next 400 - 400 x 600	= 240,000	28.951
next 800 - 800 x 400	= 320,000	38.600
Totals	= 829,000	100

Number required 1,727,750
to add to Total Traffic = 2,556,750

The 1,727,750 volume occurs in the remaining 7,246 hours in the year (average of 240 vehicles per hr.)

Volumes operating at lower speeds by classification.

Classification	% of 829,000	Number (1,000 s)
TRK	8	66.32
SU	6	49.74
Busses	1	8.29
Autos (Business)	10	82.90
R Vs (impeding)	10	82.90
Autos & R Vs - (All others)	65	538.85
Totals	100	829.00

Operating Cost and Time Differences

Unit	Total Volume Restr.	Restr. Speed km/hr.	% of Total Volume	Annual Volume (1,000 s)	Cost Diff. per. 1,000 veh.	Annual Cost Diff.	Time Diff. 1,000 veh.	Annual Time Diff.
TRKs								
	66,320	70	2.895	1.920	28.0	54	4.577	8.79
		80	11.460	7.600	20.4	155	2.791	21.21
		88	18.094	12.000	14.8	178	1.655	19.86
		95	28.951	19.200	9.1	175	0.818	15.71
		100	38.600	25.600	4.8	123	0.291	7.45
Totals				66.320		$ 685		73.02 hrs.
SUs								
	49,740	70	2.895	1.440	27.8	40	4.577	6.59
		80	11.460	5.700	29.6	169	2.791	15.91
		88	18.094	9.000	24.1	217	1.655	14.89
		95	28.951	14.400	15.0	216	0.818	11.78
		100	38.600	19.200	7.2	138	0.291	5.59
Totals				49.740		$ 780		54.76 hrs
Busses								
	8,290	70	2.895	0.240	27.8	7	4.577	1.10
		80	11.460	0.950	29.6	28	2.791	2.65
		88	18.094	1.500	24.1	36	1.655	2.48
		95	28.951	2.400	15.0	36	0.818	1.96
		100	38.600	3.200	7.2	23	0.291	0.93
Totals				8.290		$ 130		9.12 hrs
Autos (bus.)								
	82,900	70	2.895	2.400	13.4	32	4.577	10.98
		80	11.460	9.500	12.1	115	2.791	26.51
		88	18.094	15.000	9.2	138	1.655	24.82
		95	28.951	24.000	5.5	132	0.818	19.63
		100	38.600	32.000	2.5	80	0.291	9.31
Totals				82.900		$ 497		91.25 hrs
Autos & R Vs								
	538,850	70	2.895	15.600	13.4	209	4.577	71.40
		80	11.460	61.750	12.1	747	2.791	172.34
		88	18.094	97.500	9.2	897	1.655	161.36
		95	28.951	156.000	5.5	858	0.818	127.61
		100	38.600	208.000	2.5	520	0.291	60.53
Totals				538.850		$ 3.231		593.24 hrs

Summary of Operation Cost Differences (negative) and Extension of Hours into Dollars

	Operation Costs	Hrs. for Year	Occupancy per Vehicle	Rate per Hour *	Time Cost for Year
TRK	($ 685)	73.02	1.2	24	$ 2.103
SU	(780)	54.76	1.2	24	1,577
Busses	(130)	9.12	1	24	219
			20	6	1,094
Auto (Bus.)	(497)	91.25	1.5	13	1,779
Auto (Other)	(3,231)	593.24	2.5	6	8,899
Totals	($ 5,323)				$ 15,671

* Unit time costs of $ 24.00, 13.00 and 6.00 per hour are approximate values in 1988 dollars originating from rates of 22.00, 12.00 and 5.50 per hour in 1987 dollars as adopted by the Department.

Operation costs are greater at the higher speeds and the total of $ 5,323 per kilometre per year is a charge against improvements and might be subtracted from the $ 15,671 time cost saving for a net saving of $ 10,348 per kilometre per year. (Those figures would be relevant if long sections of the rural standard was being analyzed)

The factor to be applied for the short distance involved in this example is given as 20 % of what would apply for long sections. Cost saving for either improvement alternative is therefore a negative $ 5,323 per km x 20 % = $1,065 / km for operations and a saving of $ 15,671 x 20 % = $ 3,134 / km for time.

For 7 kilometres these costs are: ($ 7,500) for operation; and $ 21,900 for time, a net benefit of $ 14,400 for either alternative.

2. Cost Differences for 111 km / hr. v s 103 km / hr.

Autos and R Vs involved:

255,675 autos (business); and
1,917,562 - 82,900 (those now impeding traffic) = 1,834,662. [1]

Added operation cost at higher speed = (255,675 + 1,834,662) x $ 6.9 / 1,000 = ($ 14,423)per year per kilometre.
For 7 kilometres = (14,423) x 7 = ($ 101,000)

Time cost saving = 255,675 x 0.700 hrs. / 1,000 x 1.5 x 13 = $ 3,490
plus 1,834,662 x 0.700 / 1,000 x 2.5 x 6 = $ 19,260
Total time savings $22,750
For 7 km = 22,750 x 7 = $ 159,250

For the widening alternative, operation costs increase ($ 101,000) and time costs decrease $159,300, a net benefit of $ 58,300 for widening.

For a new route the cost differences are 70 % of those figures (70 % of the traffic would use new route):

Operation costs would increase by ($ 70,700) and time costs would decrease by $ 111,500, for a net benefit of $ 40,800.

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[1] There is insufficient information to be completely precise for this item - see page 90 for a further analysis of this item.

Net cost saving for the widening alternative = Item 1 + Item 2 = \$ 14,400 + 53,400 = \$ 67,800 per year.

3. Added time cost for truck accel. - 50 to 103 (benefit for new alternative)
   = volume x 70 % x hours / 1,000 veh. x occupancy x cost per hr.
   = 204,540 x 0.7 x 6.8 / 1,000 x 1.2 x 24 = \$ 28,040 per year.

   Use \$ 28,000 as an advantage for a new route in the summary figures for this item.

   These figures will be summarized again, however the total benefits for constructing a new route steming from operation and time costs on the 7 km section are: Item 1, plus the 70 % figure for Item 2, plus Item 3 = \$ 14,400 + 37,400 + 28,000 = \$ 79,800.

Calculations for the 3.2 km Urban Section

To the \$ 79,900 per year benefits calculated above for the new route alternative, these additional user costs savings must be added.

1. Difference in costs for 70 % of the traffic. (50 km /hr for 3.2 km v s 111 and 103 km / hr. for 4.0 km)
   Tractor Trailer Units
   Annual volume - 204,540 x 70% = 143,200
   Operating cost @ 50 = 143,200 x 243.9 / 1,000 x 3.2 = 111,800
   @ 103 = 143,200 x 282.4 / 1,000 x 4.0 = 161,800

   Difference = (\$ 50,000) per year extra cost for new facility

   Note: Total costs are easier to deal with than incremental costs in these calcullations because the distances are different.

   Time cost @ 50 = 143,200 x 3.2 ÷ 50 x 1.2 x 24 = 263,900
   @ 103 = 143,200 x 4.0 ÷ 103 x 1.2 x 24 = 160,200

   Difference = \$ 103,700 per year less for new facility.

   SUs and Busses (same operating costs)
   Volume = (153,405 + 25,567) x 0.7 = 125,280 vehicles per year
   Operating costs @ 50 = 125,280 x 311.4 / 1,000 x 3.2 = 124,800
   @ 103 + 125,280 x 309.9 / 1,000 x 4.0 = 155,300

   Difference = (\$ 30,500) per year extra cost for the new facility

   Time costs - SUs = 153,405 x 0.7 x 3.2 ÷ 50 x 1.2 x 24 = 197,900
   less time on new = 153,405 x 0.7 x 4.0 ÷ 103 x1.2 x 24 = 120,100
   Difference = \$ 77,800
   - Busses = 25,567 x 0.7 x 3.2 ÷ 50 x [24 +(20 x 6)] = 164,900
   less time on new = 25,567 x 0.7 x 4.0 ÷ 103 x [24 + (20 x 6)] =100,100
   Difference =\$ 64,800 per year

   Difference for SUs and Busses = 77,800 + 64,800 = \$142,600 per year less for new facility.

Autos and R Vs

Volume = all except those continuing to go slower
= 255,675 (business) + 1,917,562 (others) - 82,900 = 2,090,337
[actually 255,675 (business) and 1,834,662 (other)]
Operating cost @ 50 = 2,090,337 x 0.7 x 95.6 / 1,000 x 3.2 = 447,600
@ 111 = 2,090,337 x 0.7 x 111.4 / 1,000 x 4.0 = 652,000

Difference ($ 204,400) per year more to operate on a new facility

Time costs
Business = 255,675 x 0.7 x 3.2 ÷ 50 x 1.5 x 13 = 223,400
less 255,675 x 0.7 x 4.0 ÷ 111 x 1.5 x 13 =125,800
Difference 97,600
Other = 1,834,662 x 0.7 x 3.2 ÷ 50 x 2.5 x 6 = 1,232,900
less 1,834,662 x 0.7 x 4.0 ÷ 111 x 2.5 x 6 = 694,200
Difference 538,700

Total auto & R V Time cost saving for new route = 97,600 + 538.700 = $ 636,300 per year

Summary of Costs (50 km / hr. v s 103 and 111 km / hr.

	Additional Operation Costs for New Route	Savings in Time Costs for New Route
TRK	$ 50,000	$ 103,700
SUs & Busses	30,500	142,600
Autos & R Vs	204,400	636,300
Totals	(284,900)	882,600

Net Cost savings for new route = 882,600 - 284,900 = $ 597,700

2. Time Costs for Stopping at Signal (Incremental volumes = 15 % of 70 %)
TRK = 204,540 x 0.7 x 0.15 x 8.33 hrs. / 1,000 x 1.2 x 24 = 5,152
SUs = 153,405 x 0.7 x 0.15 x 8.33 hrs. / 1,000 x 1.2 x 24 = 3.864
Busses = 25,567 x 0.7 x 0.15 x 8.33 hrs. / 1,000 x [24 +(20 x 6)] = 3,220
Autos (Bus) = 255,675 x 0.7 x 0.15 x 8.33 / 1,000 x 1.5 x 13 = 4,361
Autos (other) & R Vs = 1,917,562 x 0.7 x 0.15 x 8.33 / 1,000 x 2.5 x 6 = 25,158

Total Costs for time while stopped at signal $ 41,800 per year

3. Extra Time Costs for Tractor Trailer Units Accelerating from Stop to 50 km / hr.
TRK volume affected = 204,540 x 70 % x 15 % = 21,477
Time involved = 6.25 hrs. / 1,000 occurences.

Cost = 21,477 x 6.25 / 1,000 x 1.2 x 24 = $ 3,900

4. Excess Costs for Decel and Accel
TRKs - 103 to 50 and return = 204,540 x 0.7 x 0.85 x 352 / 1,000 = 42,800
103 to stop and return = 204,540 x 0.7 x 0.15 x 516 / 1,000 = 11,100
Total TRKs 53,900

4. Excess Costs for Decel and Accel (continued)

SUs & Busses - 103 to 50 = 178.972 x 0.7 x 0.85 x 244 / 1,000 = 26,000
103 to stop= 178,972 x 0.7 x 0.15 x 344 / 1,000 = 6,500
Total - SUs & Busses 32,500

Autos & R Vs except slower ones
Volume = 255,675 + 1,917,562 - 82,900 = 2,090,337
111 to 50 = 2,090,337 x 0.7 x 0.85 x 34.8 / 1,000 = 43,300
111 to stop = 2,090,337 x 0.7 x 0.15 x 49.2 / 1,000 = 10,800
Total - Autos & R Vs 54,100

Summary of Excess Costs for Decel. and Accel.

TRKs	$ 53,900	
SUs & Busses	32,500	
Autos & R Vs	54,100	
Total		$ 140,500

Project Summaries

Descriptions	Annual User Cost Savings (1988 dollars) Vehicle Operation	Time	Total	
Twinning 7 km of Existing Route				
Increase speed to 103 km / hr.	$ (7,500)*	$ 21,900	$ 14,400	
Increase Autos to 111 km / hr.	(101,000)	159,300	58,300	
Totals	(108,500)	181,200		**$ 72,700**
New Route				
7 km Section				
Increase speed to 103 km / hr.	$ (7,500)	$ 21,900	$ 14,400	
Increase Autos to 111 km / hr. (70 % of above figures)	(70,700)	111,500	40,800	
Truck Accel time savings	-	28,000	28,000	
Totals (7 km Section)	(78,200)	161,400		83,200
3.2 km Section (4.0 km on new route)				
Running Costs and Time Costs	(284,900)	882,600	597,700	
Time stopped by signal	-	41,800	41,800	
Extra Time for Truck Accel.	-	3,900	3,900	
Excess Costs for Decel & Accel.	140,500	-	140,500	
Totals (3.2 km Section)	(144,400)	928,300		783,900
Totals (both sections)	(222,600)	1,089,700		**$ 867,100**

* Brackets indicate that costs are greater if travelling on the new route.

A Note About Traffic Data

The footnote on page 86 makes reference to this page and this note relates to the calculation on that page and other subsequent calculations.

Traffic and its analysis can be a very complicated matter and while the information given for this example is extensive, there remain some unanswered questions.

One of the assumptions given is that 10 % of the vehicles in slower moving hours of the year (1,520 hours) wish to travel at that slower speed which would involve 82,900 vehicles in a year. This raises a question about how many vehicles would travel at slower speeds in the 7,246 hours of the year (over 1.7 million vehicles involved) when no restriction is assumed - e.g. passing opportunities provide operational freedom most of the time.

While a higher proportion of slower moving vehicles might be expected during the popular, more heavily travelled portions of the year, there is no doubt that the numbers during the other 83 % of the time when two-thirds of the year's volume occurs, is significant. The important question, in an analysis, is how significant the error might be in the results by simply ignoring the balance of the slower moving vehicles. The subject gets even more involved if one interprets the given 10 % which actually restricts the speed as not being the total number of slower moving vehicles during those hours of the year neither. There may, for example, be drivers who would travel 95 km / hr. if free to do so but are one of the vehicles being held to 88 km / hr. by other traffic. An overstatement of the benefits resulting from driver freedom is made if it is assumed that the 95 km / hr. driver desires to travel at 103 or 111 km / hr. That consideration will continue to be ignored and might be placed in the same category as other refinements discussed near the end of this section.

Those issues and questions highlight the need for dialogue between analyst and the people supplying the traffic data. In complicated traffic situations the traffic people will have to be given the details of the problem being analyzed to provide good information for the analysis. They may not have all of the answers, however, one working with traffic on a continual basis will be able to make better assumptions about how to handle items for which the available data is not the best.

In an attempt to reach some conclusion about the significance of likely errors in the results calculated for this example, without taking another fifteen pages for calculations, it would be simple to approximately test the variance which would result if 10 % of the traffic in the 7,246 hours of the year operate like the restricting traffic and are also travelling at the same speed as they would if the highway were improved. The assumption is that R Vs are involved and the adjustment would therefore be made in the auto and R V category. The net benefit for increasing the speed from 103 to 111 km / hr. for that category of vehicles (1,834,662 in number) was calculated to be $ 7,627 per year per kilometre ($ 53,400 for 7 kilometres). (Page 11) The total number of vehicles involved in the 7,246 hrs would be 2,557,000 - 829,000 = 1,728,000 and the benefit for that number would be 1728 ÷ 1835 x 53,400 = $ 50,300. Ten percent of that would be about $5,000 which would be about a 7 % "overestimate" of the total benefit of $ 67,800 attributed to the widening alternative.

That $ 5,000 variance would also apply to the new route alternative but determining the total effect on that alternative is more difficult. For starters, in greater detail than already calculated, there are compensating variances in the calculations for the new route comparison.

It should be asssumed that 70 % of the traffic which was deemed to be "holding up" traffic on the rural sections (82,900 vehicles in the 1,520 hour portion of the year) would take the new route and benefit from the various speeds desired compared to 50 km / hr. operation in the urban area. Those following this example in detail will have wondered why these 58,000 vehicles were not accounted. Their omission compensates (maybe over compensates) for the benefits for the other portion of the year being high by virtue of ignoring further slower moving traffic.

Without showing the calculations, the extra cost for 70 % of the 82,900 R V's travelling the speed desired on four kilometres of the new route compared to travelling 3.2 kilometres at 50 km / hr. is $ 3,900 for 1988 and the savings in time is $ 18,100. The time saving for 15 % of that traffic not having to stop for the signal was included in the original calculations and hence needs no change here. The net saving is thus $ 14,200 for that year, for this item.

As calculated originally the 1,834,662 autos and R Vs (not including "business")gave a net benefit for the new route of $ 538,700 for time less 1,834,662 ÷ 2,090,337 x $ 204,400 for operating = $ 359,300. Removing 172,800 vehicles from that calculation would reduce that benefit by $ 33,800, however they (those vehicles) should then be considered separately just as the 82,900 vehicles were in the previous paragraph which would result in a benefit of 172,800 ÷ 82,900 x $14,200 = $ 29,600. The net overstatement of benefits, due to this factor, is therefore a small $ 4,200 and when added to the $5,000 (calculated for both alternatives) gives a total over statement of benefits of $9,200. The omission of $ 14,200 of benefits did, therefore, overcompensate and the benefits for the new route were slightly undervalued ($5,000 in $ 867,100).

The difference in cost (benefit) of $4,200 for 172,800 vehicles seems small when considering the difference for increasing their speed from 50 km / hr. to 111 km / hr. v.s. increasing speed to between 70 and 100 km / hr. Two points, at least, are relevant to this comparison:

1. Over one-third of the traffic in the 70 to 100 calculation is assumed to be travelling at 100 km / hr. and the difference will not be as great as it would be if the volume was spread uniformly over the 70 to 100 range. In fact the average running speed for the 82,900 vehicles is calculated to be 93 km / hour; and
2. The assumed speeds for these R Vs are in a more efficient speed range and the negative part of the results are proportionately smaller for these ranges than for the 111 km / hr. speed. For the 1,834,662 volume group, negative costs are ($ 197,000), more than 1 / 3 of the $ 538,700 benefits. For the 82,900 volume, the increase in operational costs are only ($ 3,900) for comparable benefits of $18,100 - a ratio between 1 in 4 and 1 in 5.

The heavier traffic volumes concentrated near the higher speed end of the 70 to 100 km / hr. range for the slower moving traffic also lends credibility to the average running speed given as 103 km / hr. This part of the traffic with an average speed of 93 km / hr. and being an assumed 10 % of all traffic would mean that the balance of the traffic would have to average only slightly more than 103 km / hr. (approximately 104 km / hr.) to give that overall average.

That comment raises another analytical point - if the 70 to 100 volume portion of the traffic for the 7,246 hour portion of the year is to be treated separately, should one then use an average speed of 104 km / hr. (e.g, a 7 km / hr. difference from 111 km / hr.) when dealing with the balance of the traffic ? These comments and observations are getting progressively more "picky" and might likely be forgotten on the basis that one is thinking in more precise terms than the accuracy of the original assumptions warrant. Perhaps the new speed will be 112 instead of 111, for example. It is however an interesting point from a theoretical perspective.

Also considered along the same theme, is a question which may be raised about the assumption that the impeding trafic (and slower moving traffic in the balance of the year also) will travel at the same speed after twinning as driven on the two-lane, two-way highway. It might be just as reasonable to assume that it will, on average, increase speed also - not as much as the balance, perhaps, but some.

How sophisticated the analysis dealing with traffic can become will be limited by the information available for the specific case at hand, or upon the assumptions which those experienced in traffic analysis dare to make.

Glossary of Selected Terms, Abbreviations and Acronyms

General Terms

Allocative costs - values assigned and used in a benefit cost analysis. Allocated costs (or benefits) may not be the same as market values. See "imputed values".

Benefit Cost Analysis - a systematic approach to evaluation and assessment comparing the stream of quantifiable benefits generated over the life of a project or program to the cost of initiation and subsequent maintenance.

Consumer Surplus - as used in this text - the amount that the satisfaction from consumption exceeds the cost.

Diminishing Return - in terms of benefits and costs, diminishing returns refers to the circumstance in which the benefit resulting from each additional unit of production is less than the benefit from the previous one (assuming the unit cost of production does not change). These terms might also apply to a program involving numerous individual projects wherein the benefit/cost ratio or the rate of return for each additional project undertaken is less than what it was for the previous project.

Economic efficiency - described in various terms:
- when total benefits over the life of the project exceed total costs; and
- production and consumption being greater with the project than without.

(also see "potential Pareto improvement")

Homogeneous - homogeneous and homogeneousness are used in the context of describing the consistency of input factors and establishing project parameters. The more that any specific factor varies within the project, the greater the case for splitting the project into smaller units, to gain homogeneousness

Imputed value - a value or price assigned to an item which does not have an established market value or the adjusted price of an item that does have a market value. Synonymous with "shadow price" as used in this text.

Incremental value - generally used in this document to refer to the difference in values between items involved in "doing nothing" or "doing a minimum" (base cases) and the value of items in some alternate project or course of action. Also applies to the difference in values of items of two different alternatives when it is desirable to compare those alternatives, one to the other.

Market value - the value or price of an item as established in the market place.

Opportunity cost - the cost of an item based upon the resources used or needed and valued in accordance with their (the resources) best alternate use.

Potential Pareto improvement - a social welfare criteria relating to efficiency. A potential Pareto improvement means that the total value of gains resulting from a project or activity potentially exceed the related losses. See "economic efficiency".

Shadow price - see "imputed value".

Related Terms Grouped Under Specific Headings

Dollars

Constant dollars - dollar values remaining the same even though price levels may change (typically increase or inflate). Often referred to as "inflation free" dollars.

Current dollars - dollar values changing in accordance with changes in price levels. If using "current dollars", future values will be higher than present values by the amount of inflation over the time interval involved.

Interest and Discount Rates

Nominal interest rate - the absolute rate at which invested wealth grows. "Prime" interest rate and "investment" interest rate have also been used in this document to mean the same thing.

Real interest rate - the rate at which wealth grows over and above price changes (inflation). Four percent (4 %) is being used as the average, long term "real" interest rate.

Note: Nominal interest rates are associated with Current dollars and Real interest rates are associated with Constant dollars.

Discount rate - the rate of interest used to adjust future values to present values.

Social discount rate - as used in these documents, the social discount rate refers to the interest rate which is appropriate to use in the analysis for a public works and will be the same value as the "minimum attractive rate of return" - see MARR. The absolute value depends upon the kind of dollars used, e.g. "constant" v.s. "current".

Depreciation, Salvage Values and Sunk Costs

Sunk Costs - expenditures made prior to a benefit - cost analysis being done that cannot be recovered and are, therefore, not relevant in the analysis.

Depreciation - the loss in value of an item over time, generally including physical wear and tear and obsolescence. In the case of the operation portion of road user costs, in these analyses, the most relevant costs are those associated with actual use of vehicles and the portion of depreciation related to the passage of time and obsolescence is excluded.

Salvage values - salvage values, terminal values and residual values are treated as being synonymous terms in this text and they all refer to an item or portion of an item which will no longer be required for its original or past purpose but will have certain value in an alternate future use. For analyses involving long periods (50 years), salvage values can generally be ignored on the basis of being insignificant.

Abbreviations and Acronyms

General

B-C - Benefit cost as used in Benefit - Cost analyses
B/C - Benefit cost as used in Benefit Cost ratio
Cap. - Capital amount (used on some figures)
Maint. - Maintenance (used on some figures)
MARR - Minimum Attractive Rate of Return
Recap - Resurfacing of a paved roadway
Rehab. - Rehabilitation (used on some figures)
Restr. - Restricted (used in some tables)
RTAC - Roads and Transport Association of Cananda
RUC - Road user costs
SPCSP - Large diameter culvert (used in culvert example)

Benefic Cost Analysis Results

B/C ratio - Benefit cost ratio
EUAC - Equivalent Uniform Annual Costs
IRR - Internal Rate of Return
NPV - Net Present Value, or Net Present Worth

Traffic Related Terms

AADT - Average annual daily traffic
PD - Property damage
PDO - Property damage only
PV - Passenger vehicle
RV - Recreation vehicle
SU - Single axel truck
TRTL - Tractor trailer truck (TRK also used in one example)
veh. - vehicle (used in some examples)

Interest Formulae

A - Annual amount as in a series of uniform annual amounts
CA - Compound amount factor
CR - Capital recovery factor
F - Future amount
i - interest rate
n - number of periods
P - Present amount
PW - Present worth factor
SCA - Compound amount factor for a series
SF - Sinking fund factor
SPW - Present worth factor for a series

Appendix A

Lists of
Committee Members

TASK FORCE MEMBERS

	TITLES AT TIME WHEN TASK FORCE WAS MEETING
G. A. Berdahl	Executive Director, Engineering
N. Boyd	Executive Director, Bridge Engineering
D. J. Bussard	Regional Director, Region 3
L. Charach	Director, Planning & Analysis Branch
** M.M. Duncan	Executive Director, Corporate Planning Services
J. Glowach	Executive Director, Regional Transportation
R. R. Hogg	Director, Safety Branch
K. E. Howery	Executive Director, Operational Planning
R. L. James	Executive Director, Financial Services
B. W. Kathol	Regional Director, Region 2
D. R. McTavish	Director, Information Services
C. Procuik,	Executive Director, Motor Transport Branch
H. Wilson	Executive Director, Equipment Branch
M. Znak	Director, Municipal Utilities Branch

BENEFIT-COST GUIDELINES GROUP

Grant Bridgeman
Ken Dmytryshyn
Ken Holmes
** Ken Howery
Darius Kanga
Peter Kilburn
Allan Lo
Neil McKay
Don McTavish
Doug Malcolm
Brian Marcotte
Richard Orrell
Frank Perich
Bryan Petzold
Dick Sawchuk
Joe Schlaut
Ralph Walters
Albert Williams
Gordon Zack

** CHAIRPERSONS

Appendix B

Interest Formulae
and
Examples

INTEREST FORMULAE

&

EXAMPLES

Ken Howery
June, 1987
Revised:
December, 1988,
and, June, 1991

LIST OF CONTENTS

TIME IS MONEY

COMPOUND AMOUNT

$ 1000.00 is invested at 8.5 % interest per annum.

After one year principal plus interest = $ 1085.00
[1000.00 x $(1 + i)$ where i = interest rate]

After two years, providing the first year's interest is also invested at 8.5 % interest, the original 1000.00 will grow to 1085.00 x $(1+ i)$ = 1085.00 x 1.085 = $1177.225

GENERAL FORMULA $\boxed{F = P (1 + i)^n}$

where: **F** = future amount

P = original principal

i = interest rate per period **n**

TABLES - Compound Amount (CA) factors $(1 + i)^n$ are available in tables and for 8.5 %, the Compound Amount for 2 periods (2 years in the above sample) is 1.177225. Multiplying that factor by $ 1000.00 gives $ 1177.225.

PRESENT WORTH

The Present Worth of a future sum can be calculated by reversing the procedure for determining the Compound Amount.

$1177.225 is to be received 2 years hence and discounting that amount at 8.5 % per annum would result in an amount of 1177.225 ÷ 1.085 = $1085.00 one year hence.

Discounting another year to bring it to Present Worth requires dividing by $(1 + i)$ again and 1085.00 ÷ 1.085 = $1000.00

GENERAL FORMULA

$$\boxed{P = \frac{F}{(1 + i)^n}}$$

where: **P** = Present Worth

F = Future amount

i = interest rate per period **n**

TABLES - Present Worth (PW) factors $\frac{1}{(1 + i)^n}$ are available in tables and for 8.5 %, the Present Worth factor for 2 periods is 0.849455. Multiplying that factor by $ 1177.225 gives a Present Worth of $ 1000.00.

COMPOUND AMOUNT FOR A UNIFORM SERIES

$ 1000.00 is received each year for 3 consecutive years and these sums, as well as the interest earned on these, all are invested at 8.5 % interest per annum.

At the time of receiving the 3rd sum, the first year's sum will have been invested for 2 years and will have a Compound Amount of ....$ 1, 177.225
The 2nd sum will have earned interest for one year and have a value of 1, 085.00
The 3rd sum, just received, will have earned no interest 1, 000.00

TOTAL $ 3, 262.225

GENERAL FORMULA

$$\boxed{F = A \frac{(1+i)^n - 1}{i}}$$

where: **F** = Future Amount

A = periodic amount (annual)

i = interest rate per period **n**

TABLES - Factors for Compound Amounts for a Series (SCA) are available in the 3rd column of standard tables and for 8.5%, the factor for 3 payments is 3.262225.

Multiplying that factor by the amount of each payment (1000.00) gives the same figure as the "TOTAL" above.

SINKING FUND

Three years hence a sum of $3,262.225 is to be accumulated and it is desired to raise that amount by contributing three equal sums - one a year from now, another two years from now and the final one in three year's time. Each sum will earn interest at the rate of 8.5% per annum and the interest will earn interest at the same rate.

In essence, this is the same as the example given for the Compound Amount for a Uniform Series.

1st 1000.00 will earn compound interest for 2 years = $1, 177.225
2nd 1000.00 will earn interest for 1 year = 1, 085.00
3rd 1000.00 will earn no interest = 1, 000.00

ACCUMULATED TOTAL $3, 262.225

GENERAL FORMULA

$$\boxed{A = \frac{F}{\frac{(1+i)^n - 1}{i}} = \frac{Fi}{(1+i)^n - 1}}$$

where: **A** = Periodic payment (annual)

F = Future amount

i = interest rate per period **n**

TABLES - Sinking Fund (SF) factors can be found in the 4th column of tables. In the table for 8.5 % the SF factor for 3 periodic sums is 0.306539.

Multiplying $ 3262.225 x 0.306539 gives $ 1000.00.

PRESENT WORTH OF A UNIFORM SERIES

1000.00 is to be received one year from now, and 2 year's hence another 1000.00 is to be received. Using a discount rateof 8.5 % per annum, the first 1000.00 has a present worthequal to

$$\frac{1000.00}{1+i} = \frac{1000.00}{1.085} = \$\,921.659$$

The 2nd 1000.00 has a present worth equal to

$$\frac{1000.00}{(1+i)^2} = \frac{1000.00}{1.085^2} = \$\,849.455$$

Present Worth of the Series $1,771.114

GENERAL FORMULA

$$\boxed{P = A\,\frac{(1+i)^n - 1}{i\,(1+i)^n}}$$

where: **P** = Present Worth

A = periodic sum (annual)

i = interest rate per period **n**

TABLES - Calculating the Present Worth of a Uniform Series can be done (as above) by treating each sum individually and discounting it by the appropriate number of years, using the factors under the column "PW" of tables. This is obviously laborsome if the series extend over a number of years and the Present Worth for a Series (SPW) factors can be used instead - column 5 in the Tables. For 8.5 % the factor from this column for two sums is 1.771114. This factor multiplied by 1000.00 gives the same amount as above.

CAPITAL RECOVERY

A debt of \$1,771.114 which is accumulating interest at the rate of 8.5 % per annum is to be paid in two equal installments - the first in one year's time and the 2nd two year's hence.

After one year and at the time of the first payment, the debt will have grown to \$1,771.114 x 1.085	= \$1,921.659
The initial debt in this example (1771.114) is the present worth of two periodic payments of 1000.00 each as calculated in the last example. Therefore test an installment amount of	\$1,000.00
Balance remaining after 1st payment	\$ 921.659
In one year's time with interest, that balance will become 921.659 x 1.085	= 1,000.00
Less 2nd installment	= 1,000.00
which retires the debt.	

GENERAL FORMULA

$$\boxed{A = P \frac{i(1+i)^n}{(1+i)^n - 1}}$$

where: **A** = periodic sum (installment payments)
P = Present worth (of debt)
i = interest rate per period **n**

TABLES - Capital Recovery (CR) factors are presented in the last column of the tables and for 8.5 % the factor for two periods is 0.564616, and 0.564616 x \$ 1,771.114 = \$ 1, 000.00 .

TERMS AND RELATIONSHIPS

"PRIME" Interest Rate = Real Interest Rate + Inflation Rate

The rate of inflation and the interest gained or charged on the most secure type of investment or loan move up and down, however, the spread between the two - the Real Interest Rate - historically has remained relatively constant. The relationship between these three specifically defined factors, in economic terms, will not be used directly by the analyst, nonetheless, it is an important formula to remember because one almost the same will be used. Both the analyst and decision maker will wish to weigh results and may find that comparisons with the Real Interest Rate or the Prime Interest Rate of the day is helpful in judging the economic merits of the project being worked upon.

Real Rate of Return

"Time is Money" headed the interest formulae section and a good example of that is one who is prepared to give up something today providing he can have more of the same at a later date.

100 apples are given to a neighbor this year on condition that the neighbor return 103 1/3 apples next season. Assuming the apples are equally good, the neighbor making the loan has received 3 1/3 apples in return for foregoing the enjoyment of 100 apples for one year.

The real rate of return is 3 1/3 %.

Assume, instead, that the 100 apples are sold with payment in cash to be received one year hence. Assume also that the price of apples is now $1.00 each and that price will increase (inflate) at the rate of 5% - each apple will cost $1.05 a year from now. To receive a real rate of return of 3 1/3 % or to be able to purchase 103 1/3 apples one year hence, an amount of $1.05 x 103 1/3 or $1.085 will be required.

Interest at the rate of 8.5 % will have to be charged to receive
a real rate of return of 3 1/3 % when inflation is 5 %.

The formulae, in words, which fits these figures are:

Value after one period = initial value (1 + real rate of return) (1 + inflation rate)
and, Value after one period = initial value (1 + interest rate)

1 + interest rate = (1 + real rate of return) (1 + inflation rate)

$$\therefore \boxed{\text{interest rate} = \text{real rate of return } (1 + \text{inflation rate}) + \text{inflation rate}}$$

$$\text{and} \quad \boxed{\text{real rate of return} = \frac{\text{interest rate - inflation rate}}{1 + \text{inflation rate}}}$$

USING THE REAL RATE OF RETURN

An article now costing \$100.00 which will increase in cost at the rate of 5 % per year (inflation) will be purchased 5 years from now.

What is the present worth of that future expenditure assuming an interest rate of 8.5 % ?

The Hard Way

Cost of article 5 years hence

$= 100.00 \times (1.05)^5 = 100.00 \times 1.27628 = \$127.63$

Present Worth of \$ 127.63 discounted at 8.5 % for 5 years

$= 127.63 \div 1.085^5 = 127.63 \div 1.50366 = \$ 84.88$

The Easy Way

Present Worth of \$ 100.00 discounted at 3 1/3 % for 5 years

$= 100.00 \div 1.03333^5 = 100.00 \div 1.17814 = \$ 84.88$

Using the REAL RATE OF RETURN eliminates the effects of inflation. For the purpose of discounting, future values can be assumed to be the sameas present values - just as if there was no inflation.

If inflation is built into the equation and "present day dollars" are used for discounting, the results will be expressed in terms of the “real rate of return”.

Example Using Both Interest Rates

Assume that gold will increase in value in line with general inflation at the rate of 5% and a loan of 1 oz. of gold is made with repayment to be in four equal annual payments of 0.271175 oz. of gold commencing one year after the date of the loan.

That particular repayment amount was chosen because it is the reciprocal of 3.687658 which is the present worth factor of a series for four years discounting at the rate of 3 1/3 %.

By design, the real rate of return = 3 1/3 % for this loan.

This corresponds to an interest rate = 8 1/2 % if dealing in inflated dollars.

If dealing in dollars, the equivalent figures would be a $ 500 loan (assuming gold has a present value of $ 500 per oz., and

1st year's payment = 0.271175 x $500 x 1.05 = $142.37
2nd year's payment = " x " x $(1.05)^{2}$ = 149.49
3rd year's payment = " x " x $(1.05)^{3}$ = 156.96
4th year's payment = " x " x $(1.05)^{4}$ = 164.81

If the formula "interest rate = real rate of return (1 + inf. rate) + inf. rate" works, one would expect the above four payments to have a present worth of $ 500 if discounted at the rate of 3 1/3 (1 + 0.05) + 5 = 8 1/2 %.

142.37 : 1.085 = 131.22
149.48 : $(1.085)^{2}$ = 126.98
156.95 : $(1.085)^{3}$ = 122.88
164.81 : $(1.085)^{4}$ = 118.92

Total = $ 500.00

A FURTHER STEP - A FURTHER APPLICATION

Assume that the quantity of an item is increasing at the rate of 2 % per year and inflation is 5 % per annum. The cost or benefit of this item is increasing in two ways - the unit price is inflating and the number of units is increasing. Each year the value of this item increases by 1.02 x 1.05 or 1.071 or 7.1 %. Its future value may be discounted in one step by determining the "REAL rate of increase" and discounting at that rate. That "rate" in this case is not the REAL Rate of Return because the future which will be used (7.1 %) is not the inflation rate, however, for the purpose of calculation, it can be used in a manner similar to the inflation rate in the last example. Again using 8.5 % as the discount rate the

$$\text{"real rate of increase"} = \frac{8.5\ \% - 7.1\ \%}{1.071} = 1.30719\ \%$$

The Present Worth factor for this item 5 years hence is

$$\frac{1}{(1.0130719)^5} = \frac{1}{1.06709} = 0.937128$$

If this item presently has a value of 100.00, the present worth of its fifth year amount would be $ 93.71.

PRESENT WORTH OF A GEOMETRIC SERIES

The last example provided the Present Worth of the fifth year for an item costing $ 100.00 now and increasing quantity wise at the rate of 2 % per year - inflating at 5 % and discounted at 8.5 %.

The Present Worth of the first five years would be

$$\$\ 100.00 \quad x \quad \left(\frac{1}{1.0130719} + \frac{1}{(1.0130719)^2} + \ldots\ldots\ldots\ldots + \frac{1}{(1.0130719)^5} \right)$$

$$= \$\ 100.00 \quad x \quad (0.987097 \quad + \quad 0.974360 \quad + \ldots\ldots\ldots\ldots + \quad 0.937128 \ )$$

$$= \$\ 100.00 \quad x \quad 4.80973 \quad = \quad \$\ 480.97$$

Again, that is a laboursome exercise, particularly if many periods are involved and easier calculations are available.

BY FORMULA $\quad SPW \quad = \dfrac{(1 + i)^n - 1}{i(1 + i)^n}$

where $\quad i = \quad$ 1.30719 % or $\quad$ 0.01307.19 (1)

$$SPW \quad = \frac{(1.0130719)^5 -1}{0.0130719 \ x \ (1.0130719)^5} \quad = 4.80973$$

FROM TABLES -

No tables are available for a rate of 1.30719 and interpolation between figures for 1 1/4 % and 1 1/2 % must suffice. The SPW for 5 years for 1 1/4 % is 4.817835 and for 1 1/2 % is 4.782645 and a "straight line" interpolation for 1.30719 gives 4.809785.

NOTE: Small discrepancy in results due to using straight line interpolation for non linear relationships.

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(1) Figure calculated in in previous example and while this is not an interest rate, it can be used as an interest rate for the purpose of this calculation.

EXAMPLE 1

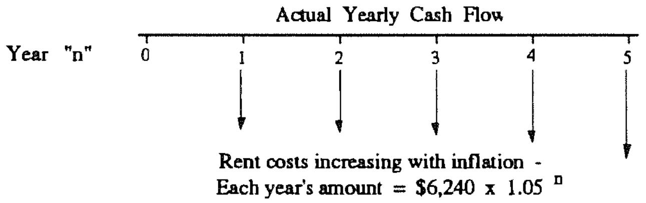
Rental fees in a specific area are currently $ 6,240.00 annually and will be same in future years except for inflationary increases.

Equipment costing $12,000.00 with operating costs of $3,000.00 in the first year and increasing each year with inflation, is an alternate to renting. This type of equipment should be replaced each five years and, over this period, will depreciate to one-third of its original value.

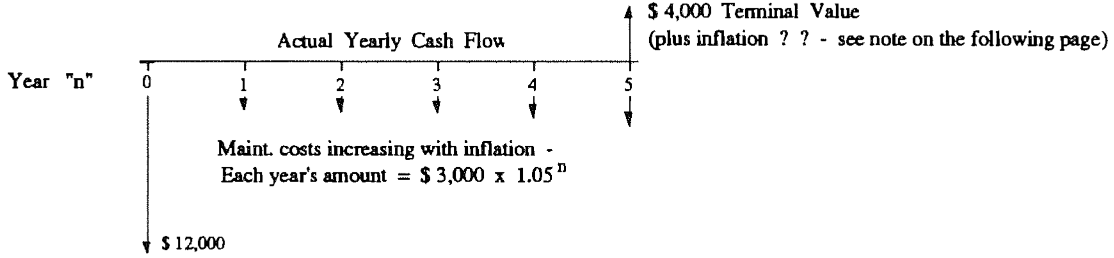
ANALYSIS

Graphically, these alternatives might be displayed in this manner, based upon the period-end step convention which is compatible with the formulas and tables described earlier. Expenditures or outlays are represented by lines pointing downward - income or reductions in expenditures are shown by lines pointing upward.

Renting Alternative



Purchasing Alternative



Assuming inflation of 5 % per annum, real rate of return of 3.5 % and interest rate = 5 % + 3.5 % x 1.05 = 8.675 %, the following calculations can be made.

PRESENT WORTH METHOD

Renting Alternative

PW = - $6,240 x (SPW - 3 1/2 % - 5)
= - $ 6,240 x 4.515052 = $ 28,174

Purchasing Alternative

PW = - \$ 12,000 - \$ 3000 x (SPW - 3 1/2 % - 5) + \$ 4,000 x (PW - 8.675 % - 5)
= - \$ 12,000 - \$ 3000 x 4.51502 + 4,000 x 0.659708
= - \$ 12,000 - 13,545 + 2,639 = \$ 22,906

Explanation and Interpretation of Results

For the Renting Alternative, investing \$28,174 now at 8.675% interest per year would pay the rental charges for 5 years which are increasing each year at the rate of 5% compounded each year. - present \$6,240.00

For the Purchasing Alternative, \$12,000 of the \$22,906 would be spent immediately for the purchase of equipment leaving \$10,906 to be invested at 8.675% interest which principal plus interest on the remaining balance from year to year, coupled with the terminal value realizable at the end of the 5 years, would pay for the operating costs over the five year period.

The Purchasing Alternative has a \$28,174 - \$22,906 = \$5,268 advantage over the Renting Alternative, all expressed in present day dollars.

NOTE: The depreciated (terminal or salvage) value of the equipment as described in the example is subject to interpretation and in the above calculations, that value is assumed to be 4,000 in dollars of that day - (5 years hence). If interpreted that its' depreciated value would be 1/3 of its' new purchase price five years hence, the \$4,000 would be discounted at 3 1/2% - the same as all of the other items which are inflating.

EQUIVALENT UNIFORM ANNUAL COST (EUAC)

This method and way of presenting results are easiest for examples which have uniform annual costs or benefits or savings and the EUAC method would simply include such figures without adjustment. In this example, the annual figures are increasing with inflation and, consequently, each year's figures require adjustment to arrive at an equivalent equal annual figure.

The EUAC method is also useful in cases where different alternatives must have different time periods. If, in this example, renting was an option for only two more years, the EUAC method might be used to test the merits of renting for those two years, compared to purchasing equipment immediately.

With this example, as it stands, the EUAC can be derived from the Present Worths calculated in the last section.

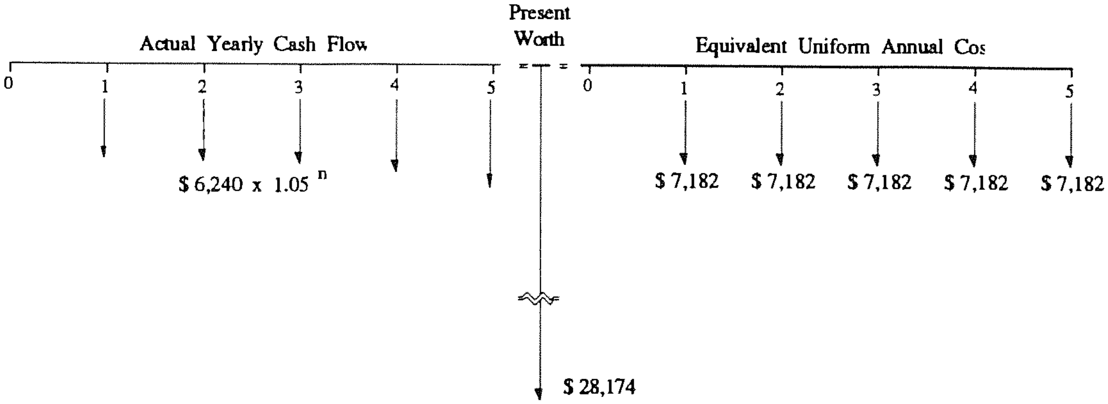
Renting Alternative - PW = \$ 28,174
EUAC = PW x (CR - 8,675% - 5)
= \$ 28,174 x 0.2549281 = \$ 7,182

Purchasing Alternative - PW = $ 22,906
EUAC = $ 22,906 x 0.2549281 = $ 5,839

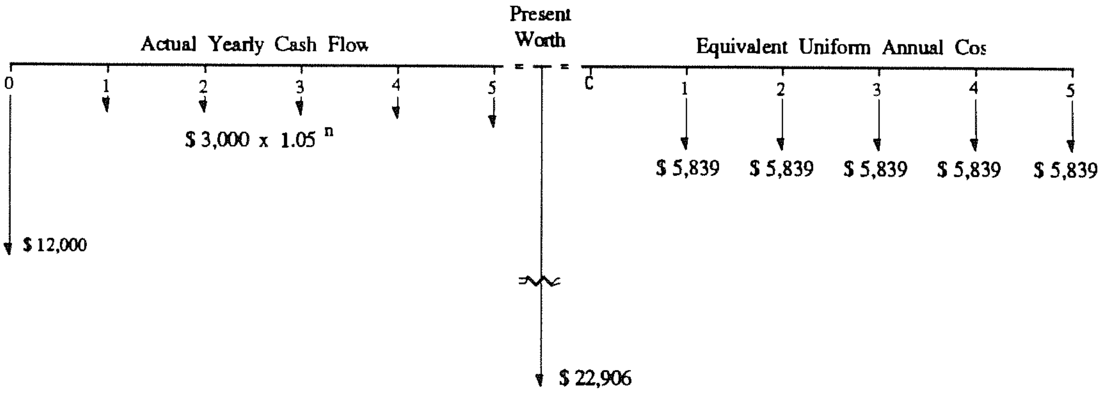
Explanation and Interpretation of Results

In diagram form the cash flows shown previously would equate to Present Worths and EUAC's like this:

Renting Alternative



Purchasing Alternative



If instead of accumulating $28,174 in cash to finance the cash flows, for that alternative, that amount is borrowed at an interest rate of 8.675%, that loan could be repaid in 5 equal annual payments of $7,182 - (amortized over 5 years).

If for the Purchasing Alternative, $22,906 is borrowed, that debt could be amortized over 5 years with uniform annual payments of $5,839 each.

Obviously, the saving each year for five years resulting from the purchase of equipment is $7,182 - $5,839 = $1,343.

BENEFIT-COST RATIO

The general formula for calculating this ratio is

$$\text{B-C RATIO} = \frac{\text{PW Benefits}}{\text{PW COSTS}} = \frac{R - Ra}{Ha - H}$$

WHERE: H = Cost for basic conditions or lower capital and maintenance costs.
Ha = cost for improvement or higher capital and maintenance costs.
R - Ra = benefit(s) resulting from making the greater investment of Ha - H.
R would be operating costs relating to H and Ra would be such costs relating to Ha.

While Example 1 is simple in having few terms, how to sort those items for the purpose of calculating a B-C ratio is subject to question.

Assuming that maintenance costs should be included with the cost of the equipment, the benefit cost ratio is simply the ratio of the two totals for Present Worth.

$$\text{e.g. B-C Ratio} = \frac{28{,}174 - 0}{22{,}906 - 0} = 1.23$$

If benefits are assumed to be the difference between the yearly cost of renting and the annual maintenance costs, the B-C ratio would become

$$\text{B - C Ratio} = \frac{28{,}174 - 13{,}545}{9{,}361 - 0} = \frac{14{,}629}{9{,}361} = 1.56$$

This simple example illustrates one problem with benefit-cost ratios - the amount above or below the value of "one" may not be indicative of the degree of "goodness" or "badness" of competing alternatives. A result higher than "one" simply indicates that the more expensive (capital) alternative is economic for the interest or discount rate used. Conversely, a result less than "one" means that the more expensive alternative is not economical at the interest rate used.

INTERNAL RATE OF RETURN

Internal rate of return is defined as the interest or discount rate which equalizes discounted costs and benefits - in other words, the rate at which the present worth totals for different alternatives is equal.

One problem with this method is in the calculation. Even for this simple example, the mathematical equation is rather complex.

The equation in words is:

Present Worth of Renting Alternative = PW of Purchasing Alternative.

$$-6{,}240\,\frac{(1+ri)^5-1}{ri\,(1+ri)^5} = -12{,}000\;-3{,}000\,\frac{(1+ri)^5-1}{ri\,(1+ri)^5} + 4{,}000\,\frac{1}{(1+\mathrm{i})^5}$$

where: i = interest or discount rate or internal rate of return.
ri = real rate of return. (inflation free interest rate).

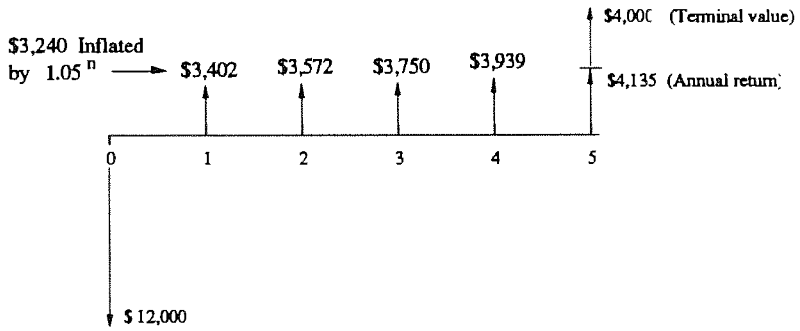
and $i = 5 + 1.05\,ri$

or $ri = \frac{i-5}{1.05}$

A trial and error solution may be easier than attempting to solve those equations.

To get a handle on an approximate internal rate of return (to use for a first trial) the problem might be simplified into as few items as possible. A combined cash flow diagram would be:

Combined Cash Flows



In words, a $12,000 investment returns between $3,402 and $4,135 per year for 5 years and a lump sum return of $4,000 at the end of the five year period. For testing purposes, assume two expenditures are being made - one to earn the lump sum 5 years hence and the balance to earn an annual return of $3,750.00 (Median of the 5 annual returns) for 5 years.

Test 15 % -

PW of $4,000 discounted at 15 % = 0.497 x 4,000 - say $2,000.
$10,000 remains to earn $3,750 per year which converts to a Capital Recovery factor of 0.375. The CR-15%-5 is 0.298--. Obviously, 15% is too low an interest rate.
CR-20%-5 = 0.334 --, and Cr-25%-5 = 0.371--.

Test 25% -

PW 25%-5 ($4,000) = 0.327--- x 4,000 - say $1,300.
$10,700 remains and $3,750 ÷ 10,700 = 0.35.
0.35 is somewhat between the 5 year CR factor for 20% and 25%.
Calculate a trial balance using an interest rate of 23%.

$i = 23\ \%$

$$ri = \frac{23 - 5}{1.05} = \frac{18}{1.05} = 17.14\%$$

PW - Renting = $6,240 (SPW - 17.14% - 5)

$$= -\$6{,}240 \times \Sigma \begin{array}{l} 0.85368 \\ 0.72877 \\ 0.62213 \\ 0.53110 \\ \underline{0.45339} \\ 3.18907 \end{array} = \$19{,}900$$

PW - Purchasing

= -12,000 - 3,000 (SPW - 17.14%-5) + 4,000 (PW-23 % - 5)

$$= -12{,}000 - 3{,}000 \times 3.18907 + 4{,}000 \frac{1}{(1 + 0.23)^5}$$

= -12,000 - 9,567 + 1,421 = - $20,146

The imbalance is now in the opposite direction, meaning that the 23% interest rate is too large.

Repeat calculations for $i = 22\ \%$
and $ri = 16.19\ \%$

PW Renting = - $6,240 x 3.25983 = - $20,341

PW-Purchasing

= - 12,000 - 3,000 x 3.25983 + $4,000 x 0.37000 = - $20,299

Summary of 22 % & 23 %

22 % for PW Purchasing - PW Renting = - 20,299 + 20,341 = + $42
23 % for PW Purchasing - PW Renting = - 20,146 + 19,900 = - $246

Interpolating on a straight line basis

$$\text{Percentage higher than } 22\ \% = \frac{42}{42 + 246} \times 1\ \% = 0.146\ \%$$

Internal rate of return should be very close to 22.146 %.

As a final check, use *i* = 22.146
and *ri* = 16.330

PW for Renting = - 6,240 x 3.24924 = - $20,275

PW for Purchasing = - 12,000 - 3,000 x 3.24924 + 4000 x 0.36779
= - $20,277 - checks within $2.

Result should be expressed as

Internal Rate of Return = 22.1 %

To illustrate that the use of *ri* (inflation free) factor gives the same result as using *i* factors throughout, the problems and solution may be restated as follows.

i = 22.146

PW factors n = 1 = 0.81869
2 = 0.67026
3 = 0.54873
4 = 0.44924
5 = 0.36779

Renting Alternative

Year (n)			COST (year n)		PW Factor		PW
1	6240 x 1.05	-	6552	x	0.81869	=	5364
2	6240 x 1.05^2	-	6880	x	0.67026	=	4611
3	6240 x 1.05^3	-	7224	x	0.54873	=	3964
4	6240 x 1.05^4	-	7585	x	0.44924	=	3407
5	6240 x 1.05^5	-	7964	x	0.36779	=	2929
					TOTAL		- $20,275

Purchasing Alternative

Year (n)	COST (year n)		PW Factor		PW
1	3150	x	0.81869	=	2,579
2	3307	x	0.67026	=	2,217
3	3473	x	0.54873	=	1,906
4	3647	x	0.44924	=	1,638
5	3829	x	0.36779	=	1,408

SUB TOTAL - $9,748

PW of $4,000 income in year 5 = 4,000 x 0.36779 = + 1,471

Initial capital expenditure - 12,000

TOTAL - $20,277

EXAMPLE 2

Maintenance costs for a provincially funded facility are currently averaging $10,000.00 per year and are expected to remain the same in the future except for inflationary increases. The general public enjoys using this facility and it is anticipated that the amount of this use will increase at the rate of 2% per year. The cost to the public for such use is currently $320,000.00 per year and the items of these costs are expected to increase with inflation just as the maintenance costs will increase.

The facility could be improved at a cost of $1,800,000 which would reduce the Province's maintenance costs to $8,000.00 per year and user costs to $250,000 per year - both in present day dollars. The new facility will last between 60 and 100 years providing major refurbishing is undertaken at approximately 20 year intervals at an estimated cost of $600,000 each, again in present day dollars.

ANALYSIS

Assuming an inflation rate of 5% per annum and an interest-discount rate of 8.675%, both the same as used in the last example, the other rates which will be helpful in the analysis of this problem for which the interest formulas and tables may be used will include:

ri = real rate of return (inflation free interest rate)

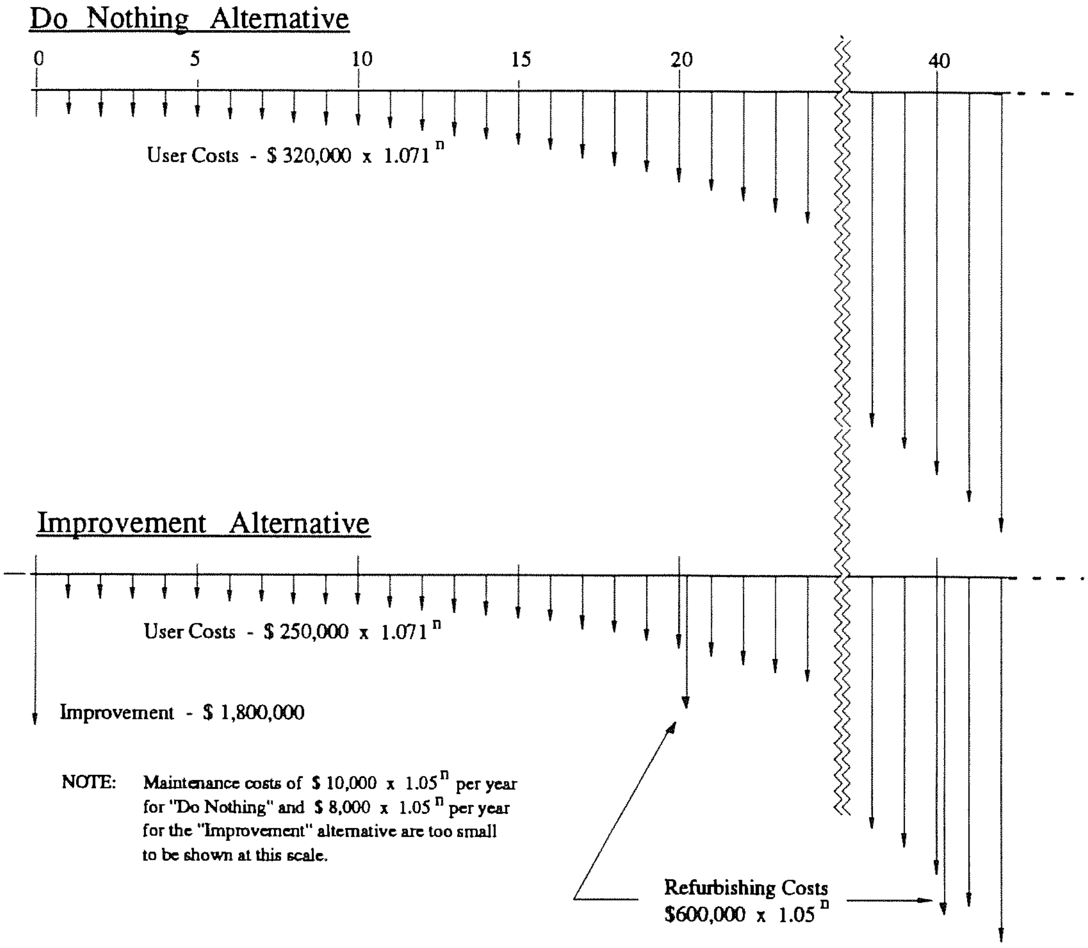
rei = rate equivalent to real rate of return for those items which are increasing quantity wise each year as well as increasing with inflation.

With inflation of 5% and growth of 2%, the combined effect is an increase each year = (1.05 x 1.02) -1 = 1.071-1 = 0.071 or 7.1%. For purposes of using in a formula, this might be called a "combined rate".

$$ri = \frac{i \text{ - inflation rate (\%)}}{1 + \text{inflation rate (dec.)}} = \frac{8.675 - 5}{1.05} = 3.5\ \%$$

$$rei = \frac{i \text{ - combined rate (\%)}}{1 + \text{combined rate (dec,)}} = \frac{8.675 - 7.1}{1.071} = 1.47059$$

CASH FLOW DIAGRAMS


Do Nothing Alternative

Improvement Alternative

NOTE: Maintenance costs of $ 10,000 x 1.05^n per year for "Do Nothing" and $ 8,000 x 1.05^n per year for the "Improvement" alternative are too small to be shown at this scale.

An important factor in the analysis of a long term open ended problem is the time frame. To illustrate the difference results for different analysis periods, both 30 years and 50 years will be calculated. Choosing times midway between the relatively large expenditures each 20 years seems like fair choices.

PRESENT WORTHS

Do Nothing Alternative

PW (30 yrs.) = - $ 10,000 x (SPW-3 1/2% -30) - 320,000 x (SPW-1.47059% -30)
= - 184,000 - 7,717,000
= - 7,901,100 say $7.90 M

PW (50 yrs.) = - $235,000 - 11,273,000
= - 11,508,000 say $11.51M

Improvement Alternative

PW (30 yrs.) = - $1,800,000
- 8,000 x (SPW-3 1/2%-30)
- 250,000 x (SPW-1.47059%-30)
- 600,000 x (PW-3.5%-20)
= - 1,800,000 - 147,00 - 6,029,000 - 302,000
= 8,278,000 say $8.28 M

PW (50 yrs.) = - $1,800,000
- 188,000
- 8,807,000
- 302,000 (600,000 + inf. - discounting for 20 years)
- 152,000 (600,000 + inf. - discounting for 40 years)
= 11,249,000 say $11.25 M

SUMMARY OF PRESENT WORTHS

Alternative	30 yr. period	50 yr. period
Do Nothing	- $7.90 M	- $11.51 M
Improvement	- 8.28 M	- 11.25 M

Over 30 yrs. - "Do Nothing" is better by $380,000
Over 50 yrs. - "Improvement" is better by 260,000
both in present day dollars.

EQUIVALENT UNIFORM ANNUAL COSTS

The Capital Recovery factor for 30 yrs. at 8.675% is 0.094544 and for 50 yrs. is 0.088126. The figures in the Summary of Present Worths can be multiplied by these appropriate factors giving this table.

	EUAC	
Alternative	30 yr. period	50 yr. period
Do Nothing	$747,000	$1,014,000
Improvement	783,000	991,000

BENEFIT/COST RATIO

Sorting the Present Worth figures into two categories
- Capital and Maintenance items, and, user costs give these results.

30 yr. Period

	Capital & Maint.	User Costs
Do Nothing	184,000	7,717,000
Improvement	1,800,000	6,029,000
	147,000	
	302,000	
	2,249,000	

$$\text{Benefit/Cost Ration} = \frac{7{,}717{,}000 - 6{,}029{,}000}{2{,}249{,}000 - 184{,}000} = 0.817$$

50 yr. Period

Do Nothing	235,000	11,273,000
Improvement	1,800,000	8,807,000
	188,000	
	302,000	
	152,000	
	2,442,000	

$$\text{Benefit/Cost Ratio} = \frac{11{,}273{,}000 - 8{,}807{,}000}{2{,}442{,}000 - 235{,}000} = 1.18$$

INTERNAL RATE OF RETURN

An initial investment of $1,800,000 followed by $600,000 each 20 years produces a $320,000 - $250,000 benefit which is increasing each year at the rate of 7.1% and a benefit of $10,000 - $8,000 which is increasing at the rate of 5% per year.

For 30 year period - test an interest rate of 7.1% - discount rate equals combined growth and inflation rate and larger benefit of 70,000 annually will have a present worth over 30 yrs. of 70,000 x 30 = $2,100,000.

Maintenance benefit $= 2{,}000 \times (\text{SPW} - \frac{7.1 - 5}{1.05} \% - 30)$

$= 2{,}000 \times (\text{SPW} - 2\% - 30)$

= 2,000 x 22.396	=	45,000
Add road user benefits (previous page)		2,100,000
TOTAL BENEFITS		2,145,000
Present Worth of Costs =		1,800,000
+ 600,000 x (PW-2%-20)	=	404,000
TOTAL COSTS		2,204,000

Summary for Interpolation Purposes

Interest Rate	Benefits	Costs	Difference
8.675			- 380,000
7.1	2,145,000	2,204,000	-59,000

Reducing interest rate by 1.575 % reduced the difference in costs by
380,000 - 59,000 = 321,000.
To reduce difference by a further 59,000, reduce interest rate by a further
59 ÷ 321 x 1.575 = 0.289 or 0.3 %.

Test $i = 7.1 - 0.3 = 6.8\ \%$

$$ri = \frac{6.8 - 5}{1.05} = 1.714\%$$

Discount rate now less than the combination of growth plus inflation for user costs and the Present Worth of these future costs for any year n must be multiplied by a factor = $(1.05 \times 1.02 : 1.068)^n = 1.0028^n$. The PW for each future year is 0.28% higher than for the preceding year. This is an increasing series situation and the SCA tables may be used with one complication, the first factor is "one" when it should be 1.0028.

This difficulty can be overcome by entering the tables one year higher and subtracting one from the factor for that higher year - in other words, we use the tables in the normal manner with this notation SCA-0.28-(n + 1) -1. In this example a 30 year factor is required.

(SCA - 0.25 - 31) - 1 = 32.191 -1 = 31.191
(SCA - 0.50 - 31) - 1 = 33.441 - 1 = 32.441

Interpolating for 0.28% interest gives a factor
= 31.191 + 3/25 (32.441 - 31.191) = 31.341

User benefit = $70,000 x 31.341 = $2,194,000
Maintenance benefit = 2,000 (SPW-1.714-30) = <u>46,000</u>
TOTAL BENEFITS = 2,240,000

Present Worth of Costs = 1800,000
+ 600,000 x (PW-1.1714-20) = <u>427,000</u>
TOTAL COSTS 2,227,000

Benefits now 13,000 more than costs.

$$\text{Interpolated new value} = 6.8\% + \frac{13}{13 + 59} \times 0.3\,\% = 6.9\,\%$$

Internal Rate of Return approximately 6.9 % for 30 year period.

For 50 year period - test an interest rate of 10% -

PW pf $70,000 net annual benefit

$$= \$70{,}000 \;\left(\text{SPW} - \frac{10 - 7.1}{1.071}\,\% \text{-}50\right)$$

$$= 70{,}000\ (\text{SPW -}2.708\%\text{-}50)$$

$$= 70{,}000\ \frac{(1.02708)^{50} - 1}{0.02708\ (1.02708)^{50}} \qquad = 1{,}905{,}000$$

PW pf $2,000 net annual benefit

$$= 2{,}000\ \left(\text{SPW} - \frac{10.5}{1.05} \text{-}50\right)$$

$$= 2{,}000\ (\text{SPW} - 4.762\%\text{-}50)$$

$$= 2{,}000\ \frac{(1.04762)^{50} - 1}{0.04762\ (1.04762)^{50}} \qquad = \underline{38{,}000}$$

TOTAL PW OF BENEFITS = $1,943,000

PW of Costs		1,800,000
+ 600,000 (PW-4.762%-20)	=	237,000
+ 600,000 (PW-4.762%-40)	=	93,000
		2,130,000

Summary for Interpolation Purposes

Interest Rate	Benefits	Costs	Difference
8.675			+ 260,000
10	1,943,000	2,130,000	- 187,000

$$\text{Interpolated rate} = 8.675 + \frac{260}{187 + 260} \times (10 - 8.675) = 9.446\ \%$$

Internal Rate of Return approximately 9.4 % for 50 yr. period

SENSITIVITY ANALYSIS

If the analyst has doubts about the values of any items included in the study, such values can be varied, the calculations repeated and the different results tabulated against the different inputs.

In effect, the procedure for determining the Internal Rate of Return by trial and error produces different Net Present Worths for the different interest or discount rates tested.

For "open ended" types of problems, the results are sensitive to the period used as illustrated in Example 2 where both 30 and 50 year periods were analyzed.

Inputs will usually require predictions and the decision maker may desire results for a range of prediction rates.

Obviously, if several inputs are varied, the number of combinations will be large and, besides the work involved in making the calculations, those who use the results will have several additional decisions to make. For individuals or agencies doing or reviewing many economic studies, it is desirable to have guidelines for inputs and procedures to reduce the number of variables and to end up with results that are more comparable.

Appendix C

Training Material

Contents

BENEFIT-COST ANALYSIS COURSE

January 6, 1989

Participants

BAIRD, Ian
* BRIDGEMAN, Grant
BROWN, Andy
CLARK, Clive
CLIFFORD, Roberta
DER, Jim
DIYALJEE, Vishnu
* DMYTRYSHYN, Ken
FORSTER, Ron

GAN, Fai
HO, Peter
KHAN, Camilla
KRAUSE, Wayne
KOLLIAS, Tas
LEIGH, Bill
BROUWER, Peter
SHEPPY, Sheena
* McKAY, Neil

MAH, Kim
MARRINIER, George
NICHOLS, Loran
OATWAY, Lionel
PHELPS, Jack
* SAWCHUK, Dick
* WALTERS, Ralph
* WILLIAMS, Albert
* ZACK, Gordon

SENIOR MANAGEMENT SEMINAR

April 21, 1989

Participants

BELKE, Ted
BERDAHL, Gordon
BOISCLAIR, Donald J.
BOYD, Neill
BROWN, Andrew
COOK, Ric
FREEMAN-MARSH, John
HEMPSEY, Les

HETU, Henri
HOLLY, Christopher
HURST, John
JURGENS, Roy
KONARZEWSKI, Jan
KORNELSEN, Rudy
KWAN, Allan

NICHOLS, Loran
QUINTON, Reg.
QUIRING, Steve
RAMOTAR, Jay
TAJCNAR, Peter
* THYGESEN, Coral
WERNER, Al

BENEFIT-COST ANALYSIS COURSE

MAY 18 & 19, 1989

Participants

ADAMKEWICZ, Dennis
ASHRAF, Mohammad
BABIAK, Roman
BASSI, Paul
BUCHANAN, Alan
EDINGA, Kim
EITZEN, G. W.
ERICK, Kenneth
FEDUK, M. D.
FELICE, Joseph

GALLIVAN, Robert
GEE, Terry
GEORGE, Dianne
HAMILTON, W. J.
HASTINGS, Rob
HAZUKA, Tom
HENDERSON, Robert D.
HUMPHREYS, Garry T.
IP, Eddie
JENSEN, Anita-Lynn

JEPSEN, John
KENNY, Bill
KOZIOL, Mike
KROMAN, Tomasz
MANN, J. J.
MORJARIA, Ash
OLINYK, Mike J.
RAMOTAR, J. G.
WAHEED, Abdul

* Guideline Committee members

Resource Staff for these Courses

Ken Howery
Darious Kanga
Allan Lo
Richard Orrell
Frank Perich
Bryan Petzold
Terry Willis

Training Material developed in 1989

Using Mathematical Formulae and Tables.

A PUBLIC WORKS WHICH COSTS $2 M HAS AN ESTIMATED USER BENEFIT OF $2.2 M IN EACH EIGHT YEAR FUTURE PERIOD BASED UPON PRESENT PRICES.

1. What is the internal rate of return after eight years assuming the entire $2.2 M benefit occurs at the end of the eighth year and the works have no value thereafter ?

2. What is the internal rate of return after 16 years, again assuming that the entire benefits for each 8 year period occur at the end of those periods and that the works have no value after 16 years ?

3. Assuming an inflation rate of 6%, what discount rates would correspond to the real rate of return calculated in both Questions 1 & 2 ?

4. The "real interest rate" has averaged 4 % over the long term. What "Prime interest rate" would approximately correspond to an inflation rate of 6 % ?

5. a .How does the real rate of return in Questions 1 and 2 compare with the real interest rate ?

   b. How do the discount rates calculated in Question 3 compare to the Prime interest rate assuming inflation of 6 % ?

   c. Is this investment good if the works are not required after 8 years?
   Is it good if it lasts at least 16 years ?

6. Assuming your boss has little confidence in this project being useful beyond 8 years and in an attempt to make it more attractive you obtain an "iron clad" offer in the market place to purchase the works for $1 M 8 years hence providing it is no longer required for public purposes. It, therefore, has a salvage or residual value of $1M, eight years hence. What analysis can you now present to support your contention that it is financially attractive ? Assume inflation = 6 %.

ALL OF THE PREVIOUS SIX QUESTIONS WERE BASED UPON THE BENEFITS OF $2.2 M OCCURRING AT THE END OF EIGHT YEAR PERIODS. NOW ASSUME INSTEAD THAT THE SAME TOTAL BENEFITS OCCUR OVER EACH 8 YEAR PERIOD BUT ACCRUE AT THE END OF EACH YEAR - i.e. $275,000 EACH YEAR.

7. How would interest rates, calculated on the basis of benefits being received each year, compare with those calculated in the previous questions ?

8. If the capital works were undertaken in 1990 with the yearly benefits beginning in 1991, between which years in the future would the real rate of return be zero, assuming no salvage value ?

9. The present worth of a series can be calculated by multiplying the factors in the interest tables under the SPW column by the annual amounts. From the calculations in Question 8 we know that that annual amount of $275,000 multiplied by 7.27 = $2.0 M - the capital amount which is also the present worth of that side of the equation. From tables, the SPW for 9 years is 7.268790 - very close to 7.27.

   What is the internal rate of return for this project after 9 years ?

   What year would that be if benefits began in year 1991 ?

10. Plotting what we no know about internal rate of return values, what is the approximate internal rate of return after 8 years when it is assumed that benefits accrue each year ?

11. Is your answer to Question 7 correct ?

12. Look in the interest tables for interest rates higher than 4 1/2% and find, under the SPW columns, other figures quite close to 7.27 and plot a couple of more points on the internal rate of return graph for years 11 and 18. From the graph now plotted, what might be the internal rate of return in the long term - in say 40 to 50 years ?

    From tables, how do you know that this figure is below 15 % ?

    By calculation, what is the IRR in perpetuity ?

ABOVE THE "INTERNAL RATE OF RETURN" GRAPH IS ONE FOR PLOTTING PRESENT WORTHS OVER TIME. USUALLY IN OUR ANALYSIS, A PLOT OF THE ACCUMULATED EXPENDITURES BY THIS DEPARTMENT DISCOUNTED AT 4 % WILL BE REQUIRED AS WELL AS A SEPARATE PLOT OF ACCUMULATED BENEFITS MINUS ACCUMULATED EXPENDITURES (forgetting about the sign), ALL ALSO DISCOUNTED AT 4 %.

13. Assuming, as before, that the capital outlay of $2 M is made in 1990, plot the present worth of accumulated expenditures over a period of 40 years, using a discount factor of 4%. What is the present worth of that expenditure 20 years hence? Would it matter if a factor of 7% were used ?

14. With yearly benefits of $275,000 beginning at the end of 1990, calculate by formula the accumulated present worth of those yearly benefits by the end of 1998 (after 8 years of benefits) discounting at the rate of 4 % ?

i

15. What factor was used to multiply the annual amount by to obtain the answer in Question 14 ?

16. Where would you expect to find that factor in the interest tables ?

17. With present worth of expenditures being $2.0 M and accumulated present worth of benefits being $1.852M after 8 years, what is the net accumulated present worth after 8 years of benefits ? - i.e. in 1998.

18. Using the tables, what are the net accumulated present worth figures after 12 years ?, after 20 years ?, after 40 years ?

19. Plot the net accumulated present worth figures on the graph for the years 8, 12, 20 and 40. Between which years does the net accumulated present worth change from positive to negative ?

20. Why does the year or time that the net accumulated present worth equals zero correspond to the year when the internal rate of return is 4 % ?

21. If a benefit-cost ratio were calculated to include benefits to the year 1999, what would you expect that ratio to be ?

22. When would the benefit-cost ratio be 1, discounting all future values by 4 % ?

23. If all future values were discounted at the rate of 10%, at what year, approximately, would this ratio be 1 ?

24. With "built in" inflation (future benefits are inflating each year) in this example, what is the real rate of return for this project in the long term when the internal rate of return is over 13 % ?

Assuming an inflation rate of 6% in the future, at what interest rate would the internal rate of return "level off" at in the long term if inflated dollars were used in the calculating for all future values ?

Questions Re: Rate of Return

1. You loan me $10.00 and in return I pay you $1.00 interest each year for 8 years (beginning one year after the loan) and repay the principal of $10.00 along with the last interest payment. What is your rate of return, assuming no taxes ?

2. What is your real rate of return assuming an inflation rate of 6 % ?

3. How can that be checked ?

4. Now assume there is a choice between constructing a public works now or 8 years hence. In present day dollars the cost is $10.00 and if constructed now, the users of that facility will receive a benefit of $1.00 each year based upon current prices. Assume construction costs and user costs are inflating at the same rate and the works will not depreciate during the eight years if constructed now.

What is the real rate of return on making that investment now ?

5. If dealing in inflated dollars in question 4, and the rate of inflation is 6 %, what is the internal rate of return at the end of the eight year period ?

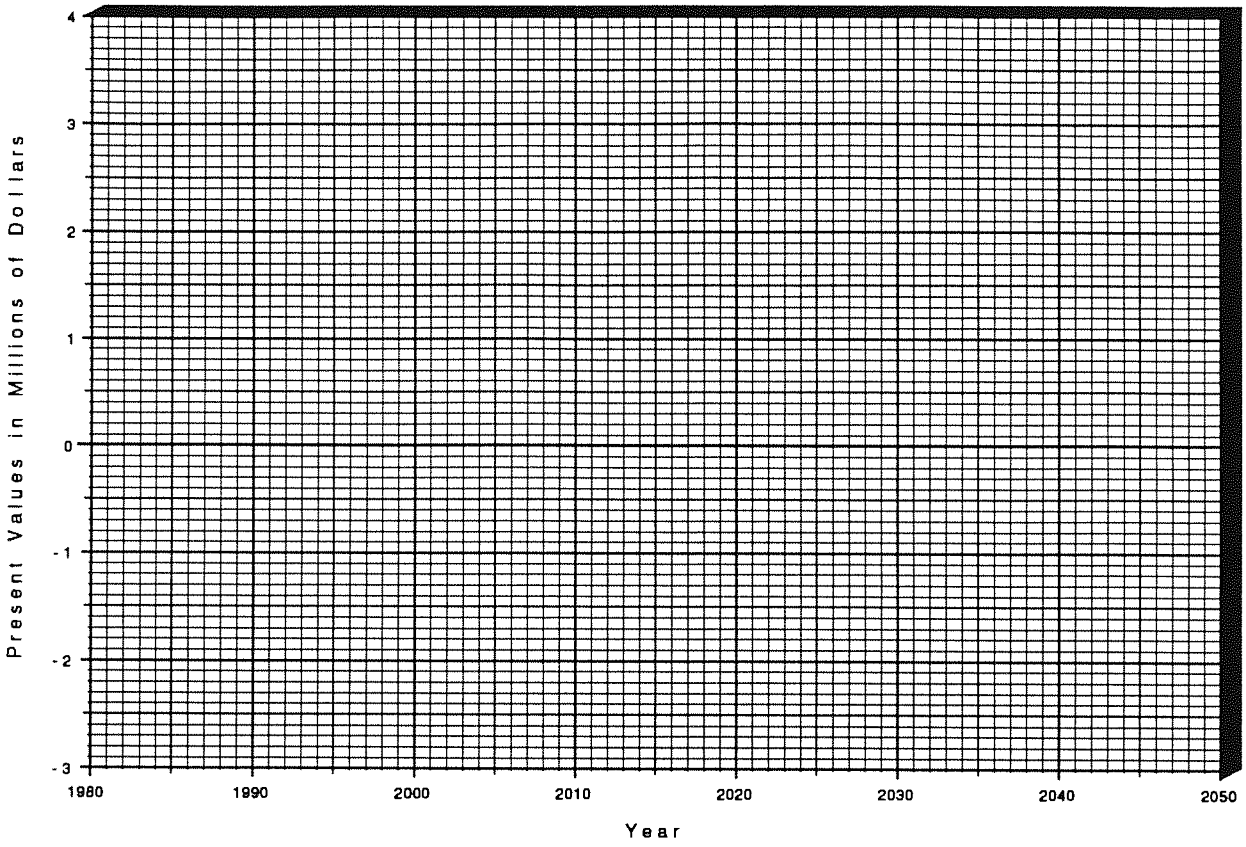
6. Why was a discount rate of 16.6 % chosen to test a balance for the internal rate of return in question 5 ?

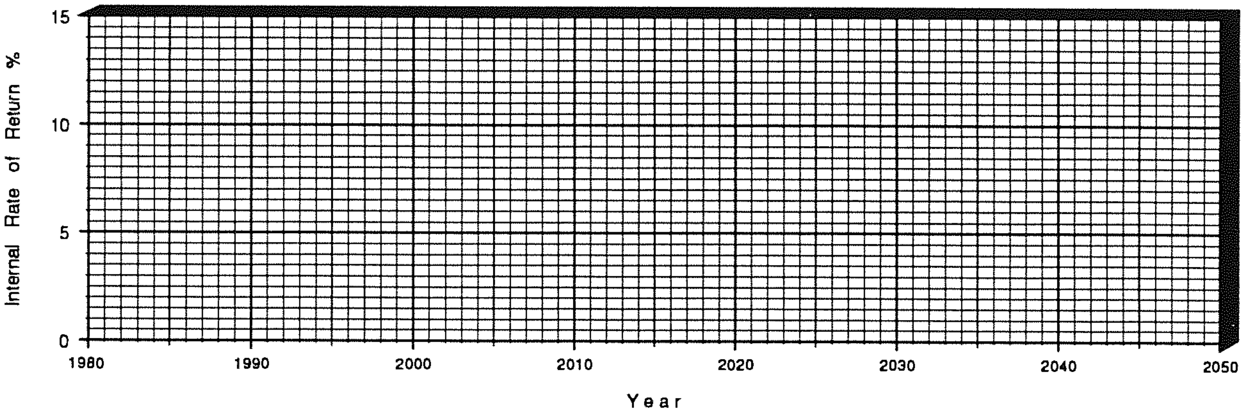
7. Had the column of figures in the answer to question 5 not added up to $10.00, what interest rate table might have been inspected to check the accuracy of the discounted single amounts making up that column ?

8. If the benefits in inflated dollars as used in question 5 were reinvested at 16.6% interest, as they are received, what total benefits in inflated dollars would accrue by the 8th year? Would $10.00 x $(1.166)^8$ = $10.00 x 3.41655 = $34,1655 be close to the right answer ?

In question 3, it was learned that the 10% interest payments, if reinvested at 10% along with repayment of the loan, would grow to $21.4359 by year eight. Would multiplying that figure by $(1.06)^8$ = 1.5938479 be a check on $10.00 x $(1.166)^8$?

Blank Graphs to Accompany Math "Questions"





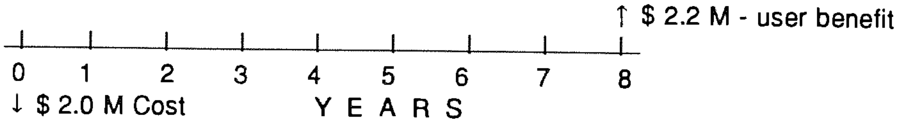
Training Material developed in 1989

Using Mathematical Formulae and Tables. (Answer Version)

A PUBLIC WORKS WHICH COSTS $2 M HAS AN ESTIMATED USER BENEFIT OF $2.2 M IN EACH EIGHT YEAR FUTURE PERIOD BASED UPON PRESENT PRICES.

1. What is the internal rate of return after eight years assuming the entire $2.2 M benefit occurs at the end of the eighth year and the works have no value thereafter ?

The question -



Solution - Present worth of capital outlay = $2.0

Present worth of benefits = $2.2 M x $\frac{1}{(1+i)^8}$

Equating the two to determine IRR

$2.0 = 2.2 \times \frac{1}{(1+i)^8}$ $\qquad (1+i)^8 = \frac{2.2}{2} = 1.1$

$1 + i = \sqrt[8]{1.1}$ (for calculators with $\sqrt{\ }$ - $\sqrt[8]{x} = \sqrt[2]{\sqrt[2]{\sqrt[2]{x}}}$)

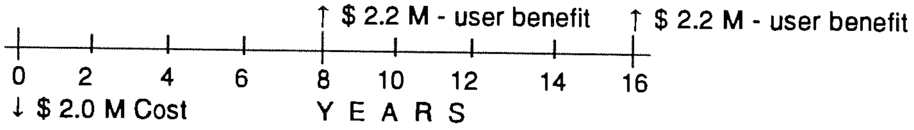
$\sqrt{1.1} = 1.0488088$, $\sqrt{1.0438088} = 1.0241136$ and $\sqrt{1.0241136} = 1.01198$

$\therefore$ $1 + i = 1.011985$ $\quad i = 0.011985$ $\quad$ or $\quad$ 1.1985 %

1 RR = 1.2 %

2. What is the internal rate of return after 16 years, again assuming that the entire benefits for each 8 year period occur at the end of those periods and that the works have no value after 16 years ?

The question -



Solution - Present worth of capital outlay = $2.0 M

Present worth of benefits = 2.2 M x $\frac{1}{(1+i)^8} + 2.2 \frac{1}{(1+i)^{16}}$

Equating the two - $2.0 = 2.2 \frac{1}{(1+i)^8} + 2.2 \frac{1}{(1+i)^{16}}$

Multiplying both sides by $(1+i)^{16}$ $\qquad 2.0\,(1+i)^{16} = 2.2\,(1+i)^8 + 2.2$

placing in a form $ax^2 + bx + c = 0$ $\qquad 2.0\,(1+i)^{16} - 2.2\,(1+i)^8 - 2.2 = 0$

let $x = (1 + i)^8$ and solve for x with equ. $x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$

$$x = \frac{2.2 \pm \sqrt{2.2^2 - 4 \times 2.0 \times (-2.2)}}{2 \times 2.0} = \frac{2.2 \pm \sqrt{4.84 + 17.6}}{4} = \frac{2.2 \pm \sqrt{17.6}}{4} = 1.7342719$$

(Positive answer)

$(1 + i)^8 = x \qquad 1 + i = \sqrt[8]{x} = \sqrt[8]{1.7342719} = 1.071247$

$i = 0.071247$
IRR = 7.12 %

3. Assuming an inflation rate of 6%, what discount rates would correspond to the real rate of return calculated in both Questions 1 & 2 ?

Discount rate = (real rate of return) (1 + inflation rate) + inflation rate
Question 1 - Discount rate = 1.2 (1.06) + 6 = 1.27 + 6 = 7.27 %
Question 2 - Discount rate = 7.12 (1.06) + 6 = 7.56 + 6 = 13.56 %

4. The "real interest rate" has averaged 4 % over the long term. What "Prime interest rate" would <u>approximately</u> correspond to an inflation rate of 6 % ?

Prime = real inf. rate + inflation rate
Prime = 4 % + 6 % = 10 %

5. a .How does the real rate of return in Questions 1 and 2 compare with the real interest rate ?

Question 1 - Not so hot - 1.2% less than 4%
Question 2 - Good - 7.12% greater than 4%

b. How do the discount rates calculated in Question 3 compare to the Prime interest rate assuming inflation of 6 % ?

Question 1 - Same as Question 5 - 7.27% less than 10%
Question 2 - Same as Question 5 - 13.56% greater than 10%

c. Is this investment good if the works are not required after 8 years?
Is it good if it lasts at least 16 years ?

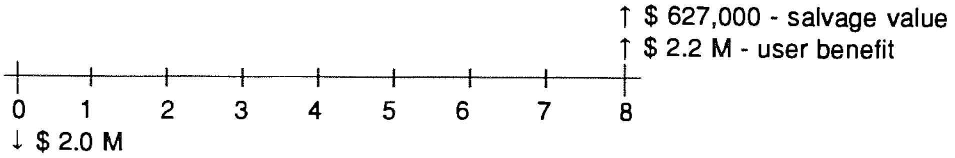
Question 1 - No
Question 2 - Yes

6. Assuming your boss has little confidence in this project being useful beyond 8 years and in an attempt to make it more attractive you obtain an "iron clad" offer in the market place to purchase the works for $1 M 8 years hence providing it is no longer required for public purposes. It, therefore, has a salvage or residual value of $1M, eight years hence. What analysis can you now present to support your contention that it is financially attractive ? Assume inflation = 6 %.

Present worth of $1 M eight years hence discounted at inflation rate

$$= 1\text{ M} \times \frac{1}{(1.06)^8} = \$\,627{,}412$$

Question in diagram form now becomes:



Solution - $$2.0 = 2.2 + 0.627412 \times \frac{1}{(1+i)^8}$$

$$(1+i)^8 = \frac{2.827412}{2} = 1.413706, \qquad 1 + i = \sqrt[8]{1.413706} = 1.0442268$$

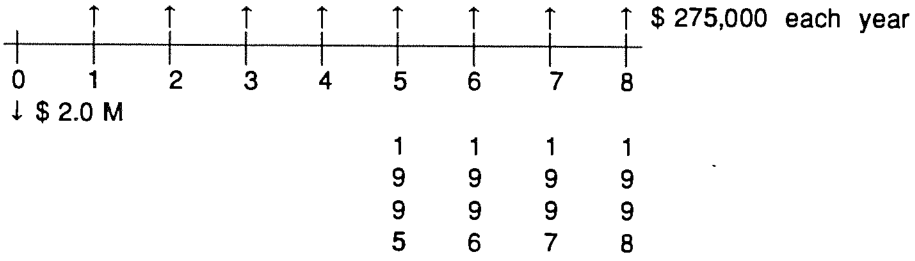
1RR = 4.42 % - slightly more than real interest rate

ALL OF THE PREVIOUS SIX QUESTIONS WERE BASED UPON THE BENEFITS OF $2.2 M OCCURRING AT THE END OF EIGHT YEAR PERIODS. NOW ASSUME INSTEAD THAT THE SAME TOTAL BENEFITS OCCUR OVER EACH 8 YEAR PERIOD BUT ACCRUE AT THE END OF EACH YEAR - i.e. $275,000 EACH YEAR.

7. How would interest rates, calculated on the basis of benefits being received each year, compare with those calculated in the previous questions ?

They would be higher.

8. If the capital works were undertaken in 1990 with the yearly benefits beginning in 1991, between which years in the future would the real rate of return be zero, assuming no salvage value ?



with interest rate = 0, $2.0 = 0.275\,/\,\text{yr} \cdot x\text{ yrs}$ $\quad x = \frac{2.0}{0.275} = 7.2727$

1RR = 0 between 7th & 8th years - i.e. between 1997 and 1998

9. The present worth of a series can be calculated by multiplying the factors in the interest tables under the SPW column by the annual amounts. From the calculations in Question 8 we know that that annual amount of $275,000 multiplied by 7.27 = $2.0 M - the capital amount which is also the present worth of that side of the equation. From tables, the SPW for 9 years is 7.268790 - very close to 7.27.

What is the internal rate of return for this project after 9 years ?

4 1/2 %

What year would that be if benefits began in year 1991 ?

1999

10. Plotting what we no know about internal rate of return values, what is the approximate internal rate of return after 8 years when it is assumed that benefits accrue each year ?

2 1/2 %

11. Is your answer to Question 7 correct ?

Yes

12. Look in the interest tables for interest rates higher than 4 1/2% and find, under the SPW columns, other figures quite close to 7.27 and plot a couple of more points on the internal rate of return graph for years 11 and 18. From the graph now plotted, what might be the internal rate of return in the long term - in say 40 to 50 years ?

In 7 1/2 % table - SPW for 11 yrs = 7.315 ... close to 7.27 (8 % = 7.13 %...)

In 12 % table - SPW for 18 yrs. = 7.249 ... close to 7.27 (10% = 8.20...)

From the tables, how do you know that this figure is below 15 % ?

In 15 % table, SPW for 50 yrs = 6.66 ....., 40 yrs = 6.64...., 30 yrs. = 6.56 levelling off fast in 50 yr period @ 6.66 +
- never would reach 7.27

By calculation, what is the IRR in perpetuity ?

Annual return = $275,000, rate of return = $\frac{275,000}{2,000,000}$ x 100 % = 13.75 %

ABOVE THE "INTERNAL RATE OF RETURN" GRAPH IS ONE FOR PLOTTING PRESENT WORTHS OVER TIME. USUALLY IN OUR ANALYSIS, A PLOT OF THE ACCUMULATED EXPENDITURES BY THIS DEPARTMENT DISCOUNTED AT 4% WILL BE REQUIRED AS WELL AS A SEPARATE PLOT OF ACCUMULATED BENEFITS MINUS ACCUMULATED EXPENDITURES (forgetting about the sign), ALL ALSO DISCOUNTED AT 4%.

13. Assuming, as before, that the capital outlay of $2 M is made in 1990, plot the present worth of accumulated expenditures over a period of 40 years, using a discount factor of 4%. What is the present worth of that expenditure 20 years hence? Would it matter if a factor of 7% were used ?

$2.0 M
No

14. With yearly benefits of $275,000 beginning at the end of 1990, calculate by formula the accumulated present worth of those yearly benefits by the end of 1998 (after 8 years of benefits) discounting at the rate of 4 % ?

i

$$\text{Present Worth of a series} = \text{annual amount} \times \frac{(1+i)^n - 1}{i\,(1+i)^n}$$

$$= 275{,}000 \times \frac{(1+0.04)^8 - 1}{0.04\,(1+0.04)^8} = 275{,}000 \times \frac{1.3685688 - 1}{0.04 \times 1.3685688}$$

$$= 275{,}000 \times 6.73274$$

$$= \$1{,}851{,}503$$

15. What factor was used to multiply the annual amount by to obtain the answer in Question 14 ?

6.73274

16. Where would you expect to find that factor in the interest tables ?

In 4 % table, under SPW for 8 yrs - (by table = 6.732745)

17. With present worth of expenditures being $2.0 M and accumulated present worth of benefits being $1.852M after 8 years, what is the net accumulated present worth after 8 years of benefits ? - i.e. in 1998.

- 2.0
+ 1.852

= - 0.148 M

18. Using the tables, what are the net accumulated present worth figures after 12 years ?, after 20 years ?, after 40 years ?

YEARS	CAPITAL (PW)		A MOUNT ANNUAL		FACTOR	BENEFITS (PW)	NET PW
12	- 2.0	+	0.275	X	9.385074	2.5809	+ 0.5809
20	2.0		0.275		13.590326	3.7373	+ 1.7373
40	2.0		0.275		19.792774	5.4430	+ 3.443

19. Plot the net accumulated present worth figures on the graph for the years 8, 12, 20 and 40. Between which years does the net accumulated present worth change from positive to negative ?

Between 1998 & 1999 (Just before 1999)

20. Why does the year or time that the net accumulated present worth equals zero correspond to the year when the internal rate of return is 4 % ?

The NET accumulated present worth is equal to zero when the benefits discounted at 4 % equal the expenditure(s) discounted at 4% which is the same procedure as used
f or calculating the internal rate of return.

21. If a benefit-cost ratio were calculated to include benefits to the year 1999, what would you expect that ratio to be ?

Slightly more than one.

22. When would the benefit-cost ratio be 1, discounting all future values by 4 % ?

When the internal rate of return = 4 % - between 1998 & 1999.

23. If all future values were discounted at the rate of 10%, at what year, approximately, would this ratio be 1 ?

2003 + (where 1 RR, from graph, = 10 %)

24. With "built in" inflation (future benefits are inflating each year) in this example, what is the real rate of return for this project in the long term when the internal rate of return is over 13 % ?

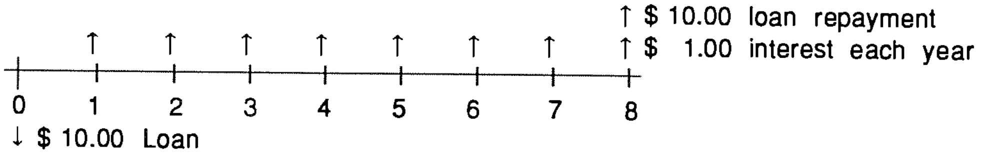
Over 13 % - real rate of return same as internal rate of return with "built in" inflation.

Assuming an inflation rate of 6% in the future, at what interest rate would the internal rate of return "level off" at in the long term if inflated dollars were used in the calculating for all future values ?

Over 19 % (over 13 % + 6 %)

Questions Re: Rate of Return (Answer Version)

1. You loan me \$10.00 and in return I pay you \$1.00 interest each year for 8 years (beginning one year after the loan) and repay the principal of \$10.00 along with the last interest payment. What is your rate of return, assuming no taxes ?



Interest rate should be $\frac{1.00}{10.00} \times 100\ \% = 10\ \%$

Test equation - PW Loan = PW (payments + repayment of principal)
with $i = 10\ \%$ - PW Loan = $10.00 \div (1.1)^0$ = \$10.00

PW(Payments) = SPW (10%- 1 to 8 yrs) x 10.00 = \$ 5.335
PW (Repayment of Principal) = $\$10.00 \div (1.1)^8$ = 4.665
Total \$ 10.00

Rate of Return = 10 %

2. What is your real rate of return assuming an inflation rate of 6 % ?

Interest Rate = (1 + inflation rate) (Real rate of return) + Inflation rate
= (1 + 0.06) (Real rate of return) + 6 %

$$\text{Real Rate of Return} = \frac{10\ \% - 6\ \%}{1.06} = \frac{4\ \%}{1.06} = 3.773585\ \%$$

3. How can that be checked ?

With a real rate of return of 3.773585 %, your purchasing power after eight years should be $(1.03773585)^8 = 1.3449132$ times greater than at beginning of period.
With inflation of 6 % per year, the cost of things will increase $(1.06)^8 = 1.5938479$ times during this period. Therefore, require \$10.00 x 1.5938479 x 1.3449132 = \$21.4359.

At end of period to increase purchasing power by 1.3449132, reinvesting the \$1.00 interest payments received each year will, by the end of period, produce:
1.00 x SCA (10% - 8 yrs.) = 1.00 x 11.435888 = \$ 11.4359
Plus Repayment of Principal = 10.00
Total \$ 21.4359 Checks

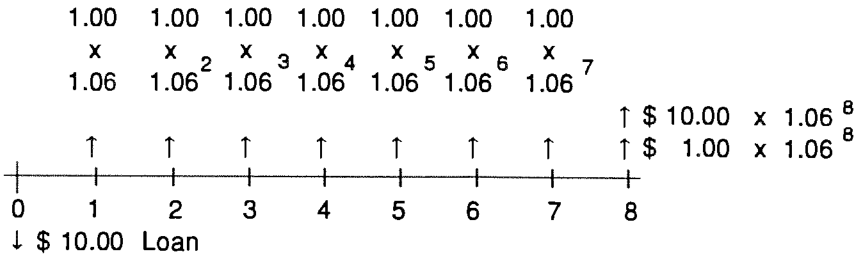
4. Now assume there is a choice between constructing a public works now or 8 years hence. In present day dollars the cost is \$10.00 and if constructed now, the users of that facility will receive a benefit of \$1.00 each year based upon current prices. Assume construction costs and user costs are inflating at the same rate and the works will not depreciate during the eight years if constructed now.

What is the real rate of return on making that investment now ?

The calculations for determining the rate of return or internal rate of return are the same as in Question 1., except in this case the 10% interest rate is the REAL rate of return.

5. If dealing in inflated dollars in question 4, and the rate of inflation is 6 %, what is the internal rate of return at the end of the eight year period ?

In diagram form, this question takes on this appearance -



The question is then - at what discount rate does -
the PW of expenditures = PW of benefits

Test a discount rate of 16.6 %

Present worth of expenditure = $10.00
Present worth of benefits

	$= 1.06$	$\div 1.166$	$= 0.9090909$
	$+ 1.06^2$	$\div 1.166^2$	$= 0.8264462$
	$+ 1.06^3$	$\div 1.166^3$	$= 0.7513147$
	$+ 1.06^4$	$\div 1.166^4$	$= 0.6830132$
	$+ 1.06^5$	$\div 1.166^5$	$= 0.6209213$
	$+ 1.06^6$	$\div 1.166^6$	$= 0.5644737$
	$+ 1.06^7$	$\div 1.166^7$	$= 0.5131578$
$+ 11$	$\times 1.06^8$	$\div 1.166^8$	$= 5.1315792$
		Total	$ 9.9999973

PW Expenditures = PW Benefits when i = 16.6 %

Internal Rate of Return = 16.6 %

6. Why was a discount rat e of 16.6 % chosen to test a balance for the internal rate of return in question 5 ?

Discount Rate = (1 + Inflation Rate) (Real Rate of Return) + Inflation Rate
= 1.06 x 10 % + 6 % = 16.6 %

7. Had the column of figures in the answer to question 5 not added up to $10.00, what interest rate table might have been inspected to check the accuracy of the discounted single amounts making up that column ?

The 10 % table

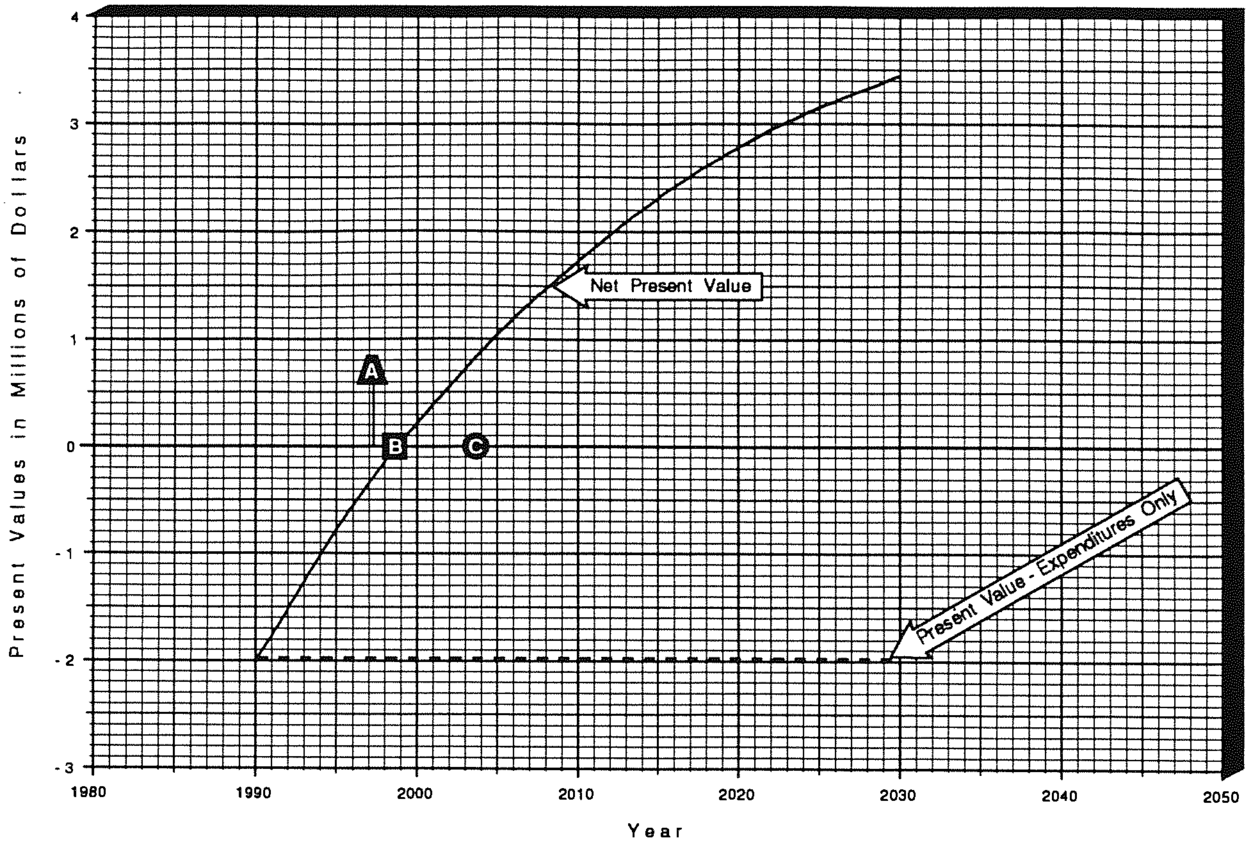
8. If the benefits in inflated dollars as used in question 5 were reinvested at 16.6% interest, as they are received, what total benefits in inflated dollars would accrue by the 8th year? Would $10.00 x $(1.166)^8$ = $10.00 x 3.41655 = $34,1655 be close to the right answer ?

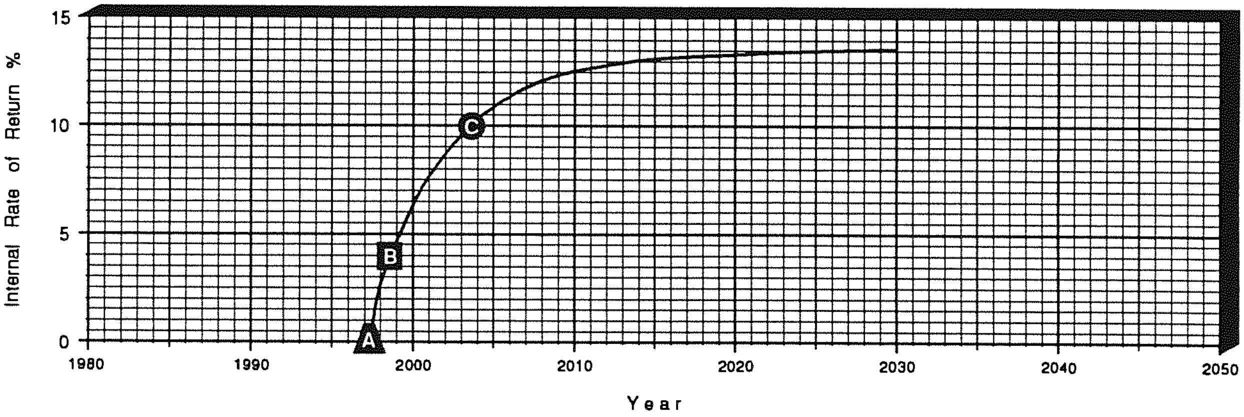
Yes, exactly

In question 3, it was learned that the 10% interest payments, if reinvested at 10% along with repayment of the loan, would grow to $21.4359 by year eight. Would multiplying that figure by $(1.06)^8$ = 1.5938479 be a check on $10.00 x $(1.166)^8$?

Yes

Graphs to Accompany Math "Answers"





The questions refer to the inherent ties between these graphs - A discount rate of 4 % was used and the NPV is therefore zero when the I R R is 4 % - points marked "B" on the graphs. Had the cash flows not been discounted (zero rate) the NPV would be zero when the I R R is zero - points "A". Had a 10 % discount rate been used, the plot of the NPV would change from negative to positive (be zero) at the same point in time that the I R R is 10 % - Points "C".

List of Plates Used for Management Seminar

BENEFIT-COST ANALYSIS

What is it?

THE DETERMINATION AND COMPARISON OF ALLOCATIVE OR ASSIGNED COSTS AND BENEFITS FOR A PROPOSED WORK OR PURCHASE, FOR THE DURATION OF IT'S USEFUL LIFE

Said in another way

A BENEFIT-COST ANALYSIS, FOR ANY ACTIVITY BEING TESTED, IS THE DETERMINATION OF ITS STREAM OF DIRECT COSTS OR EXPENDITURES AND CALCULATION OF THE RETURN TO BE GAINED FROM THE BENEFITS WHICH RESULT.

BENEFIT-COST ANALYSIS IS AN AID TO JUDGMENT.

BENEFIT-COST ANALYSIS

What it is not

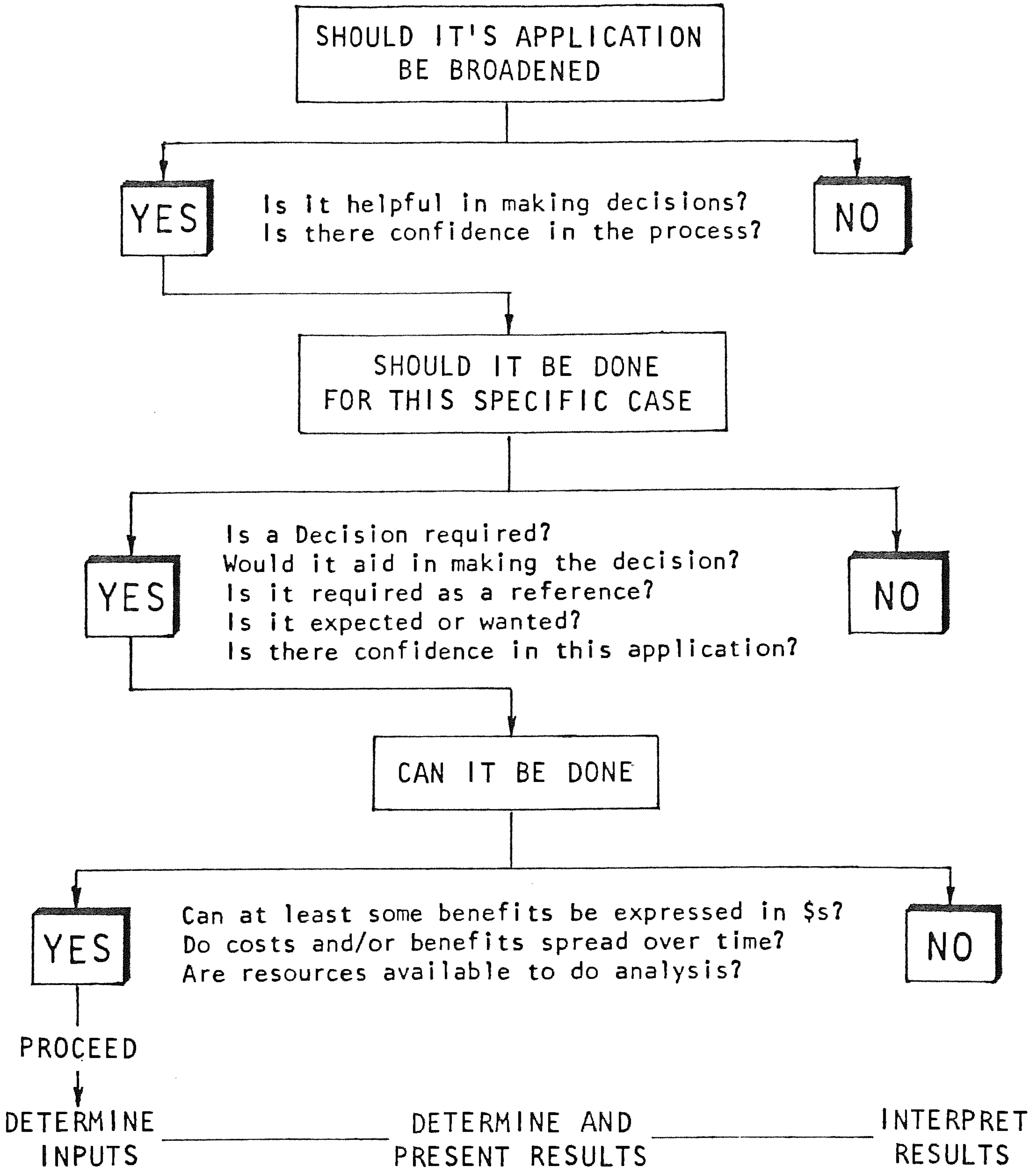
IT IS NOT A FORECAST OF GENERAL ECONOMIC CONSEQUENCES - NOR AN ECONOMETRIC MODEL PROVIDING INSIGHT INTO THE IMPACT UPON, CHANGE TO, OR RELATIONSHIP BETWEEN PRICES, LABOR, INTEREST RATES, EXCHANGE RATES, PRODUCTIVITY, CONSUMPTION OR INVESTMENT.

IT IS NOT AN ECONOMIC IMPACT ANALYSIS DETERMINING THE INDIRECT AND INDUCED EFFECTS RESULTING FROM THE DIRECT COSTS AND SAVINGS WORKING THEIR WAY THROUGH THE SYSTEM.

IT IS NOT A SUBSTITUTE FOR GOOD JUDGEMENT.

NOR IS IT THE DECISION.

BENEFIT-COST ANALYSIS



Is it helpful in making decisions?
Is there confidence in the process?

Is a Decision required?
Would it aid in making the decision?
Is it required as a reference?
Is it expected or wanted?
Is there confidence in this application?

Can at least some benefits be expressed in $s?
Do costs and/or benefits spread over time?
Are resources available to do analysis?

BENEFIT-COST ANALYSIS

Who's doing it?

Who's promoting it?

WORLD BANK
U.S. DEPARTMENT OF TRANSPORTATION (FHA)
AASHTO
RTAC
TREASURY BOARD OF CANADA
TRANSPORT CANADA
SOME PROVINCES

Who's not doing it?

SOME PROVINCES
TREASURY DEPARTMENT - ALBERTA
OTHER DEPARTMENTS IN ALBERTA

BENEFIT-COST ANALYSIS

Advantages of undertaking

ASSISTS IN MAKING DECISIONS

DECISION MAKER WILL HAVE MORE CONFIDENCE IN THE DECISIONS MADE

PROVIDES INSIGHT INTO THE EFFICIENCY AND UTILITY OF COMPETING PROJECTS AND ALTERNATE COURSES OF ACTION.

REDUCES CHANCE OF OVERLOOKING A BETTER ALTERNATIVE OR COURSE OF ACTION

INCREASES THE DESIGNER'S AWARENESS OF THE EFFICIENCY AND COST EFFECTIVENESS OF DIFFERENT DESIGNS

ADDS TO THE PERSONAL GROWTH AND CAREER DEVELOPMENT OF INDIVIDUALS INVOLVED IN THE ANALYSIS

Disadvantages of undertaking

TAKES TIME, EFFORT AND RESOURCES TO DO

RESULTS ARE SOMETIMES CLEARLY CONTRARY TO WHAT MUST BE DONE FOR OTHER SOCIAL OR POLITICAL REASONS

BENEFIT-COST ANALYSIS

Recent developments within the department

- *RENEWED INTEREST INITIATED THROUGH THE TASK TEAM HEADED BY MERRIENE DUNCAN*
- *INTERVIEWS HELD WITH POTENTIAL USERS THROUGHOUT THE DEPARTMENT*
- *IDEAS FOR APPLICATIONS AND METHODOLOGY INCORPORATED IN A REPORT FROM THE TASK TEAM TO THE EXECUTIVE IN DECEMBER, 1987*
- *THE EXECUTIVE ENDORSED THE RECOMMENDATIONS OF THE TASK TEAM INCLUDING THE ESTABLISHMENT OF A COMMITTEE TO DEVELOP USER GUIDELINES AND STAFF TRAINING PROGRAMS*
- *THE GUIDELINES COMMITTEE HAS DEVELOPED PROCEDURES WHICH THE ANALYST MAY USE FOR:*
  THE DETERMINATION OR PROCUREMENT OF INPUT DATA AND VALUES;
  WORKING WITH THE DATA; and
  SUMMARIZING AND DISPLAYING THE RESULTS.
  THE DOCUMENTATION FOR THAT WORK IN THE FORM OF USER GUIDELINES IS UNDERWAY.

BENEFIT-COST ANALYSIS

Departmental applications in the past

EQUIPMENT RENT, PURCHASE, REPLACEMENT

SURFACING & REHAB CHOICES, STAGES AND SYSTEM ANALYSIS

HIGHWAY LOCATION, DESIGN AND ANALYSIS OF VARIOUS COMPONENTS

SEWER, WATER & OTHER UTILITY SERVICES

Ideas for additional applications

ADDITIONAL COMPONENTS & CHOICE OF MATERIALS IN THE ABOVE CATEGORIES

INPUT INTO CAPITAL WORKS PROGRAMMING

VARIOUS MAINTENANCE ACTIVITIES

GRAVEL MANAGEMENT AND INVENTORY

ADVANCE LAND PURCHASES

ASSESSING NEW INNOVATIONS & TECHNOLOGIES

PUBLICITY CAMPAIGNS

STAFF DEVELOPMENT OPTIONS

ENCOURAGE OTHERS TO DO THE SAME

BENEFIT-COST ANALYSIS

Determination of values

THE ALLOCATIVE COSTS AND BENEFITS USED IN THE ANALYSIS MUST GENERALLY BE BASED UPON PRICES AS ESTABLISHED IN THE MARKET PLACE. THIS ASSUMES THAT SUCH PRICES PROPERLY REFLECT THE VALUE WHICH SOCIETY PLACES ON THE RESOURCES WHICH ARE INVOLVED.

Exceptions and adjustments

- *DIRECT AND EASILY IDENTIFIED TAXES ARE EXEMPTED.*

- *WHEN IT IS EVIDENT THAT THE MARKET PRICE OF A GOOD OR SERVICE DOES NOT FAIRLY REPRESENT ITS' RESOURCE VALUE, AN IMPUTED OR SHADOW PRICE SHOULD BE SUBSTITUTED.*

- *WHEN A NEW OR SUBSTANTIALLY IMPROVED PUBLIC WORK IS PROVIDED AND THE DECREASED COST OF ITS' USE TO THE PUBLIC RESULTS IN MORE USERS - THE CONSUMER SURPLUS ASSOCIATED WITH THAT ADDITIONAL USE SHOULD BE INCLUDED IN THE ANALYSIS.*

BENEFIT-COST ANALYSIS

Established principles (for internal departmental analysis)

BASIC PREMISE;

"A BUCK IS A BUCK"

INPUT VALUES:

INCLUDE VALUES FOR ALL USERS AND APPLY UNIFORM VALUES FOR TIME REGARDLESS OF INTERVAL

FAMILY/COMMUNITY AND MARKET LOSSES TO BE INCLUDED IN COLLISION COSTS

RESULTS TO INCLUDE:

PRESENT WORTHS BASED UPON 4% (REAL) DISCOUNT RATE

INTERNAL RATE OF RETURN

RESULTS TO BE DETERMINED OVER A 50 YEAR TIME PERIOD FOR "LONG LIFE" PROJECTS

THESE ARE THORNY FACTORS AND MOST ANALYSIS INVOLVES EACH.

WITHOUT AGREEMENT UPON HOW TO TREAT EACH, THE ANALYST WOULD MAKE CHOICES AND INCLUDE SENSITIVITY TESTS FOR THOSE MOST LIKELY TO BE QUESTIONED.

WITH THAT PROCEDURE, THE DECISION MAKER WOULD HAVE TO MAKE CHOICES EACH TIME AN ANALYSIS IS REVIEWED AND WOULD OR SHOULD STRIVE FOR CONSISTENCY BETWEEN REVIEWS.

WITH ONE DECISION MAKER, PRINCIPLES WOULD QUICKLY BE ESTABLISHED BY PRECEDENT, HOWEVER WITH SEVERAL PASSING JUDGEMENT ON THESE STUDIES, THE PROCEDURE WOULD BE MORE PAINFUL, AND ACHIEVING AND MAINTAINING UNIFORMITY WOULD BE DIFFICULT IF NOT IMPOSSIBLE.

AGREEING UPON PRINCIPLES INITIALLY IS BEST.

IF THE AUDIENCE FOR ANY WORK IS EXPANDED, A NEW CONSENSUS WOULD BE REQUIRED OR SENSITIVITY TESTING SHOULD BE INCLUDED.

BENEFIT-COST ANALYSIS

Established principles (for internal departmental analysis)

BASIC PREMISE;

"A BUCK IS A BUCK"

THE DETERMINATION OF INPUT VALUES IS RESOURCE RELATED AND THE SOURCE OF FUNDS IS IRRELEVANT.

THE COST USED IN A PROVINCIAL ANALYSIS SHOULD BE THE SAME WHETHER OR NOT THE FEDS MAY PARTICIPATE.

A MUNICIPALITY SHOULD NOT CONSIDER GRANTS FROM THE PROVINCE OR OTHERS AS "FREE" DOLLARS.

A DOLLAR SAVED BY A MOTORIST IS THE SAME AS A DOLLAR SPENT ON THE ROAD SYSTEM.

"generally speaking, and in the final analysis, those who pay for the improvement and maintenance of roads and those who use the roads and pay for the cost of travelling are one and the same - whether or not to include each and all of these costs in an analysis of roadway alternatives is not the question - instead, the challenge lies in how to best evaluate and equate all of these costs over time"

INPUT VALUES:

INCLUDE VALUES FOR ALL USERS AND APPLY UNIFORM VALUES FOR TIME REGARDLESS OF INTERVAL

FAMILY/COMMUNITY AND MARKET LOSSES TO BE INCLUDED IN COLLISION COSTS

RESULTS TO INCLUDE:

PRESENT WORTHS BASED UPON 4% (REAL) DISCOUNT RATE

INTERNAL RATE OF RETURN

RESULTS TO BE DETERMINED OVER A 50 YEAR TIME PERIOD FOR "LONG LIFE" PROJECTS

BENEFIT-COST ANALYSIS

Established principles (for internal departmental analysis)

BASIC PREMISE;

"A BUCK IS A BUCK"

INPUT VALUES:

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FAMILY/COMMUNITY AND MARKET LOSSES TO BE INCLUDED IN COLLISION COSTS

RESULTS TO INCLUDE:

PRESENT WORTHS BASED UPON 4% (REAL) DISCOUNT RATE

INTERNAL RATE OF RETURN

RESULTS TO BE DETERMINED OVER A 50 YEAR TIME PERIOD FOR "LONG LIFE" PROJECTS

OBSERVATIONS AND CONCLUSIONS REACHED WITHIN THE DEPARTMENT:

THE VALUE FOR TIME IS A JUDGMENT KIND OF FACTOR AND IT IS MOST IMPORTANT THAT THOSE WHO USE THE RESULTS ARE COMFORTABLE WITH THE INPUTS;

VEHICULAR OPERATING COSTS ARE THE LOWEST IN THE SPEED RANGE OF 50 TO 70 KM/HR. AND THE FACT THAT MOST DRIVERS, WHEN GIVEN THE FREEDOM, WILL CHOOSE TO OPERATE IN THE RANGE OF 90 TO 110 KM/HR. SUGGESTS THAT TIME HAS VALUE;

ROADWAY IMPROVEMENT PROJECTS WILL USUALLY RESULT IN HIGHER AVERAGE VEHICULAR RUNNING SPEEDS WITH A CORRESPONDING DECREASE IN TRAVEL TIMES;

ALL INTERVALS OF TIME FOR ALL ROADWAY USERS ARE IMPORTANT AND RATES OF $22.00 PER HOUR FOR BUS, TRUCK AND TRANSPORT DRIVERS, $12.00 PER HOUR FOR WORKING OCCUPANTS OF ALL VEHICLES AND $5.50 PER HOUR FOR EVERYONE ELSE, INCLUDING THE OCCUPANTS OF BUSES AND RECREATIONAL VEHICLES, BE USED IN OUR ANALYSIS; and

THESE RATES ARE IN 1987 DOLLARS AND MUST BE ADJUSTED OVER TIME TO REFLECT GENERAL CHANGES IN WAGE RATES.

BENEFIT-COST ANALYSIS

Established principles (for internal departmental analysis)

BASIC PREMISE;

"A BUCK IS A BUCK"

INPUT VALUES:

INCLUDE VALUES FOR ALL USERS AND APPLY UNIFORM VALUES FOR TIME REGARDLESS OF INTERVAL

FAMILY/COMMUNITY AND MARKET LOSSES TO BE INCLUDED IN COLLISION COSTS

COLLISIONS ARE, IN VARYING DEGREES, RANDOM EVENTS WITH THE ROADWAY'S ROLE ALSO VARYING. THE NUMBERS OF COLLISIONS ANTICIPATED FOR DIFFERENT OPTIONS BEING TESTED ARE MULTIPLIED BY THE COST PER EVENT TO PROVIDE THIS INPUT FACTOR.

WHETHER TO INCLUDE THE MORE INTANGIBLE MARKET AND COMMUNITY LOSSES IN THE CASES OF INJURY OR DEATH IS A JUDGEMENT CALL AND IT HAS BEEN AGREED TO INCLUDE THESE IN ANALYSES.

BASED UPON STUDY BY OTHERS, SOCIETAL COSTS FOR DEATH IS $619,000 AND $374,000 FOR SERIOUS INJURY, IN 1987 $'S.

USING PROVINCIAL STATS FOR DEATHS AND INJURIES PER CRASH, A FATAL COSTS $1.105M AND ONE INVOLVING INJURY COSTS $112,000 AND NON INJURY $3,550. WITH 2% FATAL AND 25% INJURY, THE COST IS $53,000 PER CRASH. WITHOUT SOCIETAL COSTS THAT WOULD BE $7,800 PER CRASH.

THE COLLISION COST PORTION OF USER COSTS IS USUALLY 10 TO 30%, HOWEVER, SAFETY CAN BE A NON-ISSUE OR IN OTHER CASES IT IS THE ONLY BENEFIT.

RESULTS TO INCLUDE:

PRESENT WORTHS BASED UPON 4% (REAL) DISCOUNT RATE

INTERNAL RATE OF RETURN

RESULTS TO BE DETERMINED OVER A 50 YEAR TIME PERIOD FOR "LONG LIFE" PROJECTS

BENEFIT-COST ANALYSIS

Established principles (for internal departmental analysis)

BASIC PREMISE;

"A BUCK IS A BUCK"

INPUT VALUES:

INCLUDE VALUES FOR ALL USERS AND APPLY UNIFORM VALUES FOR TIME REGARDLESS OF INTERVAL

FAMILY/COMMUNITY AND MARKET LOSSES TO BE INCLUDED IN COLLISION COSTS

RESULTS TO INCLUDE:

PRESENT WORTHS BASED UPON 4% (REAL) DISCOUNT RATE

INTERNAL RATE OF RETURN

RESULTS TO BE DETERMINED OVER A 50 YEAR TIME PERIOD FOR "LONG LIFE" PROJECTS

IT HAS BEEN AGREED THAT THE RESULTS SHALL INCLUDE A PLOT OF PRESENT WORTH OF COMBINED CAPITAL, MAINTENANCE, REHAB AND ANY OTHER COSTS BORNE DIRECTLY BY THE SPONSORING AGENCY. THAT GRAPH PROVIDES INSIGHT INTO THE DIRECT CONSEQUENCES TO THE DEPARTMENT IN THE CASE OF PROJECTS UNDERTAKEN BY THE DEPARTMENT.

FURTHER, ANOTHER PLOT SHALL INCLUDE THE USER BENEFITS ADDED TO THE FIRST PLOT. THAT RESULTS IN NET PRESENT WORTH WHICH IS AN INDICATOR OF THE ECONOMIC MERITS OF THE PROJECT OR ALTERNATIVE.

ALL OF THOSE VALUES AND PLOTS SHALL BE BASED UPON A DISCOUNT RATE, ACCUMULATED FROM YEAR TO YEAR AND EXTENDED 50 YEARS INTO THE FUTURE IN THE CASE OF LONG TERM CAPITAL WORK PROJECTS.

THE INTERNAL RATE OF RETURN SHALL BE CALCULATED FOR EACH OF THE 50 YEARS AND PLOTTED FOR ALL YEARS THAT IT IS POSITIVE.

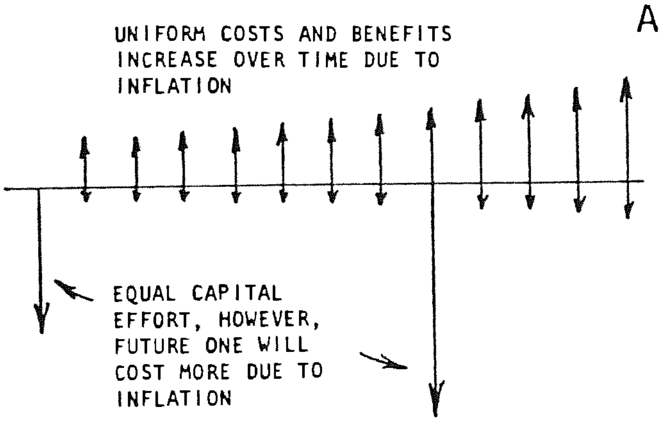
BENEFIT-COST ANALYSIS

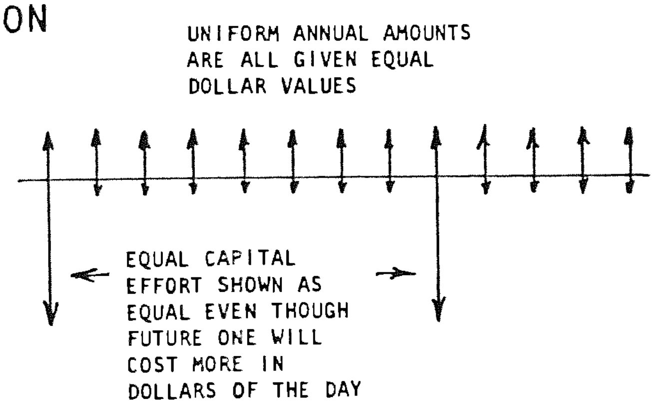
RELATIONSHIP OF TERMS

TERMS

ASSOCIATED WITH DOLLARS OF THE DAY	ASSOCIATED WITH PRESENT PRICE LEVELS
INVESTMENT INTEREST RATE	REAL INTEREST RATE
CURRENT DOLLARS	CONSTANT DOLLARS
INFLATED DOLLARS	INFLATION FREE DOLLARS
PAYMENTS IN CASH	PAYMENTS IN COMMODITIES

FLOW DIAGRAM APPLICATION





INVESTMENT INTEREST RATE (i) MIGHT BE USED FOR DISCOUNTING	REAL INTEREST RATE MIGHT BE USED FOR DISCOUNTING
INTERNAL RATE OF RETURN MIGHT BE COMPARED TO INVESTMENT INTEREST RATE	INTERNAL RATE OF RETURN MIGHT BE COMPARED TO REAL INTEREST RATE
MINIMUM ATTRACTIVE RATE OF RETURN (MARR) MIGHT BE IN THE ORDER OF "PRIME" RATE e.g. inflation rate + 4%	MARR MIGHT BE IN THE ORDER OF THE REAL INTEREST RATE e.g. about 4%

BENEFIT–COST ANALYSIS

INTEREST RATE RELATIONSHIPS

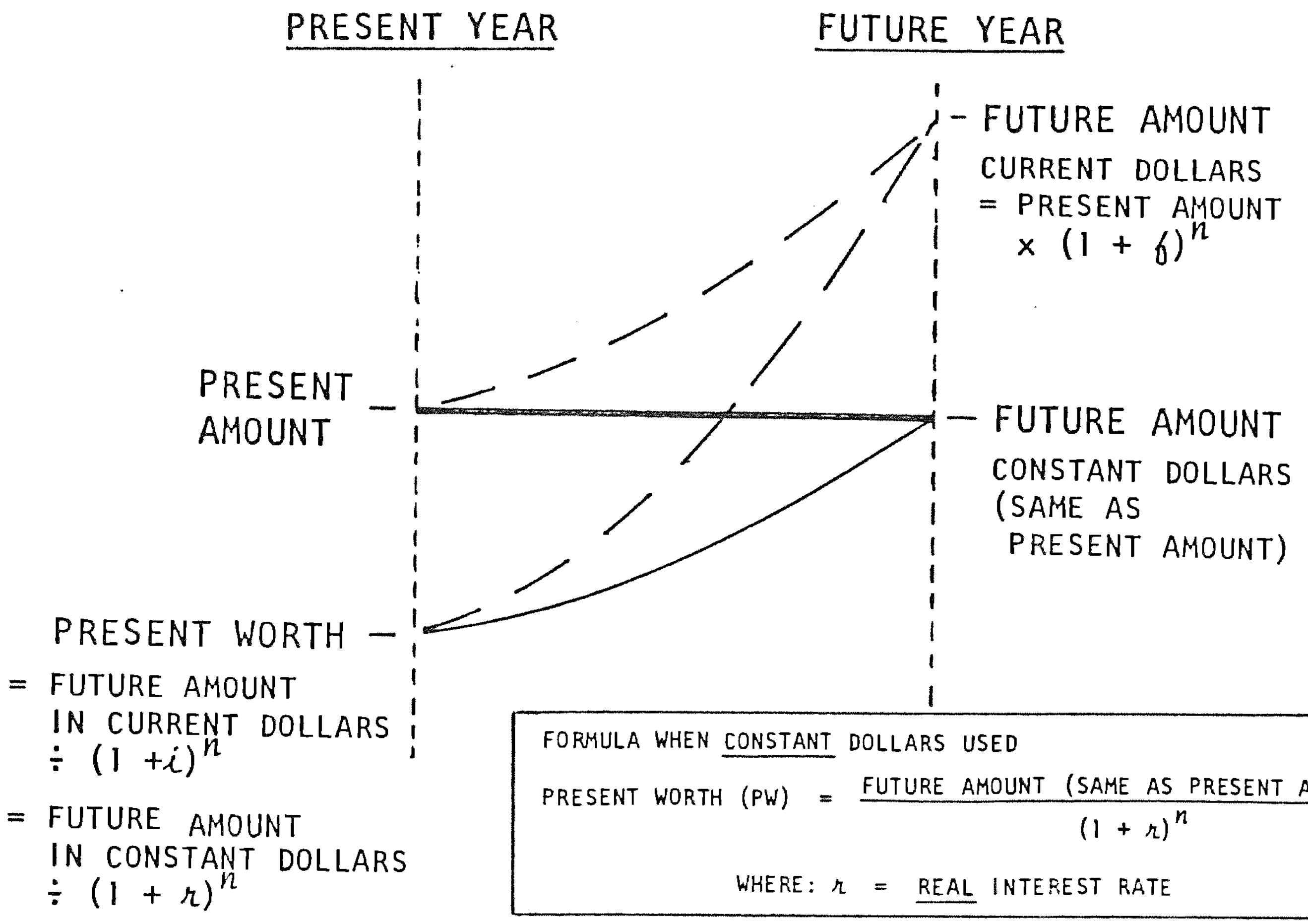
GENERAL FORMULA

$$\boxed{(1 + i)^n = (1 + r)^n (1 + f)^n}$$

OR

$$1 + i = (1 + r)\ (1 + f)$$

where i = interest rate earned on investment
r = real interest rate
f = rate of inflation



FORMULA WHEN <u>CONSTANT</u> DOLLARS USED

$$\text{PRESENT WORTH (PW)} = \frac{\text{FUTURE AMOUNT (SAME AS PRESENT AMOUNT)}}{(1 + r)^n}$$

WHERE: r = <u>REAL</u> INTEREST RATE

FORMULA WHEN <u>CURRENT</u> DOLLARS USED

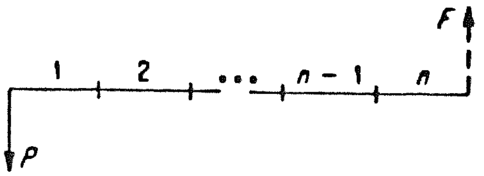
$$\text{PRESENT WORTH (PW)} = \frac{\text{FUTURE AMOUNT (INFLATED AMOUNT)}}{(1 + i)^n}$$

WHERE: i = <u>INVESTMENT</u> INTEREST RATE

SUMMARY OF FORMULAS

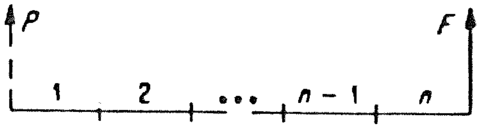
SOURCE: Robley Winfrey
Arlington, Virginia 22207

The cash-flow diagrams represent the position of the person owning the cash who deposits in or withdraws from an interest-bearing fund. Downward is outgo, or deposit, and upward is income, or withdrawal. Solid arrows represent known cash flows and dashed arrows represent unknown cash flows, or solutions of the equations.



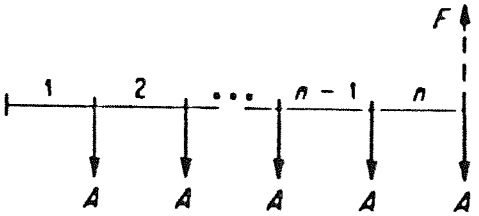
Compound amount at the end of n periods to which a single deposit will accumulate:

$$F = P(1 + i)^n ; \quad CA = (1 + i)^n$$



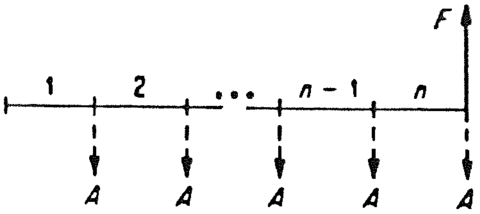
Present worth of a single sum to be withdrawn at the end of n periods in the future:

$$P = F \frac{1}{(1 + i)^n} ; \quad PW = \frac{1}{(1 + i)^n}$$



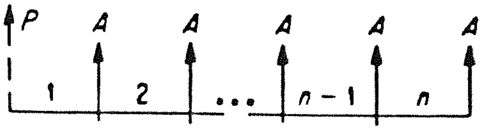
Compound amount at the end of n periods to which a series of n uniform period end deposits will accumulate:

$$F = A \frac{(1 + i)^n - 1}{i} ; \quad SCA = \frac{(1 + i)^n - 1}{i}$$



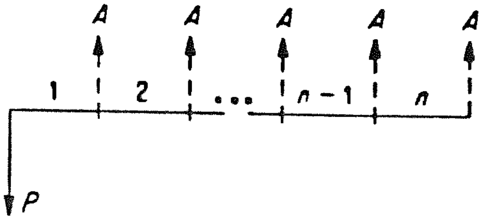
Sinking fund uniform period end deposit which will accumulate to a given sum at the end of n periods:

$$A = F \frac{i}{(1 + i)^n - 1} ; \quad SF = \frac{i}{(1 + i)^n - 1}$$



Present worth of a series of n uniform period end withdrawals:

$$P = A \frac{(1 + i)^n - 1}{i(1 + i)^n} ; \quad SPW = \frac{(1 + i)^n - 1}{i(1 + i)^n}$$



Capital recovery with interest; annuity which will return in n period end uniform receipts a given present deposit plus interest on the unreturned portion:

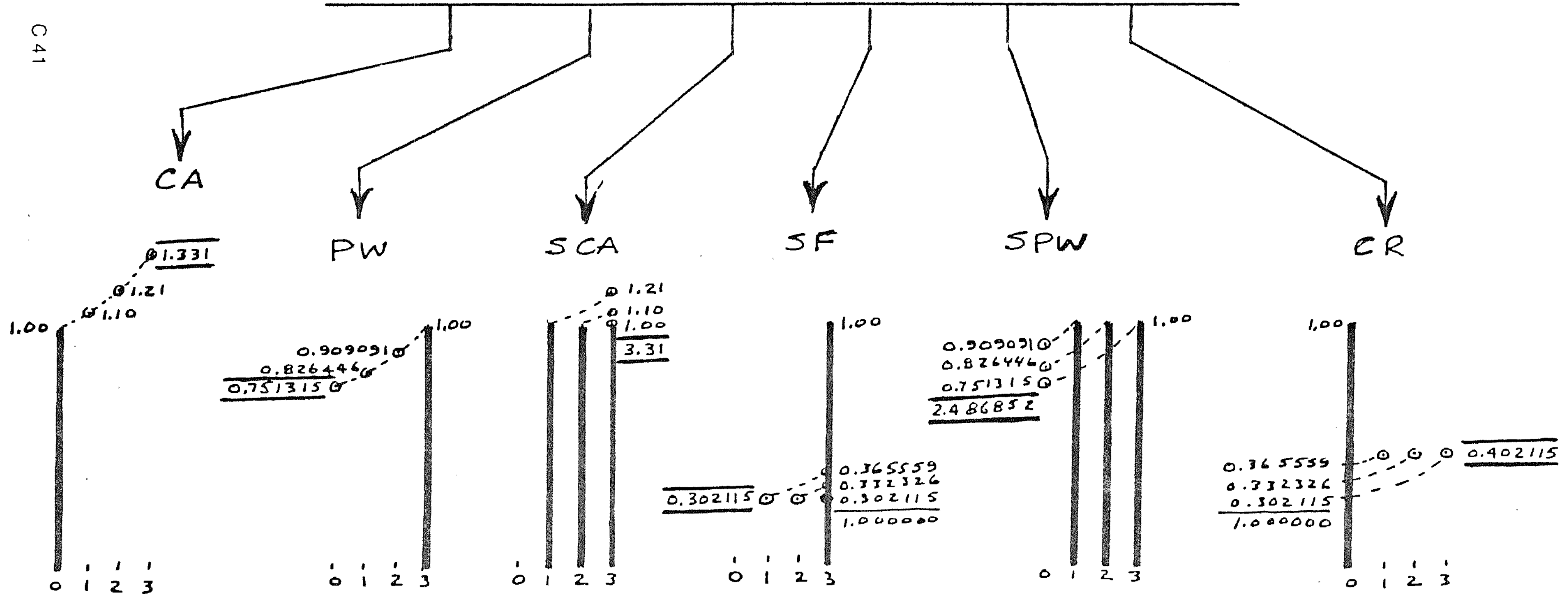
$$A = P \frac{i(1 + i)^n}{(1 + i)^n - 1} ; \quad CR = \frac{i(1 + i)^n}{(1 + i)^n - 1}$$

Cash-flow diagrams and the six standard compound interest equations based on the period-end step convention.

TABLE B-28

10 Percent Compound Interest Factors for One Dollar

n	Single Amount		Uniform Series (Periodic Equal Amounts)				n
	Compound Amount	Present Worth	Compound Amount	Sinking Fund	Present Worth	Capital Recovery	
	Given P to find F $(1+i)^n$	Given F to find P $\frac{1}{(1+i)^n}$	Given A to find F $\frac{(1+i)^n-1}{i}$	Given F to find A $\frac{i}{(1+i)^n-1}$	Given A to find P $\frac{(1+i)^n-1}{i(1+i)^n}$	Given P to find A $\frac{i(1+i)^n}{(1+i)^n-1}$	
	CA	PW	SCA	SF	SPW	CR	
1	1.1000 0000	0.909091	1.000000	1.000000	0.909091	1.100000	1
2	1.2100 0000	0.826446	2.100000	0.476190	1.735537	0.576190	2
3	1.3310 0000	0.751315	3.310000	0.302115	2.486852	0.402115	3
4	1.4641 0000	0.683013	4.641000	0.215471	3.169865	0.315471	4
5	1.6105 1000	0.620921	6.105100	0.163797	3.790787	0.263797	5
6	1.7715 6100	0.564474	7.715610	0.129607	4.355261	0.229607	6
7	1.9487 1710	0.513158	9.487171	0.105405	4.868419	0.205405	7
8	2.1435 8881	0.466507	11.435888	0.087444	5.334926	0 187444	8
9	2.3579 4769	0.424098	13.579477	0.073641	5.759024	0.173641	9
10	2.5937 4246	0.385543	15.937425	0.062745	6.144567	0.162745	10

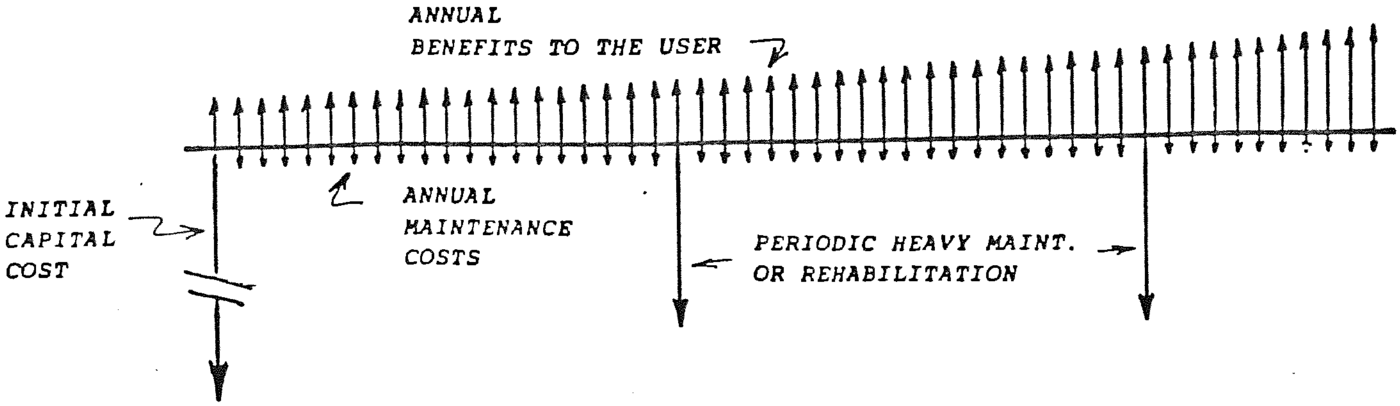


BENEFIT-COST ANALYSIS

ANALYSIS STEPS & PROCEDURES

1. DECIDE YEAR UPON WHICH ALL VALUES (COSTS & BENEFITS) WILL BE BASED.
2. DETERMINE THE MAGNITUDE OF ALL INPUTS (COSTS & BENEFITS) AND YEARS IN WHICH THEY WILL FALL.
3. DECIDE IF ALL OR MOST OF THE INPUTS WILL CHANGE IN VALUE OVER TIME (INFLATE) AT THE SAME RATE.
   - IF SO, USE "CONSTANT" DOLLARS AND ADJUST ONLY THOSE WHICH DO NOT FOLLOW THE "NORM".
   - IF MOST ITEMS WILL INFLATE AT DIFFERENT RATES CALCULATE "CURRENT" DOLLAR VALUES FOR ALL ITEMS FOR ALL YEARS.
4. DO THE ABOVE FOR ALL ALTERNATIVES AND THE RESULTS FOR ONE ALTERNATIVE COULD PICTORIALLY TAKE THIS FORM.

   COSTS ARE NEGATIVE AND PLOTTED DOWNWARD. BENEFITS ARE POSITIVE AND PLOTTED UPWARDS.



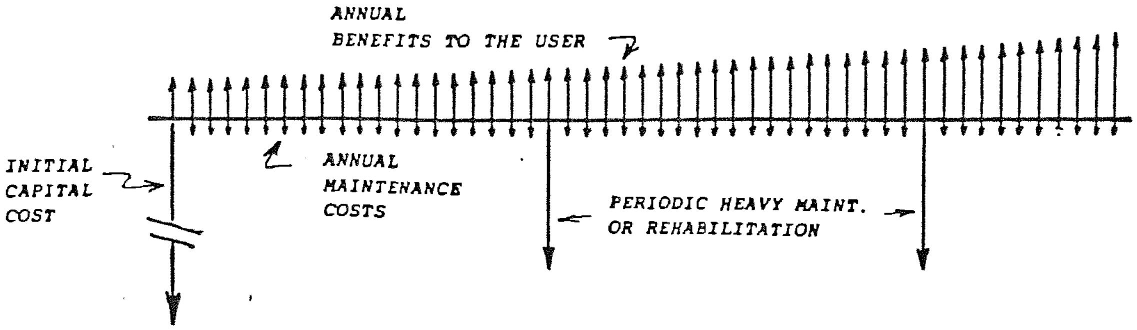
NOTE THAT CONSTANT DOLLARS ARE USED IN THIS EXAMPLE - E.G.- MAINTENANCE COSTS ARE THE SAME EACH YEAR EVEN THOUGH THEY WILL ACTUALLY BE MORE EACH SUCCESSIVE YEAR DUE TO INFLATION. BENEFITS ARE SHOWN AS INCREASING EACH YEAR BECAUSE IT IS ASSUMED THAT THE VOLUMES UPON WHICH THOSE VALUES ARE BASED ARE INCREASING - THEY TOO ARE CONSTANT DOLLARS (FREE OF INFLATION).

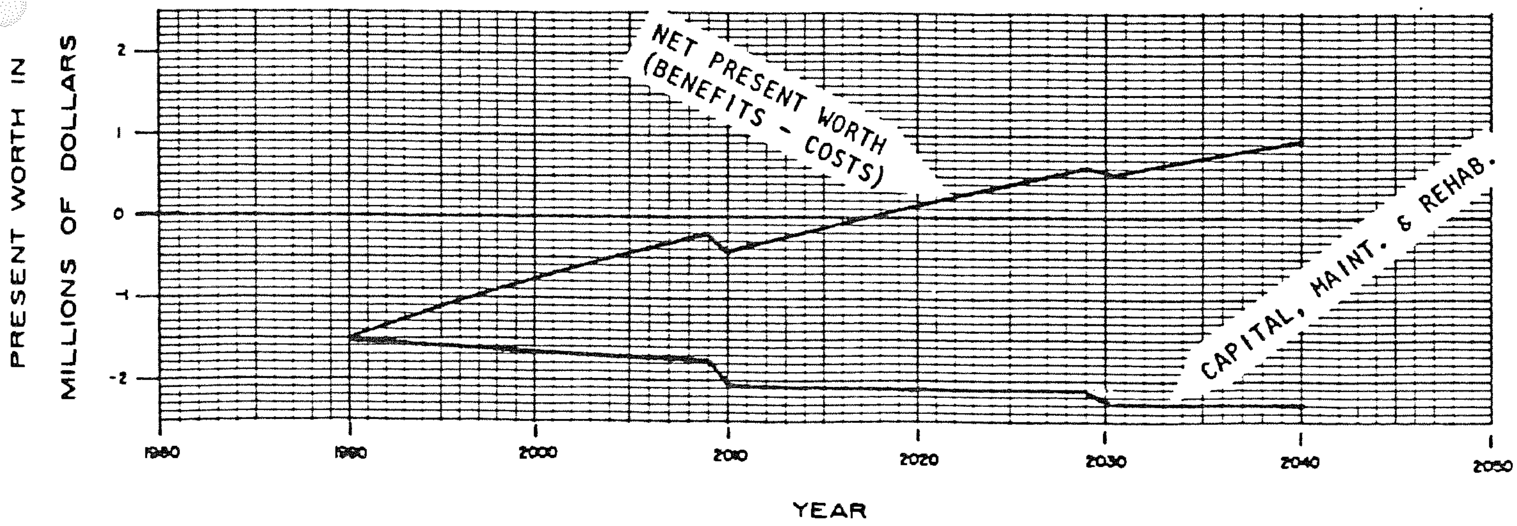
BENEFIT-COST ANALYSIS STEPS (CONTINUED)

5. *DETERMINE THE PRESENT WORTH OF COSTS BY DISCOUNTING ALL FUTURE COSTS BY 4%/YR. AND SUCCESSIVELY ACCUMULATE THESE DISCOUNTED AMOUNTS FOR EACH YEAR.*

6. *DO THE SAME FOR THE BENEFITS AND ARITHMETICALLY ADD THE ACCUMULATED DISCOUNTED BENEFITS (POSITIVE AMOUNTS) TO THE ACCUMULATED DISCOUNTED COSTS (NEGATIVE AMOUNTS) WITH THE RESULTS EXPRESSED AS THE "NET PRESENT WORTH".*

   THE FLOW DIAGRAM SHOWN ON THE PREVIOUS PLATE IS AGAIN SHOWN HERE ALONG WITH GRAPHS FOR THE PRESENT WORTHS.





NOTE THE RIPPLES IN THE PRESENT WORTH GRAPHS AT THE 20 YEAR INTERVALS WHICH ARE CAUSED BY THE RELATIVELY LARGE REHAB COSTS.

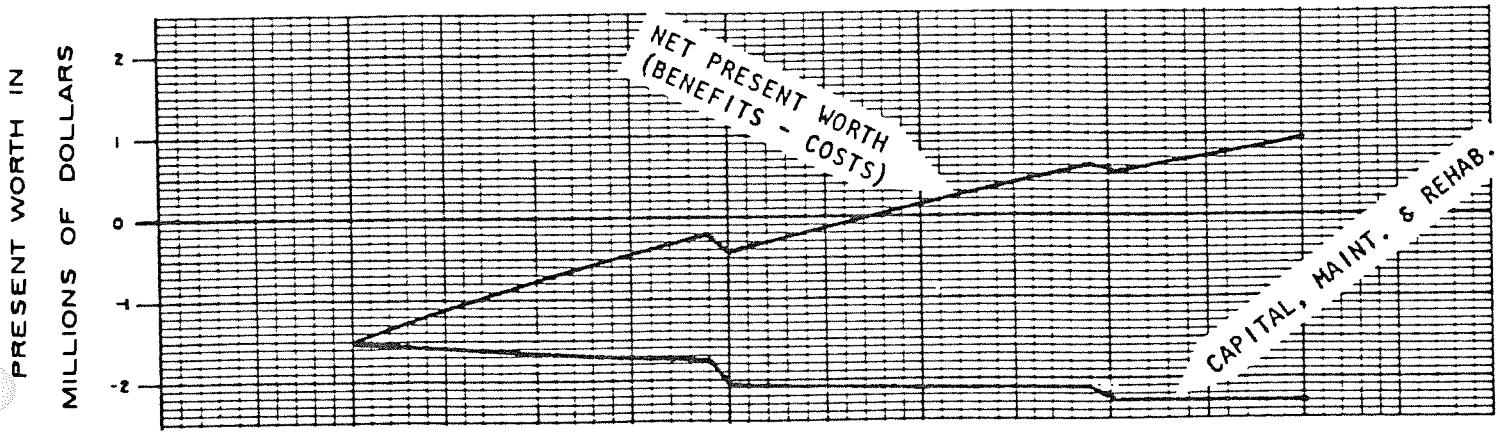
WHILE THESE REHAB COSTS ARE EQUAL (CONSTANT DOLLARS USED), THE ONE AT YEAR 2010 CAUSES A LARGER DROP IN THE PRESENT WORTH GRAPHS THAN THE ONE AT YEAR 2030. THE DISCOUNTING FACTOR FOR 4% FOR 20 YEARS IS 0.456 - FOR 40 YEARS IS 0.208.

BENEFIT-COST ANALYSIS STEPS (CONTINUED)

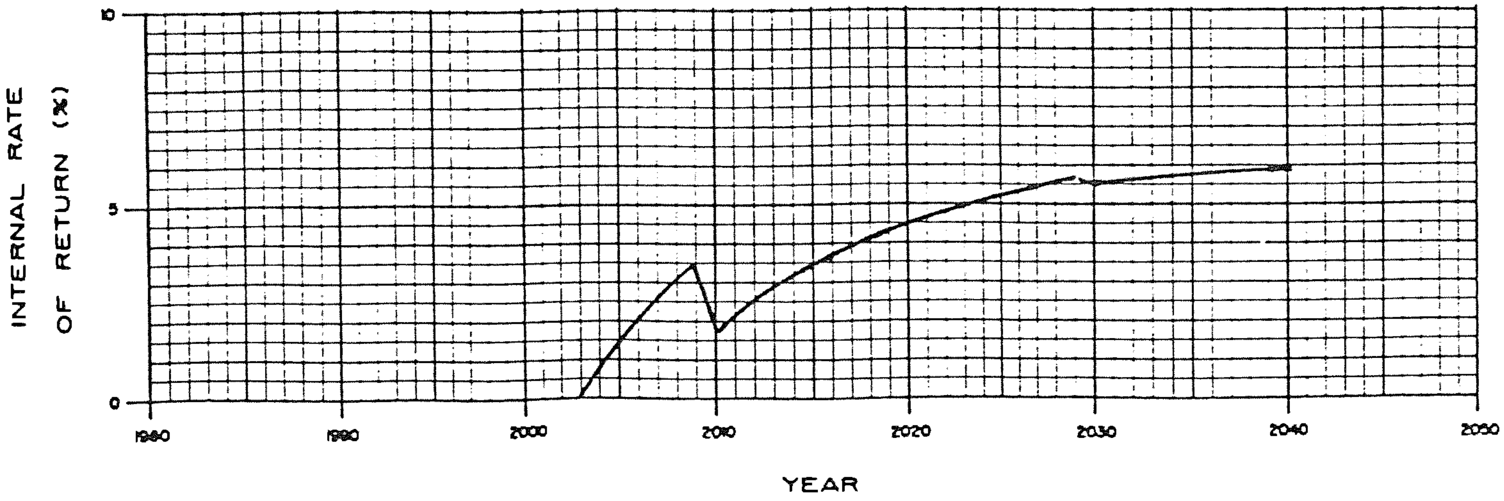
7. FINALLY CALCULATE THE INTERNAL RATE OF RETURN VALUES FOR EACH YEAR WHICH FOR ANY SPECIFIC YEAR IS THE DISCOUNT RATE WHICH EQUATES THE ACCUMULATED COSTS AND BENEFITS.

   A PLOT OF THE INTERNAL RATE OF RETURN FOR ALL YEARS THAT IT IS POSITIVE IS SHOWN BELOW THE PRESENT WORTH GRAPHS.

PRESENT WORTH



INTERNAL RATE OF RETURN

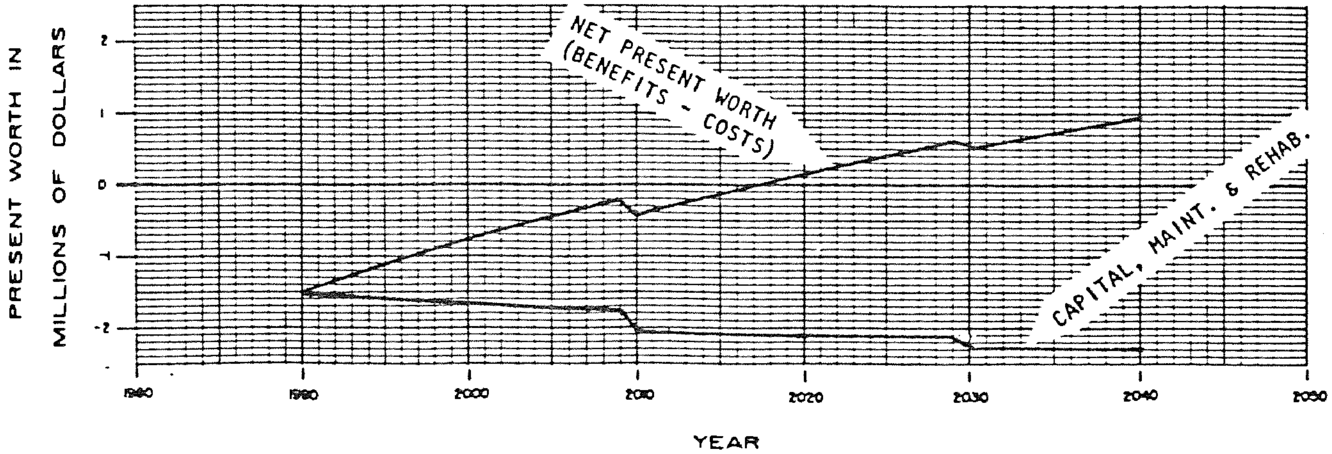


NOTE THE FUNDAMENTAL RELATIONSHIP BETWEEN THESE GRAPHS - THE NET PRESENT WORTH IS ZERO AT THE SAME POINT IN TIME THAT THE INTERNAL RATE OF RETURN IS 4% (BETWEEN YEARS 2017 AND 2018). HAD A DISCOUNTING RATE OF 5% BEEN USED, THE NET PRESENT WORTH LINE WOULD CROSS THE "ZERO" LINE BETWEEN THE YEARS 2023 AND 2024 WHERE THE RATE OF RETURN IS 5%.

BENEFIT-COST ANALYSIS

INTERPRETATION OF THE PRESENT WORTH RESULTS

THE EXAMPLE USED IN THESE PLATES ASSUMES A CAPITAL EXPENDITURE OF $1.5 M IN 1990 AND ACCUMULATING DISCOUNTED (AT 4%) MAINTENANCE AND REHAB COSTS FOR 50 YEARS RESULTS IN A PRESENT WORTH OF ALL EXPENDITURES OF APPROXIMATELY $2.3 M.



THAT PRESENT WORTH OF $2.3 M MEANS THAT IF THAT AMOUNT WERE SET ASIDE AND INVESTED IN 1990, EARNING INTEREST AT THE RATE OF APPROXIMATELY 4% + INFLATION (ACTUALLY 4% + 1.04 TIMES THE INFLATION RATE) ON THE BALANCE REMAINING FROM YEAR TO YEAR, THAT INVESTMENT WOULD JUST FINANCE THE EXPENDITURES OF THE PROJECT OVER THE 50 YEAR PERIOD.

THE DISCOUNTED BENEFITS IN THIS EXAMPLE ARE GREATER THAN THE COSTS (AT LEAST AFTER YEAR 2018) AND THE NET PRESENT WORTH ENDS AFTER 50 YEARS AT A POSITIVE $1.0 M. THE ACCUMULATED DISCOUNTED BENEFITS AT ANY YEAR IS THE AMOUNT BETWEEN THE LINES PLOTTED ON THIS GRAPH AND IN 2040 TOTALS $3.3 M.

IF $3.3 M IS BORROWED AND INTEREST AT THE RATE OF 4% + 1.04 TIMES INFLATION IS PAID ON THE BALANCE REMAINING FROM YEAR TO YEAR, THE BENEFITS FOR THIS PROJECT ALL APPLIED TO PAYING THAT INTEREST AND REDUCING THE PRINCIPAL WOULD JUST RETIRE THAT DEBT IN 50 YEARS TIME.

BRINGING THIS ALL TOGETHER - THE $3.3 M IS SUPPORTED BY THE PROJECT'S BENEFITS AND $2.3 M OF THIS $3.3 M IS REQUIRED TO FINANCE THE PROJECT'S EXPENDITURE. THAT LEAVES $1.0 M PROFIT EXPRESSED IN 1990 DOLLARS.

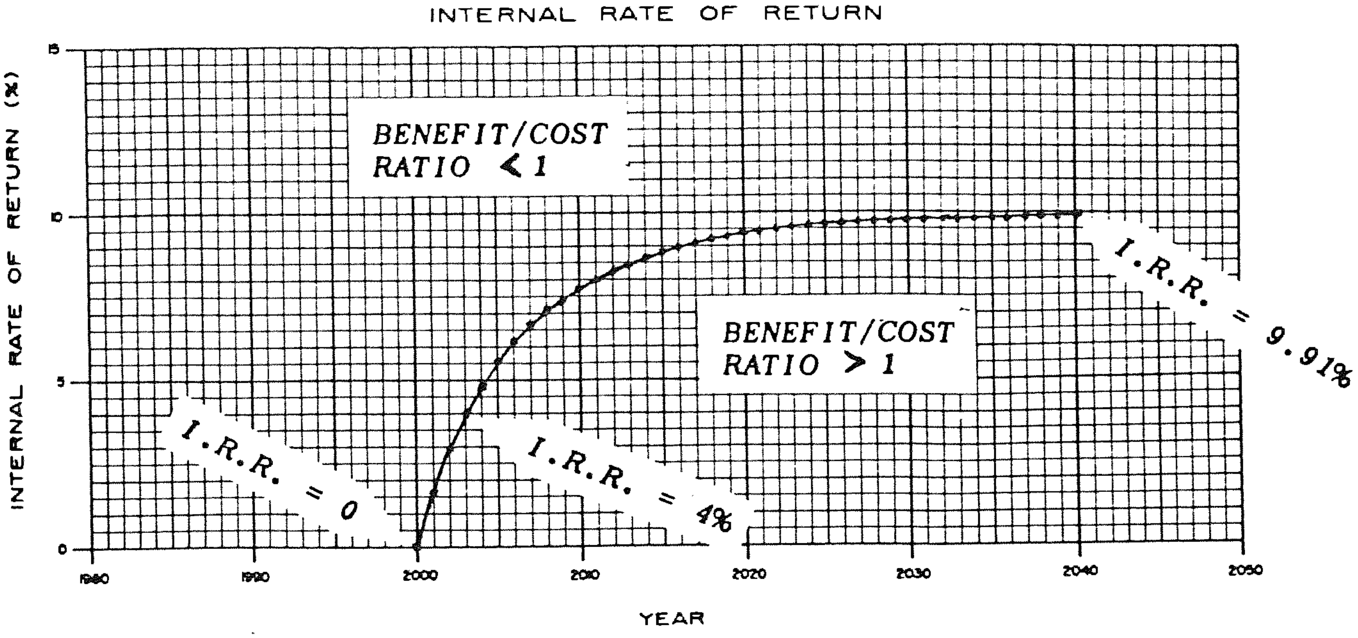
THEREIN LIES THE SIGNIFICANCE OF THE NET PRESENT WORTH. IN THIS EXAMPLE, IF ONE IS SATISFIED WITH THE INPUT VALUES AND HAS CONFIDENCE THAT THIS PROJECT WILL BE USEFUL BEYOND 2017, IT IS A WINNER FINANCIALLY.

BENEFIT-COST ANALYSIS

INTERPRETATION OF THE RATE OF RETURN RESULTS

THE INTERNAL RATE OF RETURN, PARTICULARLY WHEN CALCULATED FOR EACH YEAR OF THE ANALYSIS PERIOD, COMPLEMENTS THE NET PRESENT WORTH INFORMATION AND PERMITS FURTHER ASSESSMENT OF A PROJECT'S MERITS.

FOR EXPLANATION PURPOSES, THE FOLLOWING GRAPH IS A PLOT OF A SIMPLE EXAMPLE WHERE $100.00 IS RETURNED ANNUALLY ON AN INVESTMENT OF $1000.00 IN 1990 WITH NO RETURN OF CAPITAL - NO SALVAGE OR RESIDUAL VALUE IF IT IS A PROJECT.

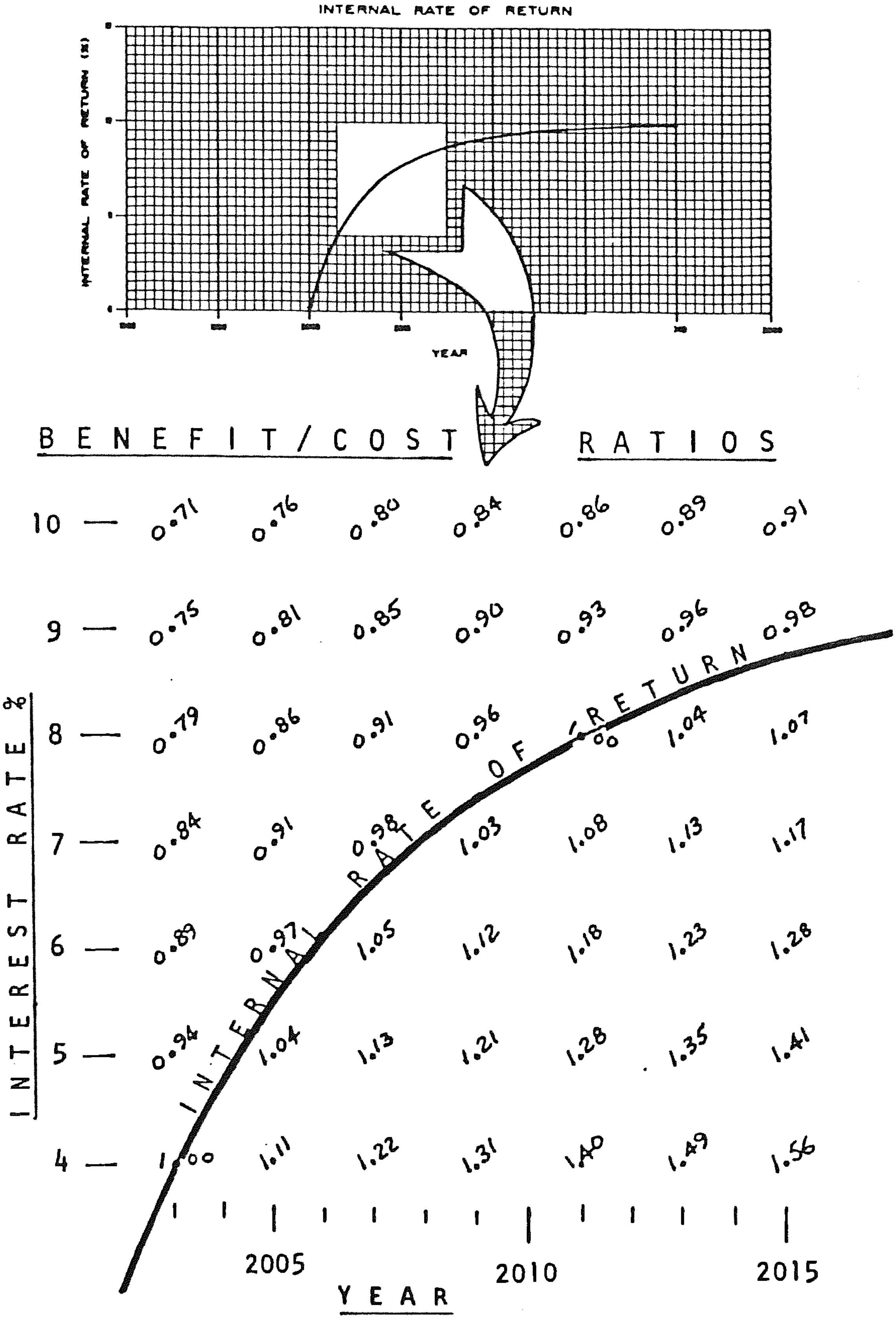


THE FOLLOWING POINTS ARE REFERENCED TO THE GRAPH.

1. THE INTERNAL RATE OF RETURN IS ZERO WHEN UNDISCOUNTED BENEFITS MATCH EXPENDITURES. NOT DISCOUNTING IS THE SAME AS USING 0% AS A DISCOUNT RATE.
2. IF CONSTANT DOLLARS ARE USED, THIS 4% RATE OF RETURN IS SIGNIFICANT - BEING WHAT IS ASSUMED TO BE THE "REAL" RATE OF RETURN.
3. AT YEAR 50, THE INTERNAL RATE OF RETURN IS 9.91% - THAT COMPARES WITH 10% IN PERPETUITY.
4. ANY COMBINATION OF INTEREST RATE AND YEAR LYING ABOVE THE INTERNAL RATE OF RETURN LINE WOULD YIELD A BENEFIT/COST RATIO LESS THAN ONE.
5. A BENEFIT/COST RATIO CALCULATED FOR ANY RATE AND YEAR BELOW THAT LINE WOULD BE GREATER THAN ONE.

BENEFIT-COST ANALYSIS

INTERNAL RATE OF RETURN & BENEFIT/COST RATIO



10	0.71	0.76	0.80	0.84	0.86	0.89	0.91
9	0.75	0.81	0.85	0.90	0.93	0.96	0.98
8	0.79	0.86	0.91	0.96	1.00	1.04	1.07
7	0.84	0.91	0.98	1.03	1.08	1.13	1.17
6	0.89	0.97	1.05	1.12	1.18	1.23	1.28
5	0.94	1.04	1.13	1.21	1.28	1.35	1.41
4	1.00	1.11	1.22	1.31	1.40	1.49	1.56

BENEFIT-COST ANALYSIS

COMPARING ALTERNATIVES

TWO ISSUES

IF "DO NOTHING" CANNOT BE DONE OR WILL NOT BE DONE, CAN THE "MINIMUM" CASE BE TREATED AS A DO NOTHING OPTION AND USED TO COMPARE ALL ALTERNATIVES?

EXAMPLE

ASSUME A FACILITY DEEMED ESSENTIAL MUST AT LEAST BE REPAIRED AT A COST OF $500— . AN OPTION IS TO REPLACE FOR $1,000— - WHICH WOULD ALSO INCREASE IT'S UTILITY BY $50— ANNUALLY.

DECISION - REPAIR OR REPLACE?

GIVEN TWO ALTERNATE COURSES OF ACTION TO JUDGE, IS IT SUFFICIENT TO ANALYSE EACH INDEPENDENTLY, IN EFFECT COMPARING EACH TO DOING NOTHING, OR MUST THE TWO ALSO BE COMPARED - ONE TO THE OTHER?

EXAMPLE

ALT. 1 COSTS $500— AND YIELDS $100— ANNUALLY - A 20% RETURN

ALT. 2 COSTS $1,000— AND YIELDS $150— ANNUALLY - A 15% RETURN

DECISION - DO NOTHING, ALT.1, OR ALT.2?

IN EFFECT THESE ARE THE SAME ISSUE, AND INDEED THE REPAIR-REPLACE EXAMPLE CAN BE MADE IDENTICAL TO THE OTHER BY ASSUMING THAT "DO NOTHING" IS AN OPTION WHICH WILL INCREASE USER COSTS BY $100— ANNUALLY.

IN EACH CASE, THE INCREMENTAL ADDITIONAL COST OF $500— EARNS $50— PER YEAR - A RETURN OF 10% AND WHETHER OR NOT THAT IS GOOD DEPENDS UPON WHAT IS CONSIDERED A MINIMUM ATTRACTIVE RATE OF RETURN (MARR) OR HOW GREATLY SOMETHING ELSE THAT COSTS $500— IS DESIRED.

FROM AN INVESTMENT POINT OF VIEW, IF GREATER THAN 10% CAN BE OBTAINED ELSEWHERE, THE LOWER COST ALTERNATIVE SHOULD BE CHOSEN - CONVERSELY, IF THE HIGHEST RATE OTHERWISE AVAILABLE IS LESS THAN 10%, THE MORE EXPENSIVE OPTION IS BEST.

FORMAT FOR SUMMARIZING

INPUT DATA AND RESULTS OF CALCULATIONS

CHECK LIST

- DESCRIPTION OF PROJECT - INCLUDE LENGTHS/DISTANCES BETWEEN COMMON POINTS FOR LINEAR PROJECTS - HIGHWAYS OR UTILITIES
- ESTIMATED COSTS - MAJOR COMPONENTS OF CAPITAL
  - ANNUAL MAINTENANCE COSTS
  - COMPOSITION (% BREAKDOWN) OF BENEFITS
  - DESCRIBE ANY CHANGES IN VOLUMES WHICH AFFECT COSTS
- YEAR IN WHICH COSTS OR PRICES APPLY (CONSTANT OR CURRENT DOLLARS)
- SPECIFY WHETHER INTERNAL RATE OF RETURN (I.R.R.) IS "REAL" OR "INVESTMENT"
- SHOW ARRAYS OF INPUTS & RESULTS FOR ENTIRE PERIOD OF ANALYSIS

EXAMPLE

NOTE: THIS DATA IS NOT THE BASIS FOR THE GRAPHS DISCUSSED EARLIER

PROJECT: HIGHWAY "X" BETWEEN A & B

BASE CASE (AGAINST WHICH ALL ALTERNATIVES ARE COMPARED) - RESURFACE EXISTING HIGHWAY - 10.68 KM BETWEEN COMMON POINTS

ALT. P-1 - BETWEEN COMMON POINTS. CONSTRUCT 7.70 KM OF NEW ALIGNMENT AND RETAIN 8.7 KM OF OLD HIGHWAY IN SYSTEM

NOTE: CONSTANT DOLLARS USED THROUGHOUT BASED UPON 1989 PRICES

Capital & Maintenance Costs

DESCRIPTION	PER KM	PROJECT	YEAR
ALTERNATIVE P-1			
GRADING	LUMP SUM	$1,850,000	
BASE & PAVE	$218,000	1,680,000	
OTHER COSTS		380,000	
TOTAL		3,910,000	* 1990
MAINTAIN OLD HWY.	3,000	26,000	
+ NEW (1ST 4 YRS.)	4,400	60,000	ANNUAL
SUBSEQUENTLY +	4,600	61,000	ANNUAL
FIRST RECAP	133,000	1,020,000	* 2010
SECOND RECAP	127,000	975,000	* 2025
BASE CASE			
RECAP EXISTING	131,000	1,400,000	* 1990
MAINT. (1ST 4 YRS.)	4,400	47,000	ANNUAL
SUBSEQUENTLY	4,600	49,000	ANNUAL
FIRST RECAP	124,500	1,330,000	* 2005
SECOND RECAP	120,000	1,280,000	* 2020
THIRD RECAP	115,000	1,230,000	* 2035

* DOES NOT INCLUDE YEAR'S MAINTENANCE COST

Road User Costs

Benefits of project would begin in 1991 with values:

DESCRIPTION	AMOUNT	%
Vehicle operation	$ 338,000	58
Collision costs	$ 41,000	7
Time savings	$ 199,000	35
	$ 578,000	100

Besides increasing with inflation, these factors will also increase in direct proportion with increases in traffic volumes which are predicted to be at a rate of 2% per year up to and including 1998 and at a rate of 1% per year thereafter

		ANNUAL COSTS				NET ANNUAL UNDISCOUNTED VALUE			SUM OF P W 4% DIS		IRR "REAL"
		ALTERNATIVE P-7		ALTERNATIVE P-1		CAP COST	R U C	COST+R U C			(guess)
No	Year	CAP	R U C	CAP	R U C	DIFF	SAVINGS	VALUES	CAPITAL	TOTAL	25 00%
0	1988										
1	1989										ERR
2	1990	1,447		3,970		(2,523)		(2,523)	(2,333)	(2,333)	ERR
3	1991	47	1,874	60	1,296	(13)	578	565	(2,344)	(1,830)	-77 61%
4	1992	47	1,909	60	1,320	(13)	589	576	(2,355)	(1,338)	-39 74%
5	1993	47	1,943	60	1,344	(13)	599	586	(2,366)	(856)	-16 71%
6	1994	47	1,978	60	1,368	(13)	610	597	(2,378)	(384)	-3 18%
7	1995	49	2,013	61	1,392	(12)	621	609	(2,385)	78	5 17%
8	1996	49	2,048	61	1,416	(12)	632	620	(2,394)	531	10 56%
9	1997	49			1,440			630		974	14 19%
42			2,769	61		(12)	854		(2,171)	10,502	
43	2031	49	2,790	61	1,930	(12)	861	849	(2,173)	10,659	24 33%
44	2032	49	2,811	61	1,944	(12)	867	855	(2,175)	10,811	24 33%
45	2033	49	2,832	61	1,958	(12)	873	861	(2,178)	10,959	24 34%
46	2034	49	2,853	61	1,973	(12)	880	868	(2,180)	11,102	24 34%
47	2035	1,277	2,873	61	1,987	1,216	886	2,102	(1,987)	11,434	24 34%
48	2036	47	2,894	61	2,002	(14)	893	879	(1,989)	11,568	24 34%
49	2037	47	2,915	61	2,016	(14)	899	885	(1,991)	11,698	24 34%
50	2038	47	2,936	61	2,030	(14)	906	892	(1,993)	11,823	24 34%