TP11875E

# GUIDE TO BENEFIT-COST ANALYSIS

# IN

# TRANSPORT CANADA

SEPTEMBER 1994

# ACKNOWLEDGEMENTS

This Guide was prepared under the direction of Eric Culley, Director, Economic Evaluation. The final text, written principally by Gord Wilson, reflects the cooperative efforts of many individuals. Written contributions to the Guide were provided by Ghislain Blanchard, Dan Laprade, Kevin Moore, Doug O'Keefe and Karen Wilson of the Economic Evaluation Branch, and Dr. David Lewis and Dr. Jenifer Wishart of the Hickling Corporation. A number of other individuals in Transport Canada, the Central Agencies and in the private sector provided review comments.

The Economic Evaluation Branch welcomes comments and suggestions on this Guide.

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**GUIDE TO BENEFIT-COST ANALYSIS IN TRANSPORT CANADA**

## TABLE OF CONTENTS


1.0 PURPOSE OF THE GUIDE ........ 1

2.0 ROLE OF BENEFIT-COST ANALYSIS ........ 1

3.0 ORGANIZATION OF THE GUIDE ........ 2

PART I - THE EVALUATION FRAMEWORK ........ 4

4.0 OPTION IDENTIFICATION ........ 4
- 4.1 Introduction ........ 4
- 4.2 Stating the Problem or Opportunity ........ 4
- 4.3 Identifying Options ........ 5
  - 4.3.1 The Base Case Option ........ 6
  - 4.3.2 Other Options ........ 8
- 4.4 Screening Options ........ 10
- 4.5 Summary ........ 11

5.0 A COMMON FRAME FOR COMPARISON ........ 15
- 5.1 Introduction ........ 15
- 5.2 Self-Standing Options ........ 15
- 5.3 Identification and Quantification of Benefits and Costs ........ 16
- 5.4 Timeframe ........ 17
- 5.5 Level of Effort ........ 18
- 5.6 Designing the BCA Model ........ 19
- 5.7 Summary ........ 19

PART II - MEASUREMENT OF COSTS, BENEFITS AND OTHER EFFECTS ........ 24

6.0. PROJECT-RELATED COSTS ........ 24
- 6.1 Introduction ........ 24

**6.2 Costing Principles .......... 24**

**6.3 Incremental Costs .......... 24**

**6.3.1 Sunk Costs .......... 25**

**6.3.2 Depreciation Allowance .......... 26**

**6.3.3 Interest Expense .......... 26**

**6.4 Project Independence .......... 26**

**6.5 Opportunity Costs .......... 26**

**6.6 Measuring Project-Related Costs .......... 27**

**6.6.1 Planning Phase .......... 27**

**6.6.2 Construction/Development Phase .......... 27**

**6.6.3 Operational Phase .......... 28**

**6.6.4 Post Forecast Phase .......... 29**

**6.7 Life-Cycle Cost Analysis .......... 29**

**6.8 Summary .......... 29**

**7.0 BENEFITS AND OTHER EFFECTS OF PROJECTS .......... 33**

**7.1 Introduction .......... 33**

**7.2 Measurement Principles .......... 33**

**7.2.1 Willingness to Pay .......... 33**

**7.3 Benefits .......... 34**

**7.3.1 Safety Benefits .......... 35**

**7.3.2 Transportation Efficiency Benefits .......... 37**

**Passenger Travel-Time Savings .......... 38**

**Small Travel-Time Savings .......... 40**

**Cargo Transit-Time Savings .......... 40**

**Congestion .......... 41**

**Operating Cost Savings .......... 41**

**Benefits to Non-Canadians .......... 42**

**Generated and Diverted Traffic .......... 43**

**Benefits from Concessions .......... 43**

**7.3.3 Productivity Gains .......... 44**

7.4 Conditional Benefits....................45
7.5 Environmental Effects....................47
7.5.1 Measurement of Environmental Effects....................47
Commercial Losses....................48
Property Value and Damage....................48
Abatement and Cleanup Costs....................48
Habitat Loss....................49
Health Risks....................49
7.6 Transitional Effects....................49
7.7 Exclusion of Economic Impacts....................50
7.8 Summary....................50
8.0 DISCOUNTING....................55
8.1 Introduction....................55
8.2 Inflation....................55
8.3 Why Discount?....................55
8.4 Discounting Arithmetic....................56
8.5 Discount Rate....................56
8.6 DISCOUNTING CONVENTIONS....................57
8.6.1 Timing of Benefits and Costs....................57
8.6.2 Calendar or Fiscal Year....................58
8.6.3 Base Year....................59
8.6.4 Choosing a Timeframe....................60
8.7 Impact of Timing....................62
8.8 Summary....................62
PART III - ANALYSIS AND PRESENTATION OF RESULTS....................66
9.0 EVALUATION OF OPTIONS....................66
9.1 Introduction....................66
9.2 Investment Criteria....................66
9.3 Illustrative Evaluation of Options....................67

**9.4 Dealing With Uncertainty ...... 69**

**9.4.1 Sensitivity Analysis ...... 71**

**9.4.2 Assessing Option Risk ...... 72**

**9.4.3 Probability Analysis ...... 73**

**9.5 Cost-Based Comparisons of Options ...... 73**

**9.5.1 Dealing With Unquantifiable Effects ...... 73**

**9.5.2 Least-Cost Analysis ...... 75**

**9.6 Presentation of Results ...... 75**

**9.7 Summary ...... 76**

**10.0 STRUCTURE OF A BCA REPORT ...... 79**

**PART IV - FINAL SUMMARY ...... 81**

**APPENDIX A - ILLUSTRATIVE APPLICATIONS OF BENEFIT-COST ANALYSIS ...... 85**

**APPENDIX B - TABLE OF DISCUOUNT VALUES ...... 100**

**APPENDIX C - SUGGESTED REFERENCES ...... 101**

**APPENDIX D - ACRONYMS ...... 103**

# GUIDE TO BENEFIT-COST ANALYSIS IN TRANSPORT CANADA

## 1.0 PURPOSE OF THE GUIDE

This guide is intended to provide practical guidance to project analysts and managers in Transport Canada on how to evaluate the economic merits of alternative expenditure proposals using benefit-cost analysis (BCA). By establishing a common framework readily adaptable to the kinds of projects undertaken by the Department, it provides a transportation project focus which is not available from the more general Treasury Board Benefit-Cost Analysis Guide.

The guide is not a "BCA cookbook". The multitude of project types and the diversity of circumstances make BCA "recipes" impractical. Nevertheless, there is sufficient commonality among projects that valuable information can often be obtained by seeing how other analyses were carried out. With this in mind, illustrative applications of BCA in Transport Canada are provided throughout the guide and in an appendix.

Although the guide is oriented towards the practical rather than the theoretical, from time to time, the rationale behind a key element of a BCA is explained.

## 2.0 ROLE OF BENEFIT-COST ANALYSIS

All organizations, whether they be commercial entities or government agencies, are faced with decisions on how best to pursue their objectives - what to do? how to do it? when to do it? To guide investment decisions of this kind, organizations use evaluation techniques which focus on options and search for the option that maximizes the payoff. The main difference between private and public sector organizations lies not so much in the evaluation principles, but rather in the frame of reference.

The frame of reference for a commercial entity is the firm itself. The payoff is internal to the firm and comes in the form of the return on investment. A firm's evaluation of a project would focus on the impact of that project on its financial accounts, even though the options under consideration would often have effects extending beyond those accounts. For example, the location of a new plant for a manufacturing enterprise would have an impact on congestion on adjacent roadways. In evaluating alternative locations, the manufacturer would likely limit its concern about congestion effects to the estimated impact on its own operations and profitability (e.g., by affecting deliveries to, or shipments from, the plant).

The frame of reference for a federal government organization is society at large. While government agencies are concerned with the effect of project options on their own financial accounts, their interest goes further, extending to the costs and benefits to be realized by society. For example, if Transport Canada were to consider the construction of a new runway at an airport to relieve congestion, it would take into account the benefits and costs to all parties affected, not just itself. Values would be put on benefits such as fuel savings to airlines and time savings for passengers, as well as on negative effects like increased noise experienced by individuals living or working in the vicinity of the airport.

Benefit-cost analysis (BCA) is a method of measuring and evaluating the relative merits of public investment projects in support of sound economic decisions. It takes into consideration all of the effects of a project on members of society, irrespective of who is affected or whether the effect is captured in financial accounts.

BCA is useful in planning and decision-making as it provides a common framework in which all of the important effects of investment choices can be made visible and, to the extent possible, quantified. It is a key tool in the quest for value for money.

As will become evident in this guide, the identification and the valuation of benefits and costs is a team effort, requiring the combined knowledge and skills of different specialists (e.g., planners, engineers, subject-matter experts and economists).

## 3.0 ORGANIZATION OF THE GUIDE

The guide is divided into four parts.

Part I deals with the BCA framework and approach to the analysis of options. It consists of two chapters:

> Chapter 4.0 sets out the basic steps in setting up a project evaluation - from the statement of a problem or opportunity, to the identification of the issues, the determination of a base case option and the selection of other options for further analysis; and
>
> Chapter 5.0 focuses on the establishment of a common frame for the comparison of options.

Part II of the guide provides more specific advice on the estimation of the costs, benefits and other effects for various options. It consists of three chapters:

> Chapter 6.0 sets out the basic principles of costing and discusses issues associated with measuring the project-related costs of options;
>
> Chapter 7.0 examines principles and issues relevant to the measurement of benefits and other effects of projects; and
>
> Chapter 8.0 covers the comparison of future costs, benefits and other effects through discounting.

Part III focuses on the analysis and presentation of results. It consists of two chapters:

> Chapter 9.0 examines the process for comparing options, including the selection of the evaluation technique and ways of dealing with uncertainties; and

Chapter 10.0 reviews the structure of a BCA report.

Chapters 4.0 through 9.0 conclude with a summary of the key points covered in the chapter, followed by two case studies. The case studies are intended to illustrate, in general terms, the application of the principles discussed in the chapter.

Part IV is a final summary of key points in the conduct of a BCA.

Three appendices follow Part IV:

Appendix A contains brief descriptions of the application of BCA principles and concepts to illustrative transportation projects;

Appendix B contains a table of discount values; and

Appendix C contains a list of key references for further reading on BCA.

# PART I - THE EVALUATION FRAMEWORK

## 4.0 OPTION IDENTIFICATION

### 4.1 Introduction

Benefit-cost analysis (BCA) is an important tool in the planning and project evaluation process.

A BCA is a requirement of the project approval process established by the Treasury Board. The revised Chapters 545 and 540 of the Administrative Policy Manual, dealing respectively with Major Crown Projects and management and control of all other projects, call for a comprehensive benefit-cost option analysis to be presented at the Preliminary Project Approval (PPA) stage, with the study results refined and/or summarized in the submission for Effective Project Approval (EPA).

At the heart of the evaluation process is the identification and analysis of options. A benefit-cost analysis is a tool for identifying the option that best conforms to the economic goal of maximizing benefits net of costs for society at large.

This chapter and the next focus on the evaluation process. This chapter examines the critical early stages of a BCA, that is, the steps leading up to the identification of the most promising options. Chapter 5.0 discusses the establishment of a common frame for comparing options.

### 4.2 Stating the Problem or Opportunity

The first step in the evaluation process is the formulation of a problem statement. It is an important step, because it sets up the issues - the questions to be resolved by the analysis - and the boundaries of the investigation.

If the scope of the problem is stated too broadly, it is unlikely that all of the trade-offs can be properly examined. If expressed too narrowly, certain key relationships may not be considered.

The project's problem statement should clearly set out the circumstances leading to the consideration of a project. In most cases, this means identifying a particular problem or potential need. For example, a particular facility may be reaching the end of its useful life, or the level of service may be declining (e.g., due to congestion in an air terminal building), or the level of risk may be approaching the maximum acceptable level (e.g., a congested airport traffic control service without the imposition of operational restrictions).

There will also be cases where the initiation of a project will begin with the identification of an opportunity (e.g., to do something more efficiently), rather than with a problem. Modernization, for example, has been an important source of productivity gains for Transport Canada in recent years.

The problem statement should cover:

- Transport Canada's mandate/mission and activities in the field;
- a description of a deficiency or projected failure in Departmental activities or services (or description of an opportunity for improvement); and
- a general indication of the range of possible actions.

The statement of the problem should be as specific as possible in identifying performance deficiencies or opportunities. The more specific the statement, the more helpful it will be in guiding the determination of options.

An example of a good problem statement is the one that was drafted in response to accidents following the introduction of swept-wing turbo-jet aircraft, i.e., a number of accidents occurred in which aircraft landed short of the runway, while conducting visual approaches. The problem was specifically stated along the following lines ---"there is a need to provide jet aircraft pilots with a means of determining their vertical position relative to a predetermined glide slope while on visual approaches". A less specific statement (e.g., to reduce the number of accidents by swept-wing aircraft) would have been inadequate.

Care should be taken to ensure that the problem statement is directed at the underlying cause of the problem, not at symptoms or effects.

The scope of the problem should be broadly stated so that key relationships and a wide range of options can be explored in the analysis.

## 4.3 Identifying Options

A wide range of options must be identified in the early stages of a BCA to ensure that promising solutions are not overlooked.

The identification of options follows from the determination of the significant decision variables. Decision variables are those elements of choice available to decision-makers. It is important to identify the decision variables which are expected to be key cost and benefit drivers. In the case of an air terminal building (ATB) project, the decision variables would include location, configuration and size/capacity of the ATB, scheduling of operations, as well as the timing of construction. For each of these variables, there would be several choices.

Options can be thought of as particular combinations of decision variables, and the specific choices for those variables.

The initial identification of options should focus on major differences in the approach to resolving a problem or taking advantage of an opportunity. Less significant differences in decision variables may be handled in later stages of an analysis, as options are refined.

There are a couple of generic issues/questions, applicable to all BCA, that will assist in the identification of options which provide for major differences in approach:

- **Can the problem be solved to different degrees?** This question deals with the matter of scope, i.e., the magnitude or extent of the solution. Differences in scope normally imply variations in the level of required investment. For example, a problem of congestion in an air terminal building (ATB) may be resolved by expanding the facility to provide for different degrees of "crowding".

  Differences in scope generally, but not always, have level of service implications. There is often a choice between options which offer different benefit levels and involve different costs.

  The question of extent may also be addressed by timing. In the ATB example, there may be distinct choices in the timing of expansion (e.g., a large-scale long-term expansion immediately or a phased expansion over time); and

- **Are there different ways of tackling the problem?** Whereas the previous question dealt with how much action, this issue concerns what kind of action to take. From this main question, a number of more specific questions follow. Are other technical solutions feasible? Are different operating strategies possible (e.g., involving trade-offs between upfront capital expenditures and ongoing O&M expenditures)? Are there feasible non-investment options (e.g., regulatory or pricing measures)?

Not all options require detailed study. Through a screening process, options that are either infeasible, or clearly not cost-beneficial, can be filtered out reliably and fairly quickly. The screening of options is discussed in Section 4.4.

The search for the best option, defined in terms of the benefits realized net of the resources consumed, requires the establishment of a base case option against which the benefits and costs of other options can be compared.

### 4.3.1 The Base Case Option

A base case provides the common point of reference against which to measure the incremental benefits and costs of other options.

Although the base case is likely to resemble the status quo to a substantial degree, rarely would it represent a "do-nothing" option. In many cases, a "do nothing" option is just not realistic, and would merely represent a "straw man" to be knocked down. An exception, however, would be replacement projects, where a "no-replacement" option may be realistic (discussed further below).

The base case should be designed to make the most out of existing facilities. It should reflect the action that management and users would likely take in response to the deficiencies/opportunities identified in the problem statement. Adjustments to present operations or facilities, consistent with ordinary managerial discretion in maintaining efficient operations, should be assumed.

It is a judgement call as to what kinds of adjustments should be included in a base case. Action necessary to maintain existing operations would generally be included. Significant improvements would normally be excluded.

In short, a base case represents the best that managers can do without major investment.

The following are examples of actual Departmental BCAs in which the base case involved certain adjustments to the status quo:

- The base case for the air terminal building project at Thunder Bay, was not a straight "do nothing" option. It included costs for the acquisition of a trailer to handle local service passengers, thereby freeing up holding room capacity for other users;

- In the Integrated Departmental Financial System (IDFS) project, the base case included the development of a simple general ledger accounting package. A strict "do-nothing" base case was not acceptable, because it has to be assumed that management would respond to the planned termination of the existing Department of Supply and Services financial reporting system (DRS);

- The base case in the Cape Race LORAN-C upgrading project involved a small investment to reconfigure the existing transmitter tower; and

- In the BCA for the Canadian Automated Air Traffic System (CAATS), the base case assumed additional sectors and controllers, and an allowance for technological advancements in hardware and software, to enhance the existing flight data processing system.

In establishing the **base case for replacement or restoration projects**, it cannot be assumed that the circumstances that led initially to the acquisition of an asset/facility have remained the same through the years. There are likely to have been significant changes in technology and/or user operations. For example, over time, the airlines serving a particular airport may have moved to smaller aircraft (e.g., B737 to a DASH-8) or terminated long-haul direct international services, making it appropriate for project sponsors to examine the costs and benefits associated with shorter and narrower runways in an analysis of repavement options.

The "no replacement" option must always be considered, but not necessarily selected, as the base case in replacement/restoration/refurbishment projects.

In some cases, a "no-replacement" base case option can be quickly dismissed as uneconomic. For example, if the problem to be addressed is a deteriorating surface on a busy runway at Pearson International Airport, it can be easily demonstrated that the benefits forgone by runway closure would far exceed the cost savings. The "no-replacement" option could, therefore, be rejected with confidence early in the analysis of options.

Most frequently, however, the consequences of non-replacement are not clear, and the development of a formal "no-replacement" base case option is called for. For example:

- In the project to replace air traffic control tower simulators at TCTI, the base case involved continued use of the existing simulators, rather than replacement. The incremental costs and benefits of eventually abandoning such simulation were quantified;

- In the project to replace 15 type 300 and 400 SAR lifeboats, the incremental costs and benefits of replacing each lifeboat were compared to the situation under a retirement scenario; and

- In the project to replace Coast Guard displacement vessels with an air cushion vehicle in buoy-tending services, a "no-replacement" base case was established as a basis for considering the possible redeployment of other vessels.

In certain situations, benefit-cost models exist which, when provided with data relating to a particular facility, quickly indicate whether a "no-replacement" option is an economic one. The benefit-cost model relating to airport traffic control services/flight information services would be used to determine whether a "no-replacement" option could be considered as the base case for an air traffic control tower or flight service station. The Vessel Traffic Services (VTS) model could be used for a similar purpose.

### 4.3.2 Other Options

As noted in Section 4.3, problems can be solved to different extents and in different ways. Not all of these solutions involve significant investment. In many cases, options are available which concentrate on making optimum use of existing assets or on altering current behaviour, practices or levels of service. These options may require little or no new investment.

While there is no established checklist for identifying the options to be considered, the following types of options are appropriate in many cases. All address one or both of the generic issues/questions set out in Section 4.3:

- adjusted levels of service (LOS);
- major or minor investment;
- altered logistics;
- redeployment;
- redistribution of responsibility;
- regulation; and
- pricing.

**Adjusted levels of service**. A level of service is a composite measure of the amount and quality of service to be provided. It is a reflection of the fact that the characteristics of a service can be varied in many ways (e.g., in terms of frequency, duration, timeliness, availability, comfort and convenience) and to different extents. These variations in service characteristics result in different cost and benefit levels. It follows that consideration of different levels of service is an important part of the search for the best option.

The extent of the solution is the central question in projects dealing with congestion and delays caused by capacity limitations (e.g., airside development project for L.B. Pearson International Airport).

**Major and minor investments**. Different levels of investment are usually accompanied by different benefit levels.

The replacement of the existing Advanced Instrument Flight Rules Simulator at the Air Traffic Services Research and Experimentation Centre is an example of a project with options reflecting different levels of investment. One option involved the acquisition of the Canadian Airspace Management Simulator (CAMSIM). Another option involved a reduced capability CAMSIM. The latter option was less expensive, but did not provide the full benefits (e.g., could only handle about half the number of aircraft).

The BCA for IDFS identified, in addition to a base case, two options involving a reduced level of integration (financial functions only) and two others with full integration of the financial and materiel management/ asset functions. The latter two options required investments many times greater than for the former, and yielded substantially greater benefits.

**Altered logistics**. Strategies for service delivery, operations, and maintenance have a direct impact on capital requirements, operating costs and the service levels provided by the Department. Alterations in these strategies may provide feasible options. For example, changing the crewing of Coast Guard vessels from a normal workweek schedule to a "lay day" schedule is sometimes a non-investment option for increasing fleet capacity. In addition, there may be opportunities to use different technologies.

**Redeployment**. Redeployment of other existing Departmental assets may represent a practical alternative to the replacement of an existing asset or the acquisition of a new one. The restructuring plan for the Coast Guard fleet in 1991 is an example of how redeployment can reduce capital requirements, without impacting on level of service.

**Redistribution of responsibility**. Sometimes, an option may be to let others assume or share responsibility. For example, the acquisition of special on-board equipment by mariners may, in some cases, be an alternative to the provision of additional Departmentally-provided navigational aids.

**Regulation**. Non-operational options should be considered. Regulation can be used to require or prohibit certain practices or behaviour. For example, one option for increasing

Search and Rescue success rates might be to require commercial fishermen to have survival suits on board.

A different type of regulatory option relates to the conditions of use placed on certain facilities. Traffic at busy airports could be directed by regulation (or by relaxing regulation) to use other existing airports. In addition, first-come-first-served rules of access to ports and airports could be replaced by access systems that put users of greatest value first in line (e.g., priority berthing rules at specialized facilities, for example, or slot controls at airports).

**Pricing**. Transport Canada levies fees and charges for the use of many of its facilities and services (e.g., harbour dues, landing fees, licensing fees and rentals). The level of these fees and charges can have an important influence on user demands for projects. A pricing option may be particularly relevant where congestion results from unrealistically low fees for the use of facilities and services. Pricing may also be used to mitigate environmental damage.

## 4.4 Screening Options

A full-scale analysis of all options is, of course, not achievable nor is it necessary. A screening process is the best way of ensuring that the analysis proceeds with the most promising options.

Screening options allows a wide range of initial options to be considered, while keeping the level of effort reasonable. The establishment of a process for screening options has the added advantage of setting out in an evaluation framework the reasons for selecting, as well as rejecting, particular options.

Options should be ruled out as soon as it becomes clear that other choices are superior from a benefit-cost perspective. A comparative benefit-cost framework should quickly identify the key features likely to make differences among options. By grouping options similar in key features, differences can often be identified that suggest cost disadvantages or benefit advantages which would persist even if subjected to more rigorous analysis.

In some cases, for a given decision variable, one element of choice may clearly "dominate" the others (i.e., options not including that element of choice would be clearly less attractive). This was the situation with respect to sites (a decision variable) for the new terminal building at Halifax International Airport. The preferred location was identified without quantification of benefits and costs. Firstly, the airport property was divided into four quadrants (elements of choice). In this first step, it was apparent that one quadrant was superior with respect to all other choices. In the second step, there were two possible locations within the preferred quadrant - one involving higher capital costs, the other leading to significantly higher aircraft taxiing times to users. The difference in the taxiing times was of such a magnitude that full quantification of benefits and costs was not necessary for a judgement to be made that the second location was clearly less cost-beneficial.

Options may also be ruled out on the basis that their success depends too heavily on unproven technology or that they just will not work (e.g., a particular air terminal building may be too large for a specific location). Some options may also be constrained by legislation (if a constrained option seemed particularly attractive, legislative changes could be considered).

Care should be taken not to confuse options that will not work with options that are merely less desirable. Options that are simply undesirable will drop out when the benefits and costs begin to be measured.

The objective is to subject options to increasingly rigorous analysis. A good rule of thumb is that, when in doubt about the economic merits of a particular option, the analyst should retain it for subsequent, more detailed rounds of estimation.

## 4.5 Summary

- The first five steps in the evaluation process are set out in Figure 4.1. They are:

    - stating the problem or opportunity;
    - identifying the issues/questions;
    - identifying the base case option;
    - identifying other options; and
    - screening the options.

- The statement of the problem or opportunity leads to the identification of the issues/questions which will guide the formulation of options.

- There are many different ways of tackling a problem. A broad range of realistic options needs to be identified.

- A base case option, reflecting the best that management can do without significant investment, is essential as a reference point against which to compare the other options.

- The "no replacement" option must always be considered, but not necessarily selected, as the base case in replacement/restoration/ refurbishment projects.

- The most commonly explored option involves significant investment. However, other options requiring smaller investments through, for example, the use of existing assets or changes in behaviour, should also be considered.

- A full-scale analysis of all options is not achievable, nor is it necessary. A process for screening options is important in ensuring that the most promising options can be considered at a reasonable level of effort.

- Figures 4.2 and 4.3 illustrate the application of the first five steps in the evaluation process to two case studies.

**Figure 4.1**

**<u>THE EVALUATION PROCESS</u>**

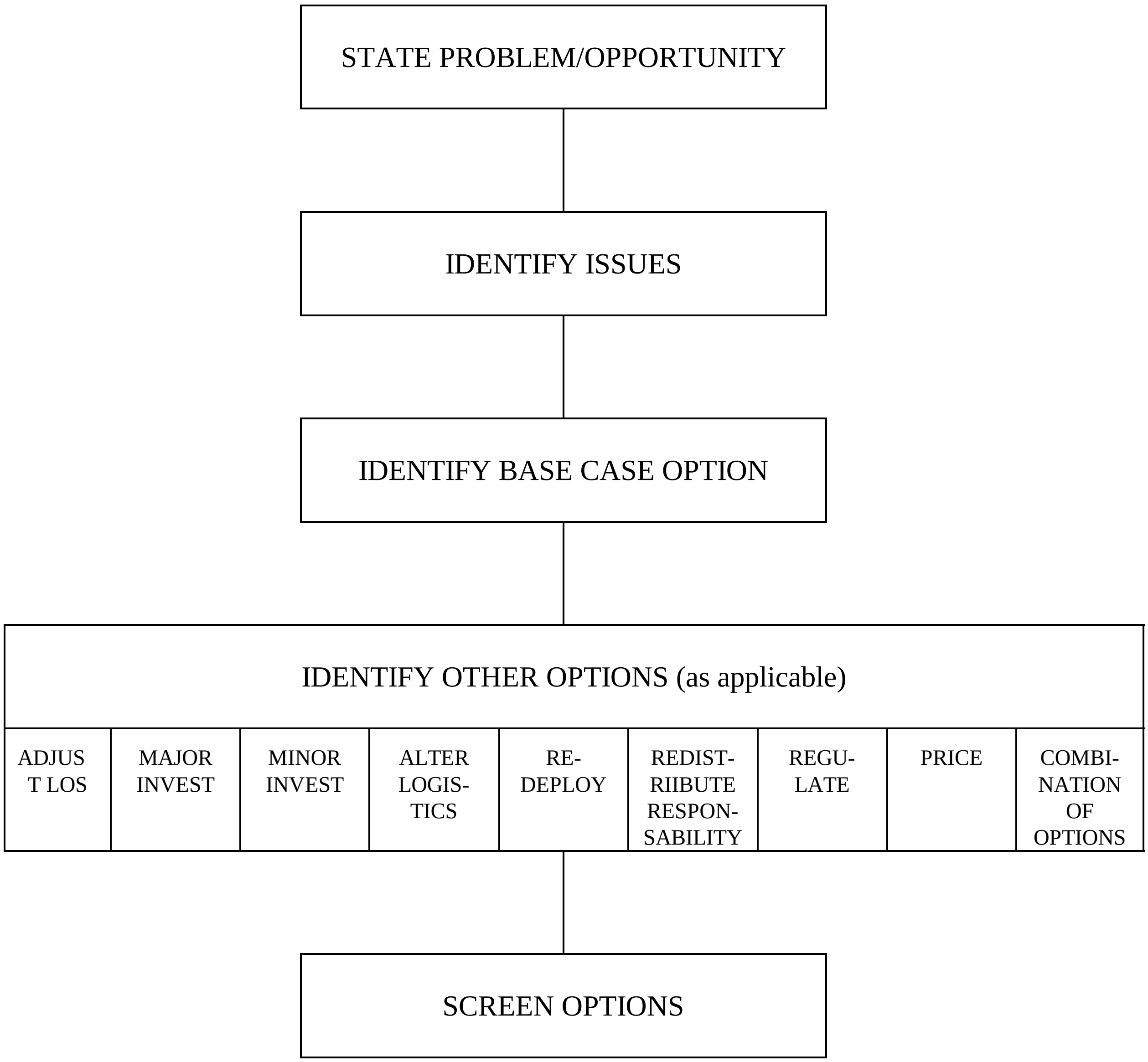

**Figure 4.2**

Case Study 1:
Installation of a CAT II ILS Precision Approach for Runway 07 at Ottawa International Airport

Problem/Opportunity:

There is an opportunity to decrease flight disruptions and cancellations at Ottawa International Airport by upgrading the category 1 (CAT I) precision approach aids to a category 2 (CAT II) system, and/or by improving runway lighting. Options to take advantage of this opportunity are constrained by a TC strategy to replace existing instrument landing system (ILS) technology with microwave technology (MLS) to comply with the ICAO transition date.

Economic Issues:

- Is a CAT II system justifiable on economic grounds?
- Should the approach system be upgraded now or later?
- Should the upgrade be delayed until MLS are available?
- When should lighting facilities be upgraded?

Base Case Option:

Continue with CAT I ILS and install CAT I MLS according to the TC MLS transition strategy.

Other Options:

1. Upgrade the lighting and install a CAT II ILS now, and replace it with a CAT II MLS towards the end of the MLS transition period.

2. Continue with CAT I ILS now and install CAT II MLS and upgrade lighting according to the TC MLS transition strategy (i.e., in 1998/99, at the start of the transition period).

3. Upgrade lighting now and install a CAT II MLS according to the TC MLS transition strategy.

4. Postpone the ICAO MLS transition date.

Screening of Options:

Option 4 was screened out as it is not a self-standing option i.e., the MLS transition date is a variable that affects all of the options. Any uncertainty with regard to the MLS transition date should be considered in a sensitivity analysis of the other options.

None of the remaining options can be screened out as being clearly less cost-beneficial than the others at this point in time.

**Figure 4.3**

Case Study 2:
Replacement of the West Berth at Sydney Marine Terminal (Sydney, N.S.)

Problem/Opportunity:

The 32-year-old Sydney Marine Terminal is in an advanced stage of deterioration and is no longer serviceable.

Economic Issues:

- Can replacement/decommissioning be postponed?
- Is there a continuing requirement for the terminal which cannot be met by using other docks, ports, or transportation modes?
- What facility sizes and configurations should be considered?
- Do construction options have different economic consequences?

Base Case Option:

Decommission the terminal; redirect traffic to other docks/ports/modes.

Other Options:

1. Rebuild a reconfigured terminal.

2. Rebuild to the same size and configuration as the existing terminal.

3. Extend the life of the existing terminal with minor capital improvements or operational changes.

4. Build at a new site within the port.

Screening of Options:

Option 2 is not practical, because building to the same dimensions requires replacement of a sheet steel pile (SSP) wall. To build at the same site, a structure must be placed in front of the SSP wall to stabilize the existing fill, resulting in a larger dock.

Option 3 is not physically feasible. The SSP wall has deteriorated such that the dock cannot safely handle any activity. Attempts to repair the wall will likely cause the dock to collapse.

Option 4 is screened out as the cost to develop a new site is obviously higher without any additional benefits.

# 5.0 A COMMON FRAME FOR COMPARISON

## 5.1 Introduction

The evaluation framework must ensure that the benefit-cost analysis deals with options which are truly comparable.

The following questions have to be addressed in ensuring consistency among options:

- Are the options self-contained and independent of other options or projects?
- Are all of the benefits and costs that vary between the options included?
- Are the short-term transitional benefits and costs included?
- Are the various categories of benefits and costs evaluated to the degree necessary to distinguish among options?
- Do the effects of the options span the same timeframe, and is the timeframe sufficiently long to ensure that all the effects are taken into account?

These questions can be grouped under three headings:

- Self-standing options;
- Identification and quantification of benefits and costs; and
- Timeframe.

## 5.2 Self-Standing Options

Self-standing options are self-contained and independent.

Being **self-contained** means that options are comprehensive, i.e., include all of the actions necessary to make the option work. For example, the benefits of increasing the capacity of an air terminal building (ATB) might not be realized unless ground access to the facility was also improved. To be self-contained, options to increase ATB capacity should include the ground access improvements.

Ensuring that an option is self-contained requires more than simply identifying what actions are required to make an option work. The achievability of an option must be established as well, i.e., what assumptions have to be made for benefits to be realized. Establishing the achievability of an option may require information and judgements in many areas, including technical, behavioural and environmental considerations.

Failure to ensure that options are self-contained leads to the misrepresentation of option benefits and costs.

Being **independent** means that options recognize only incremental benefits and costs attributable solely to them. Special care must be taken in the case of inter-related projects, as is often the case in Air Navigation Services. In the Canadian Automated Air Traffic System (CAATS) BCA, for example, only benefits over and above those resulting from the implementation of the previously approved Radar Modernization

Program (RAMP) were counted. The independence of the CAATS Study was maintained by ensuring that the user benefits derived from aircraft being able to fly the most efficient routes, altitudes and speeds were reduced by the amount of the benefits already estimated for the introduction of least-time tracks, a payoff from the RAMP project.

Failure to ensure the independence of options and projects leads to double counting of benefits and/or costs.

It may not always be practical, however, to define options in such a way as to incorporate all of the decisions at issue. One reason is that the information required to deal with all of the decisions at once may not be available within a reasonable timeframe. In such cases, it may be necessary to accept some limitations to the definition of options, by representing certain aspects of the problem by explicit assumptions.

For example, some of the benefits of CAATS were dependent on the implementation of automated dependence surveillance (ADS) technology. Consideration of ADS was not as far advanced as the evaluation of CAATS. As it was impractical to wait for a decision on ADS, an explicit assumption had to be made in the CAATS BCA about the future of ADS. Given a reasonable expectation that ADS would proceed, and in a way that would not have any negative implications for the economic merits of CAATS, the CAATS evaluation included benefits dependent on the implementation of ADS.

Whenever it is impractical to define options comprehensively, the assumptions and limitations to their definition need to be clearly identified as uncertainties and assessed in the comparison of options (See Section 9.4).

## 5.3 Identification and Quantification of Benefits and Costs

All future benefits and costs that vary between self-standing options must be identified, regardless of who accrues/incurs them.

For each option, all of the features that make that option different from the base case need to be identified and taken into account. Benefits and costs which are the same for all options, including the base case, do not need to be quantified.

It is very important, however, to carefully consider whether the benefits and the costs are indeed the same for all options. It is not always clear, prior to quantification, that this is the case.

Once identified, benefits and costs should be quantified as much as possible, provided that it makes sense. On the one hand, what is possible is limited by the availability of information. On the other hand, what makes sense is determined by the degree of precision required to distinguish among options. For example, while Class B or C estimates are typically used to compare options, there would be little reason to expend additional resources in developing such estimates for a set of options, if a Class D estimate were to establish with reasonable confidence the relationship between the options. The same principle applies whether the quantification is straightforward or difficult.

Establishing the degree of precision required to distinguish the options involves a judgement on the range of uncertainties in the estimation of benefits and costs. For example, projects on the leading edge of technology can involve more significant design risk in respect of the estimates of costs and performance than would be the case for projects based on established design criteria.

The determination of an appropriate level of effort for the quantification of benefits and costs is discussed further in Section 5.5.

There will be certain benefits and costs which remain unquantified, either because evaluation methodologies are not reliable or because the scale of the study does not justify the effort to measure them. In this latter case, the project analyst should attempt to estimate the likely value. As a minimum, options should be ranked in terms of the estimated magnitude of the unquantified effects.

Care must be taken to ensure that difficult to quantify or unquantifiable benefits and costs are not ignored. Inclusion of only those benefits and costs that are relatively straightforward to quantify could lead to selection of the wrong option.

The role of unquantifiable effects in the comparison of options, including the use of sensitivity analysis and other techniques to deal with uncertainties, is discussed further in Chapter 9.0.

A final point on quantification concerns the **distribution of benefits and costs**.

In designing the BCA framework, provision should normally be made to keep track of the distribution of benefits and costs as between the government, transport operators, other users (e.g., passengers, shippers) and third parties. It helps to identify the main stakeholders and the degree to which the economic merits of the project depend on benefits to particular categories of stakeholders.

Such a distribution may also provide support for cost recovery initiatives, by demonstrating the benefits to be realized by those subject to new or increased charges.

For some projects, it may also be of interest to decision-makers to know how benefits are distributed between Canadians and non-Canadians (this point is discussed further in Section 7.3.2).

## 5.4 Timeframe

The costs and benefits of an option are to be evaluated over a timeframe equivalent to the economic (useful) life of the associated facilities/assets affected by the decision.

When options involving facilities with different economic lives are being compared, it is recommended that the analytical timeframe equal the useful life of the most durable assets. For assets having useful life remaining at the end of this timeframe, a residual value should be estimated (refer to Section 6.6.4). For example, a 15-year timeframe would be used to compare a 9-year runway overlay cycle with a 15-year reconstruction cycle. At the end of the 15-year period, a residual value should be used to recognize the value of the remaining three years of the second overlay.

There would be few analyses (although there would be some) in which circumstances would call for a timeframe in excess of 30 years. There are two reasons for this suggested maximum timeframe. First, the economic lives of the most durable Departmental assets seldom exceed 30 years. Second, the discounting of future benefits and costs (discounting is discussed in detail in Chapter 8.0) means that their significance, in present value terms, is reduced as the timeframe lengthens. For example, with a 10% real discount rate, the present value of a dollar spent or received 20 years later is only 15 cents - six cents for a dollar 30 years into the future.

The issue of **when** to act is as important in an economic assessment as **whether** to act. Before completing a benefit-cost analysis, it is important to establish the timing that results in the most cost-beneficial outcome for individual options. For example, a comparison of a refurbishment option to a replacement option may be distorted if a premature replacement date is assumed.

The optimum timing for each option cannot be determined in the early stages of the evaluation process. It can only be established after the costs and benefits have been estimated. It would be at that stage that the timing of an option would be tested through sensitivity analysis, using different dates. This analysis would reveal the impact of project timing on the outcome.

## 5.5 Level of Effort

The determination of an appropriate level of effort is an important part of every economic evaluation. The level of effort is dependent on the payoffs that can be expected.

The key questions in determining the level of effort are:

- how much uncertainty is there concerning the choice of the best option; and
- how much could the possibility of a loss from a wrong decision be reduced by better information or more extensive analysis.

It is useful to revisit these two questions periodically during the analysis to assess the required level of effort on an ongoing basis.

The level of effort is always a matter of judgement, rather than a case of applying hard and fast rules. Generally speaking, the amount of work for an evaluation should be tailored to such things as:

- the nature of the project. Some projects have only a limited number of practical options;

- the magnitude of the project. The appropriate level of effort would tend to rise with the resource implications of a project;

- the variables most likely to make a difference in the outcome. The issue is one of materiality. It makes little sense to expend a lot of effort on obtaining a high degree of precision in the quantification of benefits or costs which are likely to vary little among options or which represent a small share of the overall project benefits or costs;

- the availability of information and techniques to establish benefits and costs. Projects on the leading edge of technology typically involve more effort than projects based on established design criteria, because of the greater design risk; and

- the extent to which one option appears to be superior to others, as the analysis proceeds. The required level of effort would tend to be reduced when one option enjoys a clear advantage.

A careful screening of options (as discussed in Section 4.4) is also a key part of ensuring a reasonable level of effort.

It should be noted that doing more work may mean some delay in making a decision. Any consequences of delay have to be considered as well.

## 5.6 Designing the BCA Model

In most cases, a BCA model is set up on a personal computer using spreadsheet software such as LOTUS 123 or EXCEL. The spreadsheet should be designed in the early stages of a BCA.

Attention should be paid to the layout of the spreadsheet, particularly in regards to the presentation of results. For example, if the presentation is to include the distribution of benefits among categories of users, provision will have to be made upfront for the required breakdown of benefits.

Analysts should build as much flexibility into the model as possible. The model should be able to easily accommodate different values for the key variables in the analysis. Traffic growth assumptions, cost estimates and the discount rate are among the variables that would normally be tested for sensitivity.

## 5.7 Summary

- The establishment of a common frame for comparison requires that:

    - options be self-contained and independent;

- all of the future benefits and costs associated with particular options be identified, regardless of who accrues/incurs them;

- once identified, benefits and costs be quantified as much as possible, provided that it makes sense. What is possible is determined by the availability of data. What makes sense is determined by the level of precision required to distinguish among options; and

- the analytical timeframe coincide with the economic life of the most durable asset under consideration (generally not to exceed 30 years).

- The level of effort is a matter of judgement, dependent on such factors as the nature and magnitude of a project, the expected payoff from incremental effort, the availability of relevant information and measurement techniques and the extent to which an option emerges as clearly superior. Study efforts should be directed at the variables that are most likely to make a difference in the outcome.

- Figure 5.1 sets out the establishment of a common frame for comparison, in the context of the evaluation process discussed to this point.

- Figures 5.2 and 5.3 illustrate the application of this process to the two case studies presented in the previous chapter.

**Figure 5.1**

**THE EVALUATION PROCESS**

STATE PROBLEM/OPPORTUNITY

IDENTIFY ISSUES

IDENTIFY BASE CASE OPTION

IDENTIFY OTHER OPTIONS (as applicable)

| ADJUS T LOS | MAJOR INVEST | MINOR INVEST | ALTER LOGIS-TICS | RE-DEPLOY | REDIST-RIIBUTE RESPON-SABILITY | REGU-LATE | PRICE | COMBI-NATION OF OPTIONS |
|---|---|---|---|---|---|---|---|---|

SCREEN OPTIONS

ESTABLISH OPTIONS FOR COMPARATIVE ANALYSIS

| SELF STANDING OPTIONS | IDENTIFICATION OF BENEFITS AND COSTS VARYING AMONG OPTIONS AND QUANTIFICATION TO EXTENT PRACTICABLE | CONSISTENT TIMREFRAME |
|---|---|---|

**Figure 5.2**

Case Study 1:
Installation of a CAT II ILS Precision Approach for Runway 07 at Ottawa International Airport

Define Self-standing Options:

Base Case Option:

Continue CAT I capability with ILS technology being replaced by MLS in 1996 and 1997.

Option 1:

Install CAT II capability & upgrade lighting (1992 & 93); Replace ILS technology with MLS in 1998 & 99; Replace lighting (2007 & 08). Note that the timing of MLS is varied within the TC MLS transition strategy to enable maximization of the benefits from CAT II ILS.

Option 2:

Continue CAT I ILS (1992 through 1995); Install CAT II capability using MLS technology & upgrade lighting in 1996 & 97;

Option 3:

Upgrade lighting (1992 & 93); Install CAT II capability using MLS technology in 1996 & 97; Replace lighting (2007 & 08).

Identify Costs & Benefits:

The project-related costs for each option are the incremental costs to install and maintain the equipment over the project lifecycle, less any residual value the equipment may have at the end of the lifecycle. The costs to users of new equipment required to use CAT II ILS (if any) are also project-related costs.

The benefits of upgrading a precision approach system arise from a reduction of weather induced transportation inefficiencies including flight delays, overflights, flight cancellations and diversions to other airports. The benefits accrue in the form of passenger timesavings and reductions in airline operating costs.

Establish Consistent Timeframe:

The economic life of a precision approach system is 15 years. A 21-year timeframe was chosen to accommodate the lifecycle of a MLS that is installed in 1996 & 97. The decision year (year 0) is 1991/92.

**Figure 5.3**

Case Study 2:
Replacement of the West Berth at Sydney Marine Terminal (Sydney, N.S.)

Define Self-standing Options:

Base Case Option: Decommission the terminal and redirect traffic to other docks/ports/modes.

This option addresses the issue of the continuing requirement for the terminal. A number of sub-options were explored. Serving Sydney from other ports proved to be very expensive (e.g., $2 million annually to truck petroleum products from Mulgrave). Relocating the docks to North Sydney would incur large costs for dredging and refurbishment. It appeared most likely that the users would relocate to Sydport docks, public facilities operated by Sydney Development Corporation (SDC). However, users would still incur various penalties due to the move e.g., cost of moving pipelines, higher transportation costs.

Option 1: Rebuild a reconfigured terminal.

This option involves the reconstruction, operation and maintenance of a reconfigured terminal over its economic life. A berm wall construction was selected, as it is less expensive than an alternative caisson construction method.

Identify Costs & Benefits:

The Base Case project costs include: (1) the Department's costs to dismantle the terminal and restore the land, net of its value in a new use; (2) the capital and O&M costs incurred by SDC to refurbish Sydport Docks; and, (3) the costs of relocating a tank farm and pipeline from the marine terminal site.

Option 1 project costs include the capital costs to construct the reconfigured terminal, refurbish it at mid-life and O&M costs over its economic life.

The incremental benefits of option 1 consist of the reduced operating costs for users and passenger time savings that occur when this option is chosen over the Base Case.

The project's beneficiaries are the terminal's users (cruise vessel operators and their passengers, an oil company and various shippers of general cargo). Another stakeholder is SDC whose costs are affected by the decision.

Establish Consistent Timeframe:

The timeframe for the analysis is the economic life of the reconfigured terminal (25 years) plus the construction period (2 years). The decision year (year 0) is 1993/94.

# PART II - MEASUREMENT OF COSTS, BENEFITS AND OTHER EFFECTS

## 6.0. PROJECT-RELATED COSTS

### 6.1 Introduction

This chapter presents the principles for identifying the project-related costs of proposals, and provides a discussion of their measurement.

Project-related costs include the costs for all capital, labour and other resources required to plan and implement a project, as well as those costs required to maintain and operate the investment throughout its economic (useful) life. They include costs incurred by Transport Canada, other federal government agencies and departments, other levels of government and any costs that other parties, such as users and transport operators, have to incur to make a project work. An example of the latter would be the new avionics equipment that operators would have to install in their aircraft to use Microwave Landing Systems (MLS) at airports.

This chapter does not deal with either the benefits (e.g., avoided accidents, timesavings, reduced operating costs) or other effects (e.g., increased noise, damage to natural habitat) of projects. These are examined in the following chapter.

### 6.2 Costing Principles

Certain principles are common to all efforts to measure costs in a BCA:

- All costs that differ among the options should be considered, no matter who incurs them (i.e., incremental costs);

- All options should be valued independently--that is, on a stand-alone basis. Care should be taken to ensure that costs attributable to other projects or events are not included in the evaluation; and

- The costs of resources used in an option should reflect their opportunity costs--the value of resources in their best alternative use.

### 6.3 Incremental Costs

A BCA is concerned with the differences among options, be they benefits or costs. Therefore, all cost elements which differ between the options (in other words, the incremental costs) must be reflected in the comparison of options. Costs which are common to the options do not have to be excluded, provided they are appropriately netted out when calculating differences among options.

**All incremental costs**, even those that are only expected to arise in the longer term, should be included in the analysis.

In estimating incremental costs, it is essential to look beyond the out-of-pocket costs that can be identified immediately. There are important categories of indirect or "hidden" costs that may not be readily identifiable from budgets or financial accounts, which need to be included in a BCA. Fringe benefits and overhead are two significant elements of these costs.

**Fringe benefits** include employer costs for legally required payments (Workers Compensation, Unemployment Insurance and Canada/Quebec Pension), pension and welfare plans, cash benefits (such as severance pay, bonus or profit-sharing plans) and non-cash benefits (such as subsidized housing, parking, and company discounts, etc.).

Fringe benefits are normally calculated as a percentage of direct labour costs. Standard fringe benefit percentages for government labour are available from the Management Accounting Branch.

**Overhead** takes the form of either conventional overhead (e.g., the costs of office accommodation, personnel, finance and other administrative support services) or of centralized technical support services (e.g., Technical Services in Aviation, Commercial Development in Airports, Fleet Systems in the Coast Guard).

Overhead should be valued on an average cost basis, using the fully allocated costing rates developed by the Management Accounting Branch.

There may be certain cases where it is necessary to assume explicitly that changes do not all occur immediately, i.e., that some adjustment period is required to restructure or reorganize. This is particularly important for projects aimed at productivity gains, where some time may be needed to realize the estimated cost savings.

In many cases, the costs included in a BCA are different from those appearing on a conventional financial statement. Some of the major differences are discussed in Sections 6.3.1 through 6.3.3.

### 6.3.1 Sunk Costs

BCAs deal with future cost streams. Past expenditures, which cannot be affected by the decision, are not relevant and should almost always be treated as "sunk" costs.

Sometimes, projects can be implemented for very little additional or incremental cost, because they make use of existing fixed assets. If those assets have no opportunity cost (Section 6.5), they are "free" to the project under consideration. However, if they have a material value in an alternative use, that value would have to be taken into account. For example, if a piece of equipment that is already owned is being considered for use in a project, the value that the equipment could command on the resale market should be treated as an economic cost of the project.

Mutually dependent projects involve a special type of sunk cost (See Section 6.4).

### 6.3.2 Depreciation Allowance

For a BCA, capital costs are measured by the cash expenditures required in future years - not by depreciation. To include depreciation, as well as cash expenditures, would result in a double counting of capital costs.

### 6.3.3 Interest Expense

The interest payable on the capital funds required to implement a project should not be included in a BCA. Interest costs are implicitly taken into account, by means of the discount rate, in the computation of net present value (See Chapter 8.0 for a detailed discussion of discounting).

## 6.4 Project Independence

As discussed in Section 5.2, all projects should be valued independently. Costs or benefits already counted in other projects should be excluded. Special care must be taken in the case of inter-related projects. As previously noted, the CAATS study specifically excluded from its benefits those that had already been counted in the justification of the RAMP project.

On the other hand, mutually dependent projects must be considered together. It is not acceptable practice to divide projects into a number of smaller "bites", with later projects taking credit for sunk costs under earlier projects. For example, the BCA of a project to expand a wharf to accommodate larger ships would have to consider the costs and benefits of any channel-dredging project necessary to allow the deeper draft vessels to transit to/from the wharf.

## 6.5 Opportunity Costs

The costs of a project option reflect the value of the resources (e.g., goods and services, labour and capital) consumed in its implementation. For the most part, project-related costs equate to actual, incremental cash expenditures. However, three qualifications apply.

First of all, many projects consume resources that are not reflected in incremental cash expenditures. Typically, these consist of existing resources (people, facilities or equipment) for which there would have been a valuable alternative use. Use of these resources implies a lost opportunity to put them to such other uses, hence the name "opportunity costs."

Consider the example where a project requires that existing staff provide on-the-job training, thereby diverting them from their normal duties. In such cases, the project should be charged with an opportunity cost equal to all of the employment costs of the people involved (which would otherwise have been allocated to their normal activities).

As another example, consider the case of a project that requires the use of vacant, government-owned land, not already committed to other purposes (e.g., to protect runway-zoning requirements). The costs of such a project would include the market value of the land required, as determined by the most valuable alternative use to which the land could be put.

The second qualification applies in cases when some of the resources consumed in a project have been subsidized, so that their prices do not reflect the true cost. In all such cases, the subsidies have to be estimated and added to the prices.

The third qualification relates to the sales or excise taxes that may form part of the expenditures to be incurred in a project. Such taxes, including the federal excise tax on fuel, provincial fuel taxes, provincial sales taxes, and the GST do not represent resources consumed in a project. Accordingly, they should be excluded from project-related costs.

## 6.6 Measuring Project-Related Costs

Measuring project-related costs requires year-by-year estimates of the future cost streams to be incurred by Transport Canada, other government departments and agencies, other levels of government, as well as by the users of the facilities and services to be provided.

The following sections outline the types of costs normally included in a BCA, broken down into four main phases of a project's life:

- planning;
- construction/development;
- operational; and
- post forecast.

### 6.6.1 Planning Phase

The project-related costs in this phase includes all costs incurred prior to procurement or construction. Typical costs are those for planning, project engineering and project design. They would include costs associated with any project team.

For projects dealing with new or advanced technology, particular attention should be paid to project engineering and design costs, as such projects usually involve a significant degree of design risk affecting cost estimates.

### 6.6.2 Construction/Development Phase

The costs associated with project implementation include:

- Land acquisition or opportunity costs of land used;

- Construction costs. Include all such costs, whether incurred for the construction of a new facility or for the modernization or refurbishment of an existing facility. Note that this should include any costs to expand or refurbish a building necessitated by the implementation of a project. For example, the implementation of CAATS required the expansion of a number of Area Control Centres which would not otherwise have occurred;

- Equipment purchase and/or lease, including spares;
- Vehicle purchase and/or lease;
- Project-related training. Include initial training costs for staff, for example, to learn how to operate new equipment. This should include not only the costs of the training programs but also related travel, accommodations and productivity forgone (i.e., staff labour costs);
- Other capital expenditures. Include all capital not elsewhere accounted for (e.g., general furnishings);
- Other start-up costs;
- Transition costs, including those resulting from disruptions during the implementation of the project;
- Decommissioning costs, if any, for facilities to be closed;
- Construction management;
- Contingencies; and
- Costs to other parties, including capital and training necessary to implement the project and accrue the benefits (e.g., access roads to expanded or new facilities, special equipment required by users).

### 6.6.3 Operational Phase

Project-related costs incurred over the operational life of a project include:

- Direct operating costs. The labour component includes regular salaries and wages, overtime, bonuses, allowances and fringe benefits;
- Maintenance costs;
- Overhead and other supporting costs;
- On-going training;
- Periodic capital outlays, such as to mid-life refits over and above regular maintenance; and;

- Operating and maintenance costs incurred by other parties (e.g., snow removal on new access roads).

### 6.6.4 Post Forecast Phase

When the investments contained in the options analyzed do not have the same operational life, an adjustment is made to take account of the fact that one or more options have value extending beyond the analytical period. This value is the residual value of the assets involved. Typically, it is reflected as a reduction in costs in the final year of the analysis.

A market price for the asset at the end of the analytical period is the preferred basis for valuation. In many cases, this price is not available, leaving the net book value of the asset as the only practical measure of residual value.

## 6.7 Life-Cycle Cost Analysis

In addition to a BCA, Treasury Board calls for a life-cycle cost analysis in support of all projects submitted for its approval.

Whereas a BCA seeks to ascertain whether a given project would improve the welfare of society as a whole, a life-cycle cost analysis measures the impact of a project, over its lifetime, on the cash expenditures of the federal government. In other words, a BCA is an **economic** evaluation, while a life-cycle cost analysis is a **financial** evaluation.

With a focus on the cash expenditures of the federal government, a life-cycle cost analysis treats taxes and subsidies differently than a BCA. Provincial sales taxes, provincial GST, and provincial fuel excise taxes paid by the federal government are included in a life-cycle cost analysis (taxes paid by the federal government to itself are excluded). Federal direct subsidies are also included in a life-cycle cost analysis.

As a form of financial evaluation, a life-cycle cost analysis uses a different discount rate than a BCA (see Section 8.5).

In view of the substantial overlap between a life-cycle cost analysis and a BCA, it makes sense to prepare the two analyses at the same time.

## 6.8 Summary

- The measurement of project-related costs:

    - focuses on future cost streams, ignoring sunk costs;

    - includes all future costs that differ among the options, regardless of who incurs them;

    - excludes any costs that are properly attributable to other projects and may already have been counted in the justification of those projects;

  - reflects the concept of opportunity costs; and

  - requires an adjustment to costs where market prices do not reflect opportunity costs (e.g., in the cases of taxes, subsidies and land valuation).

- Depreciation and interest costs must be excluded to avoid a double-counting of project-related costs.

- Figures 6.1 and 6.2 review the estimation of project-related costs for the two case studies presented in previous chapters.

## Figure 6.1

Case Study 1:
Installation of a CAT II ILS Precision Approach for Runway 07 at Ottawa International Airport

Project-Related Costs
(91/92 Constant Dollars)

Note that the costs of the transition to MLS technology were considered in a separate benefit-cost analysis and have therefore been excluded from this analysis. CAT II MLS costs used in the analysis are incremental to CAT I MLS. Capital costs for each option are outlined below:

| Capital Costs | Base Case | Option 1 | Option 2 | Option 3 |
|---|---|---|---|---|
| Improve CAT I ILS Integrity ($50.0k) | Yr 1 | | Yr 1 | Yr 1 |
| CAT II ILS ($1,341.8k) | | Yrs 1 & 2 | | |
| CAT II MLS ($1,068.7k) | | Yr 7 | Yrs 5 & 6 | Yrs 5 & 6 |
| Lighting ($3029.0k) | | Yrs 1 & 2<br>Yrs 16 & 17 | | Yrs 1 & 2<br>Yrs 16 & 17 |

Options 1 and 3 have residual values in Year 21 to account for the remaining useful life of equipment installed in Years 16 and 17.

O&M costs are:

- $93.5k for a CAT II ILS;
- $73.4k for a CAT II MLS (incremental to CAT I MLS);
  $104.4k in years in which a CAT II ILS and MLS are co-located
  .

Summary of Project-Related Costs($000's):

| Year 0(91/92) | Category | Base Case | Option 1 | Option 2 | Option 3 |
|---|---|---|---|---|---|
| 1 | Capital | 50.0 | 1119.8 | 50.0 | 223.0 |
| 2 | Capital | 0 | 3251.0 | 0 | 2856.0 |
| 5 | Capital | 0 | 0 | 1187.2 | 1014.2 |
| 6 | Capital | 0 | 0 | 2910.5 | 54.5 |
| 7 | Capital | 0 | 1068.7 | 0 | 0 |
| 16 | Capital | 0 | 173.0 | 0 | 173.0 |
| 17 | Capital | 0 | 2856.0 | 0 | 2856.0 |
| 3-8 | Annual O&M | 0 | 93.5 | 0 | 0 |
| 7-8 | Annual O&M | 0 | 0 | 104.4 | 104.4 |
| 9-12 | Annual O&M | 0 | 104.4 | 104.4 | 104.4 |
| 13-21 | Annual O&M | 0 | 73.4 | 73.4 | 73.4 |
| 21 | Residual value | 0 | (2300.3) | 0 | (2221.3) |

**Figure 6.2**

Case Study 2:
Replacement of the West Berth at Sydney Marine Terminal (Sydney, N.S.)

Project-Related Costs
(93/94 Constant Dollars)

Base Case:

The cost to decommission the terminal is estimated at $4.5 million. This includes the cost of protecting the deteriorated SSP wall with a berm wall, removing the dock and shed, containing any contaminated fill, and landscaping. The property is expected to have little commercial value and would likely be turned over to the municipality for a waterfront park.

Sydport docks, hitherto under-utilized and currently in a dilapidated condition would need replacement in five years at an estimated cost of $16,000,000 and would have annual O&M costs of $160,000 from year six to the end of the project lifecycle. These costs are less than the combined cost of upgrading and using other docks/ports. At the end of the study timeframe, the Sydport Docks will have a residual value estimated at $4.3 million.

The oil company would have to buy land at Sydport ($200k) and build a new tank farm ($150k) for a total cost of $350,000 in year 2 of the analysis.

Option 1 Rebuild Terminal:

The project-related costs to rebuild the terminal consists of the capital and O&M required over the economic life of the dock i.e. 25 years.

The capital consists of: the development of a detailed plan and specification in the current year (93/94 - year 0) at an estimated cost of $400 k; a first phase of construction in year 1 (94/95) at $3 million; a second phase in year 2 (95/96) at $9.7 million; and, a major repair of the dock scheduled for its mid-life (year 15) which is estimated at $655,000.

Annual O&M costs for years 3 to 27 have been estimated at $131,000.

Summary of Project Related Costs:

| Year | Category | Base Case | **Option 1** |
|---|---|---|---|
| 0 | Capital | 0 | 400,000 |
| 1 | Capital | 0 | 3,000,000 |
| 2 | Capital | 4,850,000 | 9,700,000 |
| 5 | Capital | 16,000,000 | 0 |
| 3-27 | Annual O&M | 0 | 131,000 |
| 6-27 | Annual O&M | 160,000 | 0 |
| 15 | Capital | 0 | 655,000 |
| 27 | Salvage Value of Sydport Docks | ( 4,300,000) | 0 |

# 7.0 BENEFITS AND OTHER EFFECTS OF PROJECTS

## 7.1 Introduction

Benefits are the intended effects of a project. In the economic evaluation of transportation projects, benefits are primarily related to the efficiency of the transportation system (e.g., reduced operating costs), safety of the system (e.g., costs of accidents avoided) and efficiency of government operations.

Projects may have other effects which are unintended. Typically, these other effects are negative (e.g., impact on the environment) and are experienced by third parties. They may be either on-going or transitional (i.e., felt only during the implementation of the project).

While the identification and the measurement of project-related costs, as discussed in the previous chapter, are relatively straightforward, the benefits and other effects are often less readily identifiable and may have no obvious dollar value. Nevertheless, in a BCA all benefits and other effects should be considered, regardless of whether they are intended or unintended, positive or negative, transitional or permanent, and no matter who experiences them.

The measurement of project benefits and other effects is dependent on knowledge of the relationships affecting transportation operations. This is one of several reasons why a successful BCA requires a team effort of different specialists (e.g., planners, engineers, subject-matter experts, economists).

## 7.2 Measurement Principles

The measurement of benefits and other effects involves three steps: the identification of the unit of measure for the benefit or effect considered; the quantification of the measure; and its valuation (i.e., placing a dollar value on it).

The broad principles set out in Section 6.2 are as relevant in measuring benefits and other effects as in measuring the project-related costs:

- incremental effects;
- project independence; and
- willingness to pay (one way of measuring opportunity costs).

Willingness to pay warrants a brief discussion.

### 7.2.1 Willingness to Pay

The estimation of the benefits and other effects of a project requires the best possible measure of the value of the impacts, either positive or negative, on affected parties. Typically, the "market price" associated with an effect (e.g., $/litre of fuel, wage rates, etc.) is taken as the best measure of value.

Consider a project to construct a high-speed turnoff from an airport runway. A key benefit would be the reduction in aircraft operating costs, most notably fuel. The magnitude of this benefit would be determined from an estimate of the quantity of fuel to be saved and the forecast market price of fuel (net of taxes). It is assumed that operators and users would be willing to pay at least the amount of fuel savings for the use of the turnoff. If this amount is greater than the costs of the project, the project would be cost-beneficial.

Of course, fuel savings alone do not provide a complete measure of the value of the project. Other elements of aircraft operating costs would be reduced and passenger time savings should be counted. We would also want to make sure that effects on other stakeholders were accounted for (e.g., aircraft noise).

In the above example, there was a readily available "value" for the fuel saving benefit. However, not all types of benefits and other effects are as easily quantified as fuel savings, e.g., passenger time savings, noise pollution. The concept of measuring willingness to pay remains equally applicable in the case of these latter benefits and effects, albeit more difficult to estimate.

In many transport projects, the presence of economies of scale and the absence of a competitive market for infrastructure means that the prices paid by users of transportation infrastructure are a poor representation of the value of the transport service received. For example, the fee that may be established for the use of a public facility (e.g., landing fees) generally represents only a basis on which to share costs.

The agreement of users to incur higher costs in order to enjoy the use of an improved facility can be taken as an indication that the value of the benefits accruing to the users is as least as great as the incremental costs they agree to bear. For this reason, consultations with users, particularly those involving agreements with direct cost implications, provide information that can simplify the determination of some of the benefits.

It is important to recognize, however, that the magnitude of the benefits identified in this way is limited to the incremental costs actually incurred by the beneficiaries and may only represent a minimum estimate of benefits. As well, the effects on other parties and stakeholders would have to be taken into account.

The following sections provide guidance on estimating the benefits of transportation projects.

## 7.3 Benefits

The benefits from transportation projects take many different forms. The most significant may be grouped into three broad types:

- <u>Safety</u>. Society benefits from a reduction in the number and severity of accidents;

- Transportation Efficiency. Society benefits from a reduction in the resources consumed in transportation. Such benefits accrue to the operators of transport services and the users of transport services (e.g., passengers, shippers, consignees); and

- Productivity Gains. Society benefits from improvements in the efficiency and/or effectiveness of government operations.

There are also environmental benefits. Sometimes, they are the main intended benefits of a project, as would be the case for a glycol containment reservoir at an airport. Other times, environmental benefits follow from the intended safety benefits of a project. For example, the introduction of Vessel Traffic Services in a particular waterway would reduce the risk of accidents, thereby lessening the possibility of a major oil spill from a tanker.

In addition, there are other benefits associated with such difficult to quantify intangibles as comfort, convenience, aesthetics, travel time predictability and contribution to social objectives (e.g., national unity). Some of these benefits may be partially recognized through transportation efficiency benefits. For example, reduced passenger transit times in an expanded air terminal building may reflect additional passenger convenience.

### 7.3.1 Safety Benefits

Safety benefits are among the main payoffs from many transportation investments-Transport Canada's number one priority is safety.

The measurement of safety benefits per se requires an analysis of the safety risks that are associated with the project. Risk is a composite measure of the probability and the severity of an adverse occurrence. A risk analysis is a complex undertaking, requiring answers to the following questions:

- What can go wrong?
- How likely is it? and
- What are the consequences?

A BCA takes the consequences determined by a risk analysis, and attributes a specific dollar value to them.

Safety enhancements reduce the risk of accidents, and the resulting injuries, fatalities and property damage. The benefits of projects designed to enhance safety are the resulting avoidance of, or the reduction in, the number and severity of, accidents that might otherwise occur.

Where accident losses involve tangible goods such as property, accident risks can be valued in a relatively straightforward way, on the basis of replacement or repair costs. However, where losses have intangible consequences such as personal injury or the loss of life, the proper valuation of accident risk becomes more uncertain and judgemental.

Most recent empirical studies on the valuation of the intangible consequences of accidents have focused on what individuals are willing to pay to reduce the risks of accidents. For example, if we could establish that individuals on average are willing to pay $10 to reduce the probability of an accident with fatal consequences by one chance in 100,000, we could use that value directly in an evaluation. However, in order to generalize the results and simplify the presentation, empirical values are often aggregated and expressed on a standardized basis - benefits per statistical accident avoided. In this example, the value of safety benefits could be expressed as one million dollars per fatal accident avoided (i.e., $10 times 100,000 exposures).

Assigning a dollar value to fatalities avoided reflects a widespread recognition of a need for guidance on what should be spent to reduce the risks of transportation accidents. There has been extensive research world-wide to find a solid basis for such guidance, i.e., to determine the amount that society is willing to invest to reduce the statistically-predicted number of accidental deaths in transport. Of course, this is a different concept from what would be spent to save a particular individual whose life might be at risk at a particular time.

It is difficult to establish a value of a fatality avoided with objectivity and precision. There are wide variations in the value used by analysts in Canada and in other countries for project evaluation purposes.

Based on a review of international studies and practices, Transport Canada uses the figure of $1.5 million (1991 dollars) as the value of a fatality avoided in all modes of transport. To ensure that the attractiveness of a given safety-enhancing project does not rest on a single judgemental value for fatalities avoided, the benefits should be subjected to sensitivity analysis to test how cost-beneficial the project would be if higher ($2.5 million) or lower ($500,000) values had been used.

The standard values to be used in benefit-cost analysis in respect of other safety benefits (e.g., the value of avoided injuries) are available from the Economic Evaluation Branch.

It should be noted that the response to many safety-related problems is to trade off the performance of the transportation system, in favour of safety.

For example, in poor visibility, air traffic controllers will slow down the arriving traffic stream at an airport (by increasing the distance separation between aircraft) so as to reduce the risk of conflicts arising. Thus, capacity is reduced to maintain acceptable safety levels. Were instruments to be installed that would allow controllers and pilots to be as sure of the locations of other aircraft in poor weather as in good weather conditions, the arriving traffic stream could be speeded-up to the rate allowed in good weather, and the capacity reduction effects of poor visibility--imposed for safety reasons--would be eliminated. The benefits of such an instrumentation project would be the efficiency gains (e.g., reduced aircraft operating costs, passenger travel-time savings) resulting from the speeded-up flow of traffic.

### 7.3.2 Transportation Efficiency Benefits

Both the operators of transport services, (e.g. airlines, trucking companies, marine carriers) and the users of transport services, (e.g. airline passengers, ferry passengers, shippers/consignees) benefit from improvements in the efficiency of the transportation system.

For the operators of transport services, improved transportation infrastructure may affect the costs of operating existing fleets, increase speed, or permit the introduction of newer technology. For example, extending a runway may make it possible to introduce more efficient aircraft, thereby reducing airline operating costs. In a competitive environment, these savings in transportation costs tend to be passed on to users.

Furthermore, quite apart from reductions in the costs of operating vehicles, vessels or aircraft, the users of the transport services may themselves benefit. For example, a project that reduces flying time (say, by allowing more direct routing of aircraft) will benefit travellers. Similarly, a project that results in reduced sailing times, and more reliable shipping schedules, will benefit shippers and consignees by decreasing the amount of inventory that has to be financed. Such benefits to users are added to the benefits of lower operating costs.

Transportation efficiency benefits, to both the operators and the users of transport services, fall into one of the following broad categories:

- Savings arising from reductions in travel/transit time. Savings result from shortened routes, higher operating speeds or reduced congestion;

- Savings arising from operation of more efficient vehicles, vessels and aircraft. An example includes the reduction in transportation costs resulting from the operation of larger, more heavily laden transportation equipment. These benefits are the main payoff for infrastructure improvement projects such as channel dredging, runway lengthening and strengthening, and highway strengthening;

- Savings because of greater transportation service reliability and predictability. Facilities such as crosswind runways, guidance systems for aircraft landings, and marine navigational aids which mitigate the effects of the weather, provide benefits by avoiding the costs of disruptions to the transport system;

- Savings arising from more direct routing and shifts to more efficient modes of transport. The provision of a new route, access point or service can avoid the use of more costly modes, circuitous routes or double handling of cargo; and

- Savings arising from more efficient cargo handling at terminals. Projects which reduce the handling costs of cargo have pay-offs to shippers/consignees.

Information typically used to assess transportation efficiency benefits includes:

- vehicle operating costs (aircraft, road transport vehicles, ships and other marine vessels, etc.);
- transportation fuel prices and projections;
- value of passenger travel time;
- value of transit time for cargo;
- labour wage rates and wage rate projections; and
- other information specifically related to the project evaluated.

This information is available from a variety of sources. The Economic Evaluation Branch will assist project analysts in identifying these sources.

The measurement of transportation efficiency benefits raises a number of issues. Some of the key ones are discussed below:

- passenger travel-time savings;
- small travel time-savings;
- cargo transit-time savings;
- benefits from reduced congestion;
- benefits to non-Canadians;
- generated and diverted traffic; and
- benefits from concessions.

Passenger Travel-Time Savings

If large enough to be put to productive use (the more debatable value of small travel-time savings is discussed below), savings in travel time represent one of the principal benefits to transport projects involving the movement of passengers, particularly in the case of projects aimed at solving congestion problems.

Travel-time savings arise from faster trips enroute in vehicles/aircraft/ships/trains, quicker processing in terminals or faster access to connecting services. Travel-time savings can also arise from reduced waiting times and delays.

Travel-time savings have an economic value, because time spent travelling means giving up time for something else. In the case of business travel, significant time savings have economic value to the extent that additional productive work is forgone. In general, the value placed on travel time is reflected in the economic decisions people and businesses make concerning the location of businesses, residences and services, and in the expenditures made on travel (e.g., the choice between air travel and less expensive, but more time-consuming, travel by surface mode).

Substantial research has been undertaken in many countries to see whether an average value of time can be inferred from the choices travellers make (say by trading off a higher fare for a faster route or mode of travel). A number of different methodologies can be found, leading to wide variations in the values obtained.

There is widespread agreement, however, that the average travel-time savings for business trips should be valued at the equivalent hourly cost of an employee to the employer. Transport Canada has adopted this procedure, taking into account differences in employment costs among travellers in the different modes of transportation. On this basis, the value of business travel-time savings has been estimated, in 1990 dollars, at $33.70 per hour for air travellers, $24.00 per hour for automobile travellers, and $23.70 for bus and rail travellers.

Implicit in this procedure is the assumption that time spent in travel is entirely wasted. However, it is clear that productive work is often done during travel. Accordingly, a lower value of time for business travellers should be used when the mode of travel allows work to be done enroute, thus reducing the economic value of travel-time savings.

For example, the value of time saved enroute during aircraft or rail travel might not be as great to employers as savings in other circumstances (e.g., when the traveller is also the operator of the vehicle), because the air or rail passenger may be able to do productive work in a part of the time that is to be saved. In Transport Canada, the practice is to assume that no work would be done by an air traveller during landing, take-off or taxiing to/from a terminal building.

In the absence of empirical evidence, the Department has adopted the practice of reducing the value of time savings for business travel by 25% in circumstances where work can be done while travelling.

In regard to non-business travel, the research results suggest that there may be many reasons for the average value of travel-time savings to vary by mode and by traveller income. However, none of the research is sufficiently conclusive to warrant the adoption of a particular approach. Accordingly, Transport Canada assigns equal value to the time savings of non-business travellers, regardless of the mode used and the traveller's income level. The value of time for non-business travel by adults is set at 50 percent of the national average wage -- the approximate mid-point of research results. This value has been estimated at $7.45 per hour in 1990 dollars.

A lower value of time savings for children, who account for approximately 25% of non-business travel, is considered appropriate. While children are not able to fully act on their preferences, their presence does affect the time sensitivity of accompanying adults. For children age 17 and under, Transport Canada uses a value that is 50% of the adult value for non-business travel.

Where the numbers of adults and children affected are not separated, a weighted average value of travel-time savings for all non-business travellers, including children, can be used ($6.50 per hour in 1990 dollars).

Similarly, where reliable information on trip purpose (i.e., business/non-business) is not available, a weighted average value of travel time can be used. The estimated hourly value in 1990 dollars is $22.70 for air travellers, $10.10 for rail travellers, $9.10 for auto travellers and $8.40 for bus travellers.

It should be noted that the values for travel-time savings do not apply to reductions in the time spent in recreational activities per se, such as recreational boating or fishing, or sightseeing. Reductions in the time spent in travelling to or from these activities would constitute a benefit, because it means that more time is available for the leisure activities.

Small Travel-Time Savings

While there is a consensus that large travel-time savings are valuable, there is much less agreement on the value of small travel-time savings, of a few minutes or less. Is their value proportional to the value of large savings, so that a minute saved is worth one-sixtieth of an hour saved? Or is there some threshold below which small travel-time savings decline rapidly in proportional value, because they are too small to be put to any productive use?

This question is not purely academic, as the economic justification of many transport projects might be dependent on whether small travel-time savings are valued proportionally.

The recommended answer to the question is to value all travel-time savings at the rates suggested above (i.e., proportionally), but to isolate any (perhaps cumulative) travel-time savings of less than five minutes per one-way trip as "small", requiring separate consideration by management.

On that basis, the value of small travel-time savings (STS) should be clearly identified but not included in the Net Present Value (NPV) calculation. Instead, the value of STS should be shown separately, together with any "conditional" benefits and costs associated with the project (discussed in Section 7.4 below), enabling management to weigh those effects as it sees fit.

The value of STS should be accompanied by a narrative discussing any factors considered relevant in management's assessment of the weight to be given to this category of benefit (e.g., the likelihood of combinability with other STS outside the project, or the average time saving per one-way trip affected).

Cargo Transit-Time Savings

For shippers and consignees, the cost of using the transport system includes the cost of transportation plus the cost of carrying the inventory of goods in the transportation pipeline. These latter costs can be material, especially in the case of higher-valued goods. Reductions in the time for the transportation, handling or consolidation of shipments would reduce the inventory of goods held in the transportation pipeline. These benefits can be calculated by multiplying the value of the benefiting cargo by the time saved and the carrying cost of the inventory. The prime interest rate should be used as a proxy for the carrying cost.

Improvements in transportation can also lead to efficiencies in the distribution system for goods that yield benefits over and above vehicle operating costs and transportation pipeline benefits referred to above. For example, an improvement in the speed of the freight transport system can lead suppliers to restructure the system of warehouses and thereby reduce the overall distribution system costs. At isolated communities served by water transport in the ice-free navigation season, the construction of temporary winter roads avoids the cost of carrying large inventories of goods over the winter. The Economic Evaluation Branch should be consulted on the measurement of such efficiency benefits.

Congestion

Reduced congestion is a key source of transportation efficiency benefits. The number of berths to be provided at a wharf, the number of runways at an airport, and the number of gates at an air terminal building all represent questions relating to how much capacity should be provided to accommodate the demand for transportation.

Capacity may also be dealt with indirectly. A high-speed turnoff will, for example, decrease the occupancy time of a runway and thereby increase its capacity. The Canadian Automated Air Traffic System (CAATS) project will increase the number of aircraft that can be handled by an air traffic controller, thereby increasing airspace capacity.

The benefits of increased capacity consist of reductions in the frequency and length of delays experienced by vehicles, passengers and cargo. In relatively straightforward cases, such as determining the number of berths at a wharf, average delays are readily estimated using standard models. In other cases, a simulation of traffic flows and processors may be required to estimate average delays (e.g., where severe peaking problems are evident).

Determination of the capacity requirements demands a case-by-case consideration of the benefits and costs associated with alternative capacities. Non-investment options involving pricing measures or capacity controls should also be considered, as ways of addressing the problems of delays and congestion. In the case of the Vancouver and Toronto runway projects, combinations of the number of runways, various runway sizes and airfield configurations were considered, all in the context of pricing and capacity control options.

Operating Cost Savings

The key to the estimation of operating cost savings is a clear understanding of the cost drivers - the factors that have the greatest influence on the costs.

In transportation projects, many of the elements of operating costs can be considered as time-dependent. In this case, the main cost driver would be time (e.g., vehicle transit time) and cost savings could be quantified by multiplying the estimated time saving by a cost per unit of time.

In the case of an airfield improvement project estimated to reduce aircraft taxiing to and from the air terminal building by one minute, the direct relationship between "engine-on" time and fuel consumption would result in a saving of one minute's worth of fuel per aircraft.

However, operating costs are not always time-dependent.

For example, with regard to search and rescue, it is the number of crews required to maintain a state of readiness, rather than the time spent in actual operations, that drives labour costs. Accordingly, crew costs would vary among options only to the extent that the state of readiness varied (e.g., response time, hours of standby, etc.).

Further, there may uncertainty over the extent to which time-dependent costs vary with small time savings. For example, the lumpiness of crew costs and rigidities in employee compensation may mean that a one-minute saving for each aircraft at a particular airport would be insufficient to allow a reduction in the number of crews employed by an airline, or a saving in the amount of monetary compensation to crew on affected flights (it is assumed that there is no other productive activity to which the crew could apply the one-minute saving).

These examples point to the need for considerable care in the estimation of operating cost savings, starting with a clear understanding of the cost drivers. Uncertainties in regard to the assumptions must be identified and assessed (Chapter 9.0) and may require that some operating cost savings be counted among the so-called "conditional benefits" (Section 7.4).

Benefits to Non-Canadians

Benefits to non-Canadians are typically included in Transport Canada project evaluations. The primary rationale is one of reciprocity. Canadians benefit from investments made by foreign governments who, in turn, expect Canada to provide certain facilities and services to their citizens. In addition, there are projects which depend on other governments implementing a similar system before benefits to Canadians and non-Canadians can be realized. For example, the benefit of reduced flying times across the North Atlantic could not be realized from an automated dependence surveillance (ADS) system unless the U.K. implemented a similar system in its oceanic flight information region.

There may be cases where decision-making can be assisted by information which separates benefits to Canadians and non-Canadians. For example, a higher level of service for marine aids to navigation services in the Great Lakes area would benefit vessels proceeding to/from a U.S. port, or between two U.S. ports, in addition to vessels using Canadian ports. The project-related costs would all be borne by Canada, but a significant part of the benefits would accrue to non-Canadians, perhaps some of whom would be competing with Canadians.

In practice, there are often insufficient data to separate benefits to Canadians from benefits to others, especially in the case of domestic transportation services.

Generated and Diverted Traffic

Projects involving major improvements to the transportation system may result in the generation of new traffic or a diversion of traffic from other routes or modes. Such generated or diverted traffic would not normally be an issue for projects which either replace, or make minor adjustments to, existing facilities.

A distinction is needed between benefits to current traffic (or traffic which would continue without the project) and to generated or diverted traffic brought about because of the transportation improvements associated with the project. The benefits for these types of traffic are different.

For current traffic, savings in travel time or costs represent resources freed for other uses. Thus, if an improved highway linking a remote community were to result in a travel-time saving of two hours compared to the existing road, the benefits of the highway for travellers currently using the road would be two hours times the number of trips. This represents a net saving, because existing transportation needs can be met for a smaller cost.

However, the same rationale does not apply to the additional trips that the improved highway might attract -- say, by an increase in the frequency of trips made by local residents. The incremental benefits associated with generated trips are much less than the benefits to current users.

A lower value for generated traffic makes sense, because decisions made by travellers in these cases are taken "at the margin" and it is by no means clear that the full extent of the transport cost savings would in fact represent resources freed for other uses.

The extent to which benefits to generated traffic should be marked down depends upon the nature of the demand for the service. Evidence from economic literature suggests that a factor of 1/3 to 1/2 would normally be appropriate. It is recommended that analysts use a value for generated traffic that is 1/2 of the estimated value of savings to current traffic.

In the case of diverted traffic, there is no easy rule of thumb. The scope of the analysis should be broadened to specifically estimate the impacts of the options on other services. For example, an improved highway to a remote community could attract a number of travellers who would otherwise use air services. The benefits of the highway to these travellers would have to be assessed separately. The Economic Evaluation Branch should be consulted for advice.

Benefits from Concessions

Concessions in an ATB (e.g., restaurants, retail outlets) provide benefits to airport users by allowing them an opportunity to purchase goods and services at the airport. In this way, airport concessions provide a convenience type of benefit.

The fee paid by the concessionaire to the airport operator is not in the nature of a user charge. Instead, it represents what the concessionaire is willing to pay, usually as a result of a competitive bidding process, for the space in the ATB required to run its business. What the concessionaire is willing to pay, is a reflection of the premium that airport users are prepared to pay, at a minimum, for the convenience.

Accordingly, concession fees are an acceptable proxy for the benefits of concession space (the costs of providing the space are counted in the project-related costs).

### 7.3.3 Productivity Gains

Some projects are aimed, either in part or entirely, at improving the productivity of government operations. Examples of projects generating productivity gains include automation projects such as the Canadian Automated Air Traffic System (CAATS), information system projects such as the Integrated Departmental Financial System (IDFS) and training simulators.

Productivity gains are achieved through a reduction in costs for the same output, through an increase in the level of service (LOS) and/or effectiveness of operations with the same resources, or as some combination of the two.

Changes in the value of an output may be either internal or external to the organization. For example, implementation of IDFS will benefit Transport Canada's suppliers (i.e., by enabling prompter payment of invoices), as well as the Department itself.

The **first step** in evaluating productivity gains is to identify the impact of the project on the total organization.

This step may lead the analysis to a wide range of effects including cost avoidances, opportunities for redirecting resources, improved services, and various intangible benefits such as improved communications.

Attention should be paid to existing and projected work activities. As productivity gains are usually derived from a change in the way work is performed, the evaluation should be supported by an analysis of work activities/processes with and without the project. In some projects, such as CAATS, a detailed time-and-motion study is required. In other projects, approximations of workload impact are sufficient.

The **second step** in evaluating productivity gains is their quantification in terms of reliable estimates of changes in costs and level-of-service impacts.

Estimates of changes in costs should not be limited to incremental costs, as discussed in Section 6.3. They should also include the cost of resources freed up for use in other productive activities. This concept is discussed further in Section 6.5.

For example, productivity gains related to improved training might be linked to related indirect costs, such as the time spent in training by the trainees themselves; the cost to the organization of identifying or hiring trainees; the time spent by supervisors or colleagues for on-the-job training; the time required for self-learning; and the costs of errors.

Small changes in workload per worker may not always translate into a cost or a benefit. Where it is not practical to make adjustments to labour costs, and other productive activities are not available, a workload saving will not translate into either a resource cost saving or a level of service improvement. For example, during quiet hours there may not be a benefit from a workload saving for air traffic controllers.

While level-of-service impacts are often of an intangible nature, they can sometimes be linked to tangible benefits. For example, improved communications may be linked to a reduction in the number of face-to-face meetings, which in turn can be measured by out-of-pocket cost savings and reductions in unproductive time due to shorter or more productive meetings.

Some benefits and costs may be unquantified but still need to be considered (see Section 9.5).

The **third step** in evaluating productivity gains is to identify and assess the conditions, limitations and uncertainties to the quantification of benefits (see Section 9.4).

For example, some productivity gains are often conditional on the outcome of actions that lie beyond the scope of the defined options. For instance, rigidities in organizations may limit the extent to which costs can be varied in response to changes in workload, particularly in regard to their timing. Further, the harvesting of **conditional benefits** frequently depends on separate management decisions on restructuring the organization, decisions that may or may not be taken. This concept is discussed further in Section 7.4.

Cost savings associated with allocated costs may give rise to uncertainties, because their realization depends on other things happening. Such cases could include changes in overhead functions, shared facilities such as maintenance bases or data centres, or projects where reductions in workload account for only a small portion of an individual worker's time. An assessment of the likelihood of savings being realized, as well as their timing, would be required.

## 7.4 Conditional Benefits

Most benefits can be achieved as a direct result of the implementation of a project option. Certain benefits, however, may be dependent on unrelated decisions and actions that are beyond the scope of the BCA in question. Such consequences are referred to, in this guide, as **conditional benefits**.

Where decisions and actions lie beyond the scope of a BCA, they have to be handled by way of assumptions. Often, the assumptions can be made with a high degree of confidence, in which case the benefits need not be treated as conditional. For example, a portion of the benefits of CAATS were dependent on the implementation of automated dependence surveillance (ADS), on which a separate decision was to be made at a later date. These benefits were not identified as conditional in the CAATS study, because of the high degree of confidence attached to the assumption that ADS would proceed.

In other cases, assumptions cannot be made with the same confidence (i.e., there may be substantial uncertainty surrounding the separate decision(s) and action(s) required to allow certain project benefits to be achieved). For example, in a project to expand cruise ship-handling facilities at Vancouver, an assumption would have to be made concerning the outcome of legislative proposals in the United States affecting Seattle's ability to compete with Vancouver for the Alaska cruise business. As long as there were substantial uncertainty about this legislation, some of the benefits of the project would have to be identified as conditional.

Sometimes, it may not be possible to identify the separate decisions or actions on which the actual achievement of particular benefits may depend. In the case of small operating cost savings, the achievability of benefits may require other savings with which the projected savings can be combined. It may be, for example, that a small saving in airline crew time would be insufficient on its own to allow a reduction in crew costs. The realization of an actual benefit would then be conditional on the airline's ability to generate other time savings that would, in combination, produce an actual reduction in labour costs.

Where resources are shared or "multi-tasked", there is an increased potential for benefits to be conditional. In such cases, a project may allow one of the tasks to be completed in less time without generating an equivalent reduction in the resources required overall. The conditional benefits would then be realized only if other tasks were to be streamlined as well. For example, the achievability of real savings in the ship costs supporting marine short-range aids to navigation may depend on other decisions also reducing the use of ships for icebreaking or search and rescue activities.

Information technology (IT) projects also have a high probability of generating conditional benefits, because they usually generate workload savings in administrative and overhead functions ("office work"). A significant portion of the benefits from this type of project come from small reductions in workload, representing only a small portion of an individual employee's time. The ability to turn these small time savings into real labour cost savings depends on whether the freed-up resources can be used to perform other productive activities (see Section 6.5) or on whether the savings can be combined with other time savings. IT benefits are therefore often conditional on a decision to restructure overhead functions. This decision would be based on a separate analysis, involving its own set of considerations.

Unless there is a high degree of confidence that these kinds of benefits can be achieved, they should be identified as conditional. Conditional benefits should **not** be included in the calculation of the net present value. They should be presented separately, as discussed in Section 9.6.

In the past (and thus in the case studies cited in this guide), these types of uncertainties were handled as part of the assessment of risks. The presentation of conditional benefits now recommended would provide decision-makers with a better picture of the actual benefits to be expected, and thereby focus their attention on the actions required to achieve all of the benefits potentially available.

## 7.5 Environmental Effects

Impact on the environment is an important effect of many transportation projects. While environmental effects are difficult to measure in a precise way, it is important that they be identified and carefully evaluated (techniques for dealing with unquantifiable effects are discussed in Chapter 9.0).

Environmental effects are unintended and typically negative (e.g., aircraft noise experienced by residents in the vicinity of an airport).

The importance of environmental effects is evidenced by the fact that the government has established a formal process for assessing the impacts of projects on the environment. The Environmental Assessment and Review Process (EARP) involves the identification of potential environmental and directly-related social effects of a project. These effects include changes to the environment and the impact that these changes could have on people. Effects are assessed as to their magnitude and whether they are mitigatable.

In Transport Canada, an environmental impact statement is required for every project. Some Groups have developed a standardized format for such statements. These statements represent a valuable starting point for an analyst in the evaluation and possible quantification of environmental effects.

The main types of environmental effects associated with transportation projects include:

- ground, air or water pollution;
- noise;
- degradation of habitat and natural environment;
- loss of amenities, such as the loss of parkland or reduced accessibility to an area; and
- disposal of contaminated soil.

### 7.5.1 Measurement of Environmental Effects

Identifying environmental effects is one thing, measuring them is another. Information about the values Canadians place on environmental qualities is very subjective and uncertain.

Observed data on environmental effects are often not straightforward. Data on health risks and commercial losses from various pollutants, for example, need careful interpretation. Studies have also shown that people buy houses near airports without necessarily understanding or being able to predict how disturbed they will be by the noise; thus, the lower price that they pay may not fully compensate for the annoyance.

People also tend to downplay risks. An individual's reaction to environmental nuisances often does not represent informed behaviour.

Some environmental values are only established after a disaster. Some environmental effects may not have been identified or faced before, and there may be no precedents for how to value them.

In addition, some environmental effects raise particularly subjective concerns such as the preservation of the environment for the enjoyment of future generations, or the avoidance of irreversible consequences like the destruction of species.

Nevertheless, a number of techniques exist to measure these effects. The measurement of the key types of environmental effects is discussed in the following paragraphs.

Commercial Losses

Some environmental effects of transportation projects might be linked to losses in non-transportation activity. For example, oil spills in ports or along waterways can reduce fishery production; disposal of dredging material can harm fish spawning grounds. In such cases, the estimated commercial losses avoided would be a measure of these environmental effects.

Property Value and Damage

Since an adverse environment reduces the enjoyment of, or the profits from, owning property, and a pleasant setting may enhance both, changes in property values can often be identified with changes in environmental conditions in the vicinity of transportation projects.

Aircraft and freeway noise, for example, affect housing prices near airports and major roads. Estimates of the impact that increased aircraft noise associated with a new parallel runway at Vancouver International Airport would have on property values in the vicinity of the airport were an important part of the quantified environmental effects of the airfield enhancement project of the airport. A similar analysis was conducted in the BCA for the airside development project at Pearson International Airport.

Abatement and Cleanup Costs

The cost of abatement measures is a possible proxy for the value of environmental damage avoided.

In the Vancouver International Airport airfield enhancement project, the costs of providing noise insulation to hospitals and schools that would be affected by aircraft noise formed part of the quantified environmental effects.

In the project to construct a free standing air traffic control tower at Halifax International Airport, there was a possible environmental effect caused by disturbing the mineralized slate on the site. This effect could be quantified by estimating the construction costs necessary to minimize the disturbance.

The Vessel Traffic Services benefit-cost model also uses estimated cleanup costs in its valuation of environmental effects of a marine incident.

In most marine projects to increase channel depth and in some projects to construct or replace wharves, a significant amount of dredged material has to be disposed of. The costs of disposal including, where appropriate, the costs to build containment cells, transport the dredgeate, and treat contaminated soils prior to disposal, are included in the project costs.

Habitat Loss

Some projects may have effects on the natural habitat of animals, birds or fish. One way of valuing the loss of habitat is to estimate the cost of moving the affected wildlife to a new location, when this is feasible. The Vancouver airfield enhancement project considered the cost of establishing replacement habitat, either by improving existing wildlife preserves or by purchasing land currently used for other purposes.

Health Risks

Some environmental effects of projects, particularly changes in the level of air or water pollution, may be linked to changes in health risks, and hence can be evaluated using a methodology analogous to that used for valuing safety improvements (Section 7.3.1).

## 7.6 Transitional Effects

In only a few cases will Transport Canada projects require new construction that is not, in some way, either a replacement of, an expansion to, or an improvement in, facilities and services that are already in use, and possibly quite congested. This means that adjustments to the normal operational patterns at facilities are usually needed to accommodate construction or equipment installation. These temporary or transitional effects must be included in the analysis.

Many of the adjustments needed to implement projects lead to additional transportation costs during the transition period while the project is being implemented. Resurfacing of a runway, for example, may require its closure for extended periods, or at least during certain hours of each day, or may necessitate aircraft using other runways. The use of alternate runways may involve longer taxiing times or, if the runway is shorter, reduced payloads. Restrictions on the use of existing facilities may also divert traffic to other times or places.

Adjustments may also have other effects, temporarily, on third parties. The diversion of traffic to alternate runways could force aircraft to overfly residential rather than industrial areas, thereby leading to increased noise during the construction period. These impacts are also part of the transitional effects of the project which should be taken into account.

Transitional effects should be valued using the same measurement principles as long-term effects (Section 7.2).

## 7.7 Exclusion of Economic Impacts

Economic impact studies demonstrate how payments for transportation and construction activity permeate an economy. A common mistake in benefit-cost analysis is to count these economic impacts or "multiplier effects" as benefits.

When considering the benefits which might accrue from a proposed transportation project, only those benefits which flow directly from the project should be counted. For instance, an additional icebreaker may bring transportation cost savings to vessel operators (e.g., by allowing fuel savings and reduced transit times during the winter shipping season). These benefits are rightfully included in a benefit-cost analysis. While these cost savings may translate into additional income for some individuals, it would be wrong to count as a benefit from the project those secondary impacts or "multiplier effects" which arise from the spending of that income. By doing so, the benefits from the project would be counted twice.

Economic activity should only be included in the estimation of effects if it would not have occurred in the economy at large in the absence of the project. It would take an exceptional set of circumstances to warrant the explicit inclusion of any macroeconomic benefits in a BCA.

Developing estimates of the extent to which these economic impact benefits are incremental to the economy is difficult. It typically requires the use of large-scale and expensive macroeconomic and input-output models in order to develop baseline and project-related macroeconomic scenarios. Hence, level of effort considerations would suggest that the project has to be very large to warrant this type of analysis.

Sponsors of projects who are concerned about the measurement of such effects should discuss them with the Economic Evaluation Branch.

## 7.8 Summary

- All benefits and other effects should be considered, regardless of the party experiencing them, and of whether they are intended or unintended, positive or negative, transitional or long term.

- The basic principles for measuring benefits and other effects are: incrementality, project independence, and willingness to pay.

- Benefits are of three main types:

    - safety;
    - efficiency to users and operators of transportation services; and
    - productivity gains.

- Environmental benefits and other effects should also be identified in a BCA and quantified to the extent practicable.

- A BCA may include a variety of other benefits that are difficult to quantify (e.g., comfort, convenience, aesthetics, contribution to national unity).

- Small travel-time savings (i.e., under five minutes per individual one-way trip) should be separately identified.

- Some benefits are dependent on separate decisions and actions that are beyond the scope of the BCA in question. Unless there is a high degree of confidence that these benefits will be achieved, they should be clearly identified as conditional benefits. Such benefits should not be included in the calculation of the net present value.

- Economic impacts or multiplier effects are excluded, unless they are incremental to the economy at large.

- Figure 7.1 provides a summary of the major benefits and other effects for a number of illustrative projects.

- Figures 7.2 and 7.3 summarize the estimation of benefits and other effects for the two case studies presented in previous chapters.

**Figure 7.1**

Major Benefits and Other Effects of Illustrative Projects

| | Safety Benefits | Transportation Efficiency Benefits | Productivity Gains | Environmental Effects | Transitional Effects |
|---|---|---|---|---|---|
| <u>Airports</u> | | | | | |
| • New Runway at Vancouver International Airport | | • Reduced aircraft operating costs<br>• Passenger time savings | | • Increased aircraft noise to certain neighbourhoods | • User disruption during con-struction |
| • Halifax ATB | | • Reduced aircraft operating costs<br>• Passenger time savings<br>• Increased passenger comfort and convenience | | | |
| <u>Aviation</u> | | | | | |
| • Canadian Automated Air Traffic System (CAATS) | | • Reduced costs for operators (e.g., fuel savings)<br>• Passenger time savings | • Savings in air traffic control operating costs<br>• Improved information for DND, Revenue Canada and Immigration | | |
| • Installation of CAT I Precision Approach Aids at an Airport | • Reduced risk of accidents | • Reduced costs for operators (e.g., fuel savings)<br>• Passenger time savings | | | |
| <u>Marine</u> | | | | | |
| • Replacement of Radar Surveillance in the Port of Montreal | • Reduced risk of vessel collisions, accidents | • Reduced operating costs for ships<br>• Reduced cargo transit times | | • Avoidance of environmental damage from release of dangerous goods or oil in shipping accidents | |
| • Acquire Catamarans for Sounding in St. Lawrence River | • Reduced risk of commercial shipping groundings | • Reduced costs to commercial shipping from ability to carry greater cargo loads | • Reduced operating costs of catamarans compared to present conventional vessels | • Reduced risk of pollution spills | |

## Figure 7.2

Case Study 1:
Installation of a CAT II ILS Precision Approach for Runway 07 at Ottawa International Airport

Benefits and Economic Effects
(1991/92 Constant Dollars)

Base Case Option: The base case has no incremental benefits.

Options 1, 2 & 3 :

An analysis of weather at Ottawa International revealed that a CAT II approach system would allow landings for 49 additional periods a year. CAT II lighting would allow take-offs in a further 19 periods a year. The benefits of a CAT II approach system would arise from reductions in flight delays, overflights, flight cancellations or diversions to other airports. The magnitude of the benefits will depend on the duration and mix of the flight disruptions and their impacts on airline operating costs and passenger delays.

In year 1, the increase in airport usability under option 1 is expected to prevent disruption of 200 flights carrying 11,300 passengers. A standard model was used to quantify the reductions in airline costs and value of passenger time savings for each of the options. These benefits vary over time for each option due to traffic growth assumptions and the differing CAT II implementation schedules.

Another factor affecting the benefits is the rate at which the air carriers equip with MLS avionics. It was assumed that the carriers would exchange MLS for ILS receivers for 25% of their aircraft annually from 1998 to 2001. The annual benefits are summarized below.

Summary of Incremental Benefits:

| Year | Option 1 | Option 2 | Option 3 |
|---|---|---|---|
| 3 | 753.7 | | 94.9 |
| 4 | 790.6 | | 99.4 |
| 5 | 829.4 | | 104.1 |
| 6 | 780.3 | | 109.0 |
| 7 | 913.2 | 224.3 | 224.3 |
| 8 | 946.7 | 350.9 | 350.9 |
| 9 | 981.5 | 604.9 | 604.9 |
| 10 | 1017.6 | 881.7 | 877.1 |
| 11 | 1055.0 | 1062.7 | 1057.9 |
| 12 | 1093.7 | 1100.4 | 1096.8 |
| 13 | 1123.2 | 1130.1 | 1126.3 |
| 14 | 1153.4 | 1160.5 | 1156.6 |
| 15 | 1184.5 | 1191.7 | 1187.7 |
| 16 | 1216.4 | 1223.8 | 1219.7 |
| 17 | 1252.6 | 1252.6 | 1252.6 |
| 18 | 1252.6 | 1252.6 | 1252.6 |
| 19 | 1252.6 | 1252.6 | 1252.6 |
| 20 | 1252.6 | 1252.6 | 1252.6 |
| 21 | 1252.6 | 1252.6 | 1252.6 |

**Figure 7.3**

Case Study 2:
Replacement of the West Berth at Sydney Marine Terminal (Sydney, N.S.)

Benefits and Economic Effects
1993/94 Constant Dollars

Base Case Option:

While there may be benefits from the use of the site as a park, these benefits are not quantified due to uncertainties over environmental considerations.

Option 1 - Rebuild a reconfigured terminal:

The benefits of this option are the savings that accrue to the terminal users when this option is chosen over the Base Case.

The cruise industry prefers the Marine Terminal because of its convenient location relative to the town of Sydney and Fort Louisburg. On occasion, cruise ships using Sydport have hired buses for passengers to visit Sydney at a cost of $3,000 per call. Assuming no increase in the current traffic, bus operating cost savings are estimated at $90,000 per year.

The trip to Fort Louisburg would take half-an-hour longer from Sydport. Each of the estimated 25,000 passengers that visit there each year would spend an additional hour in transit (assuming no increase in passenger traffic). At the non-business passenger time ($8.33 an hour in 93/94 dollars), the total value of travel time savings is estimated at $208,250 per year.

Cargo landed at Sydport must be trucked 14 kilometres to Sydney. The forecasted cargo is 175,000 tonnes in 1996/97 and a typical truck handles 50 tonnes. Unit trucking costs are $120 per round trip. Annual trucking costs are estimated at $420 k in year 3. The cost rises thereafter due to increases in cargo such that the equivalent annual cost over the life of the dock, from year 3, is $453,000.

Decommissioning the terminal will reduce the number of available berths at Sydney by one, resulting in delays to vessels as they await a berth. A queuing model suggests that each of 61 ships that use the docks in the peak period would experience 55 minutes of delay which at an average rate of $600 per hour yields vessel delay cost savings of $33.6 k per year.

Summary of Incremental Benefits:

| Year | Description | Option 1 |
|---|---|---|
| 3-27 | Annual bus operating cost savings | 90,000 |
| 3-27 | Annual passenger time savings | 208,250 |
| 3-27 | Equivalent annual trucking cost savings | 453,000 |
| 3-27 | Annual vessel delay cost savings | 33,600 |
| | **Total Annual Benefits** | 784,850 |

# 8.0 DISCOUNTING

## 8.1 Introduction

This chapter focuses on the mechanics of converting future project-related costs, benefits and other effects to present values so that they can be compared on a common basis.

Transport Canada may, for example, need to choose between repaving a runway with asphaltic concrete with an expected pavement life of 16 years or replacing the base with portland cement concrete with a 25 to 30 year pavement life expectancy. With portland cement, the initial project costs will be higher than asphaltic concrete but the ongoing maintenance costs may be less. To decide which course of action is most advantageous, the future costs and benefits need to be converted to a common base so that they can be compared. Discounting provides the means to do this.

## 8.2 Inflation

Ideally, costs, benefits and other effects should be forecast in nominal dollars (i.e., current or budget year dollars), taking account of the particular way in which their values are expected to change over time. The effects of general inflation would then be removed by converting these nominal dollars to constant dollars.

Transport Canada has adopted a simplified approach in which it is assumed that nominal dollar values (i.e., prices) will typically move in step with the general level of inflation (i.e., to remain the same in terms of constant dollars).

Where values are material and there is a degree of confidence that specific price increase forecasts are likely to be more accurate than general inflation forecasts, estimates should be made in nominal dollars. Fuel is one example of a significant cost element where explicit forecasts of price trends are available (from the Policy and Coordination Group).

Where nominal dollar amounts are to be converted to constant dollars, the Gross Domestic Product (GDP) price deflator is normally used.

## 8.3 Why Discount?

The need to discount stems from the fact that, even when dealing with constant dollars, the value that we place on income and expenditures depends on when they occur.

A dollar to be received a year from now is worth less than the dollar in one's pocket today, because of opportunities forgone during the year.

Two economic concepts follow:

- It is preferable to accrue benefits earlier rather than later (whether the benefits relate to tangible or intangible effects), and to delay expenditures (because there are many competing uses for current resources); and

- There is a need to test whether the future returns from a project are at least equal to the opportunities forgone by not investing current resources in alternative projects.

A detailed conceptual discussion of discounting is contained in Procedures for Discounting Future Values in Economic Evaluations (TP 10567).

## 8.4 Discounting Arithmetic

Future values need to be converted to the common basis of today's value, referred to as the **present value,** in order to compare them.

The present value (PV) of a future cost, benefit or other effect is determined by the formula:

$$PV = \frac{s}{(1+r)^n}$$

where:

| | | |
|---|---|---|
| s | = | future value |
| r | = | the annual discount rate |
| n | = | number of years from the base year |

The difference between a future value and its corresponding present value increases with the number of intervening years and the discount rate.

Present value tables can also be used. These tables provide factors for specific combinations of the discount rate and the number of years which, when multiplied by the future value, yield the present value. Appendix B contains such a table for discount rates used in Transport Canada.

The present value of a stream of future values is the sum of the present values of each element of the stream.

## 8.5 Discount Rate

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%.

In a 1992 letter to the Deputy Minister of Transport, the Secretary of the Treasury Board confirmed 10% as the discount rate, but suggested a narrower range (i.e., 7.5% and 12.5%) for sensitivity analysis.

It has been argued that the 10% real discount rate should be adjusted downwards in the case of certain future benefits and other effects involving a significant degree of judgement in their valuation, namely fatalities, injuries and environmental damage avoided. The issue is one of intergenerational equity -- does a 10% discount rate result in too little weight being given in the investment decision to the value of these benefits and other effects to future generations?

Such an adjustment would result in an implicit increase, relative to other benefits, in the values of future fatalities, injuries and environmental damage avoided. At this time, there is insufficient evidence to support a change in relative values over time.

Pending further consideration of this issue, the same discount rate should be used for all costs, benefits and other effects.

In the case of financial evaluations, such as a life-cycle cost analysis or a review of various financing options for a project, a different discount rate should be used. For such applications, the discount rate should reflect the rates of interest paid by the federal government, rather than the 10% real discount rate used for BCA. The Economic Evaluation Branch should be consulted on the selection of the discount rate for **financial** evaluations.

While the discussion in the following sections is focused on use of the economic discount rate, much of the text applies to use of the financial discount rate as well.

## 8.6 DISCOUNTING CONVENTIONS

### 8.6.1 Timing of Benefits and Costs

To simplify the analysis, the usual convention is that benefits and costs are represented by single annual amounts in each year. In Transport Canada, the end-of-year convention is usually adopted for BCA.

This approach assumes that all transactions occur on the last day of the year in which the costs are incurred or the benefits accrue. The present value is expressed as of the last day of year zero, i.e., the year of decision.

Figure 8.1 illustrates the calculation of present value using the end-of-year convention.

**Figure 8.1**

Illustrative Discounting Calculations

Example: $10,000 is the estimated cost, in constant dollars, in each of years 1993/94 through 1997/98.

The real discount rate is 10%. What is the present value, at the end of the year 0 (i.e., 1992/93), of each of the costs?

It is assumed that costs are incurred at end of each year.

| **Discounting Year** | | | **Present Value at End of Year 0 (1992/93)** |
|---|---|---|---|
| 0 | (1992/1993) | | |
| 1 | (1993/1994) | $10\,000\,\$/(1+0{,}1)^{1} =$ | $ 9,091 |
| 2 | (1994/1995) | $10\,000\,\$/(1+0{,}1)^{2} =$ | $ 8,265 |
| 3 | (1995/1996) | $10\,000\,\$/(1+0{,}1)^{3} =$ | $ 7,513 |
| 4 | (1996/1997) | $10\,000\,\$/(1+0{,}1)^{4} =$ | $ 6,830 |
| 5 | (1997/1998) | $10\,000\,\$/(1+0{,}1)^{5} =$ | $ 6,209 |
| | | | **$ 37,908** (1) |

(1) Present value tables for a stream of payments may also be used to arrive at this figure.

### 8.6.2 Calendar or Fiscal Year

Dollars may be expressed on either a fiscal year or a calendar year basis, but not mixed in the same analysis.

In many cases, it is convenient to adopt a calendar year basis, because of the greater availability of calendar year statistics and forecasts. For project evaluations involving benefits that accrue on a fiscal year basis, such as government labour cost savings, it may be simpler to work on a fiscal year basis.

Figure 8.2 illustrates a conversion of costs from a fiscal- to a calendar-year basis.

**Figure 8.2**

Conversion From Fiscal To Calendar Year

Example: Capital costs are forecast as follows:

| Fiscal Year | Constant 1992/93 $ |
|---|---|
| 1992/93 | 0 |
| 1993/94 | 500,000 |
| 1994/95 | 500,000 |
| 1995/96 | 1,000,000 |
| 1996/97 | 500,000 |
| Total | 2,500,000 |

What are the capital costs expressed on a calendar year basis?

| Year | Conversion to Calendar Year | Capital Costs 1992 $ |
|---|---|---|
| 1993 | 9/12[(1)] x $ 500,000 | $ 375,000 |
| 1994 | 3/12[(2)] x $ 500,000 + 9/12 x $ 500,000 | $ 500,000 |
| 1995 | 3/12 x $ 500,000 + 9/12 x $ 1,000,000 | $ 875,000 |
| 1996 | 3/12 x $ 1,000,000 + 9/12 x $ 500,000 | $ 625,000 |
| 1997 | 3/12 x $ 500,000 $ | $ 125,000 |

(1) April to December = 9/12
(2) January to March = 3/12

If the analyst has better information regarding the seasonal distribution of values in a given year, that information should be employed rather than the uniform distribution assumed in the calculation above.

### 8.6.3 Base Year

Although any base year may be selected, the base year for discounting is normally the same as the year in which the decision is made.

For example, the cost data presented in Figure 8.2 could be part of a project submission prepared for consideration in July 1992. The calendar year 1992 might be selected as the base year for discounting, with future benefits and costs being discounted to December 31, 1992. Expenditure forecasts would be expressed in 1992 constant dollars, as in Figure 8.2.

The capital costs expressed in constant 1992 dollars are discounted, as shown in Figure 8.3, to calculate their present value.

In some cases, there may be costs (e.g., for design work) in the year of decision (Year 0). Option 1 in Case Study 2 (Figure 6.2), for example, included capital costs in the decision year. Costs incurred in the base year are not discounted.

**Figure 8.3**

Calculation of Present Value

| Discounting Year | Calendar Year | Capital 1992 $ | Discount @ 10% | Present Value in Year 0 |
|---|---|---|---|---|
| 0 | 1992 | 0 | 1.0000 | 0 $ |
| 1 | 1993 | 375,000 | 0.9091 | $ 340,909 |
| 2 | 1994 | 500,000 | 0.8265 | $ 413,223 |
| 3 | 1995 | 875,000 | 0.7513 | $ 657,400 |
| 4 | 1996 | 625,000 | 0.6830 | $ 426,883 |
| 5 | 1997 | 125,000 | 0.6209 | $ 77,615 |
| Total | | 2,500,000 | | |
| Present Value as of Dec. 31, 1992 | | | | 1,916,030 $ |

Consistency between the constant dollar year (used to express expenditures) and the base year for discounting is recommended, but not essential.

### 8.6.4 Choosing a Timeframe

As discussed in Section 5.4, the analytical timeframe should coincide with the economic life of the most durable asset under consideration. In most cases, this timeframe would not exceed 30 years.

Figure 8.4 provides an example of present value calculations for two options involving different economic (useful) lives. For illustrative purposes, it is assumed that the benefits are the same for both options - only the capital and operating costs differ. Option 1 involves refurbishing an existing asset at an upfront capital cost of $1 million and then replacing the asset at the end of year 8 at a capital cost of $5 million. Option 2 involves replacement of the asset in Year 1. The refurbishment option has a lower present value cost than the replacement option ($5.28 vs $6.29 million), even though a new asset is required in year 8 and higher operating costs are incurred in years 2 through 8.

Note that, for the refurbishment option, the new asset acquired in year 8 has 7 years of economic life remaining at the end of the study period (a residual value of $2.67 million is netted out of expenditures in the final year of the analysis to account for this remaining life).

**Figure 8.4**

| **Cost comparison of options (10% discount rate)** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **Option 1 Refurbished Asset** | | | | **Option 2 Replacement Asset** | | | |
| **Initial Cost** | **$1 million** | | | | **$5 million** | | | |
| **Annual Maintenance** | **$450,000** | | | | **$250,000** | | | |
| **Useful Life** | **7 years** | | | | **15 years** | | | |
| **Cost Streams, $ millions, Capital purchases at end of year begin operations the following year.** | **Capital** | | **Operations** | | **Capital** | | **Operations** | |
| | **Costs** | **Present Value** | **Costs** | **Present Value** | **Costs** | **Present Value** | **Costs** | **Present Value** |
| Year 1 -- Initial transaction | 1.00 | 0.91 | | | 5.00 | 4.54 | | |
| Year 2 -- Remade and new asset begin their useful lives. | | | 0.45 | 0.37 | | | 0.25 | 0.21 |
| Year 3 | | | 0.45 | 0.34 | | | 0.25 | 0.19 |
| Year 4 | | | 0.45 | 0.31 | | | 0.25 | 0.17 |
| Year 5 | | | 0.45 | 0.28 | | | 0.25 | 0.16 |
| Year 6 | | | 0.45 | 0.25 | | | 0.25 | 0.14 |
| Year 7 | | | 0.45 | 0.23 | | | 0.25 | 0.13 |
| Year 8 -- Remade asset is retired at the end of Year 8. Purchase of new asset required, for use from year 9. | 5.00 | 2.33 | 0.45 | 0.21 | | | 0.25 | 0.12 |
| Year 9 -- From year 9, maintenance costs are the same in both options and could be omitted. | | | 0.25 | 0.11 | | | 0.25 | 0.11 |
| Year 10 | | | 0.25 | 0.10 | | | 0.25 | 0.10 |
| Year 11 | | | 0.25 | 0.09 | | | 0.25 | 0.09 |
| Year 12 | | | 0.25 | 0.08 | | | 0.25 | 0.08 |
| Year 13 | | | 0.25 | 0.07 | | | 0.25 | 0.07 |
| Year 14 | | | 0.25 | 0.07 | | | 0.25 | 0.07 |
| Year 15 | | | 0.25 | 0.06 | | | 0.25 | 0.06 |
| Year 16 -- At the end of Year 16 the new asset purchased in Year 1 is exhausted while the new asset purchased at the end of Year 8 under the first option has 7 useful years remaining. The residual value of the asset is deducted from the cost. | -2.67 | -0.58 | 0.25 | 0.05 | | | 0.25 | 0.05 |
| Totals | 3.33 | 2.66 | 5.15 | 2.62 | 5.00 | 4.54 | 3.75 | 1.75 |
| Total Expenditures for Option | 8.48 | | | | 8.75 | | | |
| Present Value of Option in Year 0 | 5.28 | | | | 6.29 | | | |

## 8.7 Impact of Timing

While the timing of expenditures may not impact on the constant dollar cost of a project (depending on projected changes in real prices), it does change the present value in an important way.

Figure 8.5 shows that even if the costs expressed in constant dollars remain the same, the nominal dollar amount changes with inflation. The present value depends on the timing of the expenditures, due to discounting. The further off in time the capital expenditures, the higher the nominal dollar total and the lower the present value of the costs.

Naturally, project delay also means deferral of its benefits, and a reduction in their present value.

**Figure 8.5**

IMPACT OF TIMING ON PRESENT VALUE OF COSTS

| Discounting Year | Nominal $ | Constant $ | Present Value @10% Real (Year 0$) |
|---|---|---|---|
| 0 | - | - | - |
| 1 | 10,400 | 10,000 | 9,091 |
| 2 | 10,806 | 10,000 | 8,265 |
| 3 | 11,249 | 10,000 | 7,513 |
| 4 | - | - | - |
| 5 | - | - | - |
| | **32,455** | **30,000** | **24,869** |

If costs were delayed by two years:

| Discounting Year | Nominal $ | Constant $ | Present Value @10% Real (Year 0$) |
|---|---|---|---|
| 0 | - | - | - |
| 1 | - | - | - |
| 2 | - | - | - |
| 3 | 11,249 | 10,000 | 7,513 |
| 4 | 11,766 | 10,000 | 6,830 |
| 5 | 12,296 | 10,000 | 6,209 |
| | **35,311** | **30,000** | **20,552** |

## 8.8 Summary

- Discounting is a means to put all costs, benefits and other effects, relating to different time periods, on a comparable basis, i.e., present value.

- In Transport Canada, benefits, costs and other effects are normally forecast in constant dollars.

- Where values are material and specific price increase forecasts are likely to be more accurate than general inflation forecasts, nominal dollar forecasts should be used (e.g., future price of fuel).

- Where nominal dollars are to be converted to constant dollars, the GDP deflator is normally used.

- A 10% real discount rate (i.e., using constant dollars) should be used as a standard value. Sensitivity analysis should be conducted at 7.5% and 12.5%, in real terms.

- Project timing has an effect on net present value.

- Figures 8.6 and 8.7 summarize the discounting of project-related costs, benefits and other effects for the two case studies presented in previous chapters.

## Figure 8.6

Case Study 1:
Installation of a CAT II ILS Precision Approach for Runway 07 at Ottawa International Airport
Discounting ($ '000)

| | | Option 1 | | | Option 2 | | | Option 3 | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Year | Discount Factor | Incremental Costs | Incremental Benefits | Net Present Value | Incremental Costs | Incremental Benefits | Net Present Value | Incremental Costs | Incremental Benefits | Net Present Value |
| | **(1)** | **(2)** | **(3)** | **[(3)-(2)]*(1)** | **(4)** | **(5)** | **[(5)-(4)]*(1)** | **(6)** | **(7)** | **[(7)-(6)]*(1)** |
| 1 | 0.9091 | 1119.8 | 0.0 | -1018.0 | 50.0 | | -45.5 | 223.0 | 0.0 | -202.7 |
| 2 | 0.8264 | 3251.0 | 0.0 | -2686.8 | | | 0.0 | 2856.0 | 0.0 | -2360.3 |
| 3 | 0.7513 | 93.5 | 753.7 | 496.0 | | | 0.0 | 77.2 | 94.9 | 13.3 |
| 4 | 0.6830 | 93.5 | 790.6 | 476.1 | | | 0.0 | 77.2 | 99.4 | 15.2 |
| 5 | 0.6209 | 93.5 | 829.4 | 456.9 | 1187.2 | | -737.2 | 1091.4 | 104.1 | -613.0 |
| 6 | 0.5645 | 93.5 | 870.3 | 438.5 | 2910.5 | | -1642.9 | 131.7 | 109.0 | -12.8 |
| 7 | 0.5132 | 1162.2 | 913.2 | -127.8 | 104.4 | 224.3 | 61.5 | 104.4 | 224.3 | 61.5 |
| 8 | 0.4665 | 93.5 | 946.7 | 398.0 | 104.4 | 350.9 | 115.0 | 104.4 | 350.9 | 115.0 |
| 9 | 0.4241 | 120.6 | 981.5 | 365.1 | 104.4 | 604.9 | 212.3 | 104.4 | 604.9 | 212.3 |
| 10 | 0.3855 | 120.6 | 1017.6 | 345.8 | 104.4 | 881.7 | 299.7 | 104.4 | 877.1 | 297.9 |
| 11 | 0.3505 | 120.6 | 1055.0 | 327.5 | 104.4 | 1062.7 | 335.9 | 104.4 | 1057.9 | 334.2 |
| 12 | 0.3186 | 120.6 | 1093.7 | 310.1 | 104.4 | 1100.4 | 317.4 | 104.4 | 1096.8 | 316.2 |
| 13 | 0.2897 | 73.4 | 1123.2 | 304.1 | 73.4 | 1130.1 | 306.1 | 73.4 | 1126.3 | 305.0 |
| 14 | 0.2633 | 73.4 | 1153.4 | 284.4 | 73.4 | 1160.5 | 286.3 | 73.4 | 1156.6 | 285.2 |
| 15 | 0.2394 | 73.4 | 1184.5 | 266.0 | 73.4 | 1191.7 | 267.7 | 73.4 | 1187.7 | 266.8 |
| 16 | 0.2176 | 246.4 | 1216.4 | 211.1 | 73.4 | 1223.8 | 250.4 | 246.4 | 1219.7 | 211.8 |
| 17 | 0.1978 | 2929.4 | 1252.6 | -331.7 | 73.4 | 1252.6 | 233.3 | 2929.4 | 1252.6 | -331.7 |
| 18 | 0.1799 | 73.4 | 1252.6 | 212.1 | 73.4 | 1252.6 | 212.1 | 73.4 | 1252.6 | 212.1 |
| 19 | 0.1635 | 73.4 | 1252.6 | 192.8 | 73.4 | 1252.6 | 192.8 | 73.4 | 1252.6 | 192.8 |
| 20 | 0.1486 | 73.4 | 1252.6 | 175.3 | 73.4 | 1252.6 | 175.3 | 73.4 | 1252.6 | 175.3 |
| 21 | 0.1351 | -2226.9 | 1252.6 | 470.2 | 73.4 | 1252.6 | 159.3 | -2147.9 | 1252.6 | 459.5 |
| **Total** | | **7872.2** | **20192.2** | **1565.7** | **5434.7** | **15194.0** | **999.5** | **6551.2** | **15572.6** | **-46.4** |

All costs and benefits are expressed in 1991/92 dollars and discounted at 10% to year 0 (1991/92). There are no incremental benefits to the base case. The present value of the base case cost is $50k * 0.9091 = $45.5k

# Figure 8.7

Case Study 2:
Replacement of the West Berth at Sydney Marine Terminal (Sydney, N.S.)
Discounting

| | **Scénario de réf.** | **Option 1** | | | | | |
|---|---|---|---|---|---|---|---|
| Year | Total Costs | Total Costs | Incremental Costs | Incremental Benefits | Net Benefits | Discount Factor | Net Present Value |
| | **(1)** | **(2)** | **(3) = (2)-(1)** | **(4)** | **(5) = (4)-(3)** | **(6)** | **(6)*(5)** |
| 0 | 0 | 400 000 | 400 000 | 0 | -400 000 | 1 0000 | -400 000 |
| 1 | 0 | 3 000 000 | 3 000 000 | 0 | -3 000 000 | 0 9091 | -2 727 273 |
| 2 | 4 850 000 | 9 700 000 | 4 850 000 | 0 | -4 850 000 | 0 8264 | -4 008 264 |
| 3 | 0 | 131 000 | 131 000 | 784 850 | 653 850 | 0 7513 | 491 247 |
| 4 | 0 | 131 000 | 131 000 | 784 850 | 653 850 | 0 6830 | 446 588 |
| 5 | 16 000 000 | 131 000 | -15 869 000 | 784 850 | 16 653 850 | 0 6209 | 10 340 731 |
| 6 | 160 000 | 131 000 | -29 000 | 784 850 | 813 850 | 0 5645 | 459 397 |
| 7 | 160 000 | 131 000 | -29 000 | 784 850 | 813 850 | 0 5132 | 417 634 |
| 8 | 160 000 | 131 000 | -29 000 | 784 850 | 813 850 | 0 4665 | 379 667 |
| 9 | 160 000 | 131 000 | -29 000 | 784 850 | 813 850 | 0 4241 | 345 152 |
| 10 | 160 000 | 131 000 | -29 000 | 784 850 | 813 850 | 0 3855 | 313 774 |
| 11 | 160 000 | 131 000 | -29 000 | 784 850 | 813 850 | 0 3505 | 285 249 |
| 12 | 160 000 | 131 000 | -29 000 | 784 850 | 813 850 | 0 3186 | 259 318 |
| 13 | 160 000 | 131 000 | -29 000 | 784 850 | 813 850 | 0 2897 | 235 743 |
| 14 | 160 000 | 131 000 | -29 000 | 784 850 | 813 850 | 0,2633 | 214 312 |
| 15 | 160 000 | 786 000 | 626 000 | 784 850 | 158 850 | 0,2394 | 38 027 |
| 16 | 160 000 | 131 000 | -29 000 | 784 850 | 813 850 | 0,2176 | 177 117 |
| 17 | 160 000 | 131 000 | -29 000 | 784 850 | 813 850 | 0,1978 | 161 016 |
| 18 | 160 000 | 131 000 | -29 000 | 784 850 | 813 850 | 0,1799 | 146 378 |
| 19 | 160 000 | 131 000 | -29 000 | 784 850 | 813 850 | 0,1635 | 133 071 |
| 20 | 160 000 | 131 000 | -29 000 | 784 850 | 813 850 | 0,1486 | 120 974 |
| 21 | 160 000 | 131 000 | -29 000 | 784 850 | 813 850 | 0,1351 | 109 976 |
| 22 | 160 000 | 131 000 | -29 000 | 784 850 | 813 850 | 0,1228 | 99 978 |
| 23 | 160 000 | 131 000 | -29 000 | 784 850 | 813 850 | 0,1117 | 90 889 |
| 24 | 160 000 | 131 000 | -29 000 | 784 850 | 813 850 | 0,1015 | 82 627 |
| 25 | 160 000 | 131 000 | -29 000 | 784 850 | 813 850 | 0,0923 | 75 115 |
| 26 | 160 000 | 131 000 | -29 000 | 784 850 | 813 850 | 0,0839 | 68 286 |
| 27 | -4 106 667 | 131 000 | 4 237 667 | 784 850 | -3 452 817 | 0,0763 | -263 373 |
| Total | 20 103 333 | 17 030 000 | -3 073 333 | 19 621 250 | 22 694 583 | | 8 093 356 |

All costs and benefits are expressed in 1993/94 $, and discounted at 10% to year 0.

## PART III - ANALYSIS AND PRESENTATION OF RESULTS

## 9.0 EVALUATION OF OPTIONS

### 9.1 Introduction

Previous chapters reviewed the establishment of the evaluation framework and the measurement of benefits, costs and other effects. This chapter looks more closely at the analysis of options -- with the goal of finding the option which has the greatest payoff.

### 9.2 Investment Criteria

There are a variety of criteria available for the ranking of investment options. All focus on incremental benefits and costs vis-à-vis the base case option. The most common criteria are:

- **Net present value (NPV)**. The NPV is calculated by subtracting discounted project-related costs and negative effects, from discounted benefits.

  Provided that unquantified costs, benefits and other effects have been considered, a positive NPV means that selection of that option would leave society better off than it would be with the base case. Any option with a negative NPV should be rejected.

  The preferred option, from an economic perspective, is the one with the largest positive NPV;

- **Benefit-cost ratio**. The benefit-cost ratio is calculated by dividing the present value of the discounted stream of benefits, by the present value of the discounted costs and negative effects. Using this criterion, an option is attractive if the ratio is greater than 1.0. The preferred option, from an economic perspective, is the one with the highest ratio.

  The major drawback of this criterion is that the option with the highest ratio may not have the greatest payoff in aggregate terms (i.e., largest NPV).

  Another weakness is the possibility of inconsistencies in the treatment of negative effects. Some may be handled as reductions to benefits, while others may be considered as part of the costs. The benefit-cost ratio would, of course, be different, depending on whether the negative effects are included in the numerator (i.e., as a reduction in benefits) or in the denominator (i.e., as part of the costs) of the ratio;

- **Pay-back period**. The pay-back period measures the number of years required for the net benefits to recover the initial investment. This criterion may not point to the best economic solution, because it ignores net benefits beyond the payback period. The shortest payback period may not have the highest payoff in the long term; and

- **Internal rate of return (IRR)**. The calculation of the IRR is the reverse of the process for determining the NPV. Instead of establishing the discount rate at 10%, and deriving the present value of the stream of net benefits, as is the case for the NPV, the IRR is calculated by setting the NPV of the net benefit stream to zero and deriving the discount rate necessary to arrive at this answer.

  A problem arises with the IRR criterion when the net benefit stream switches "signs" (i.e., stream changes from positive to negative) during the analytical period. This situation may occur when an option involves large replacement costs during the period. The result is more than one IRR figure.

**Transport Canada uses the NPV criterion for evaluating its projects.** The NPV criterion measures the difference between benefits and costs, which occur at various points in time. It avoids the difficulties arising from "sign" changes in the net benefits stream, inconsistencies in the treatment of negative effects, and differences in the aggregate value of net benefits.

Like any investment criteria, the measure of NPV does not automate decision-making. Instead, NPV estimates are information for the often complex decision-making process that follows the evaluation. The more information that project sponsors can provide about the benefits and other effects of proposed projects, the less decision-makers have to rely on private judgements. Therefore, analysts should strive to put as much of the information they produce into a common yardstick--dollars.

## 9.3 Illustrative Evaluation of Options

Decision-making requires a careful evaluation and comparison of information assembled about each option.

The airfield capacity enhancement project at Vancouver International Airport provides a good example of how the generic issues/questions discussed in Section 4.3 can lead to a wide range of possible solutions. In addition to options requiring various levels of investment, the BCA for this project considered options involving pricing strategies and the shifting of traffic. As a result, this project serves as a useful example on which to base a discussion of the evaluation of options.

Figure 9.1 contains a simplified presentation of the BCA for this project. The options include:

- a base case, involving a number of relatively minor infrastructure improvements (e.g., a high speed runway exit) and procedural changes (e.g., reduced aircraft separation). These improvements and changes also form part of the other options;

- a new 5,000 foot parallel runway;

- a new 8,000 foot parallel runway;

- a new 9,940 foot parallel runway;
- the introduction of a $25 minimum landing fee in addition to a 9,940 foot parallel runway; and
- enhancements at alternative airports (i.e., Abbotsford and Boundary Bay), and a $100 minimum landing fee at Vancouver International Airport.

Other options are compared to the base case option in terms of incremental benefits and costs.

As displayed in Figure 9.1, it is estimated that four of the five other options would have a positive net present value (i.e., be preferable to the base case). Option 5 had a negative net present value, because of the large project-related costs required to expand alternative airports and to provide the required surface transportation infrastructure.

Of the remaining four options, the ones involving 8000 and 9940 feet parallel runways, with and without a minimum landing fee, are substantially more cost-beneficial than the 5000 foot runway option. Although the former requires larger capital investments, they generate several times more savings to carriers (e.g., in fuel and labour costs) and to passengers (in terms of reduced travel times). The larger investment costs, as well as the higher noise costs, associated with the longer runway options are more than offset by the increase in user benefits.

If we were equally confident about all of the estimates of benefits and costs in the table, the 9940 foot parallel runway with the $25 minimum landing fee (Option 4) would be preferred as having the highest net present value of the options compared. If we were also sure that no significant options had been left out of the evaluation process, this option could be confidently recommended.

Setting aside the possibility of other untested options, two factors might alter this choice.

First, unevaluated effects may differ among options. If, for example, the 9940 foot runway involved unquantified environmental damage (e.g., damage to wildlife natural habitat), not present with the 8000 foot runway, the balance of advantage may be altered. In such a case, decision makers would have to assess whether the habitat loss could be valued at $154.5 million ($3915.6 million less $3761.1 million) or more, thus equalizing or reversing the net present value advantage of the 9940 foot runway.

The second situation that may alter choices is if estimates of the different costs and benefits are affected differently by forecasting uncertainties. All forecasts are affected by economic risk--the future course of the economy. But not all forecasts would be affected to the same extent by particular risks. Fuel price forecasts, for example, affect vehicle cost estimates directly, but noise costs only indirectly (e.g., higher fuel prices could lead airlines to switch earlier to new aircraft with quieter more fuel-efficient engines). Accordingly, uncertainties about fuel prices impose different risks on the various types of estimates.

Additionally, different degrees of uncertainty may be attached to different estimates, because analytical techniques are subject to varying degrees of verification. There may be better empirical verification of vehicle costs estimates, compared with travel demand forecasts or noise cost methodologies.

**Figure 9.1**

AIRFIELD CAPACITY ENHANCEMENT PROJECT FOR
VANCOUVER INTERNATIONAL AIRPORT
SUMMARY OF INCREMENTAL BENEFITS AND COSTS
(expressed in present value using millions of 1988 dollars)

| | **Options**[1] | | | | |
|---|---|---|---|---|---|
| | Option 1 | Option 2 | Option 3 | Option 4 | Option 5 |
| | **5000 Foot Runway** | **8000 Foot Runway** | **9940 Foot Runway** | **9940 Foot Runway &$25 Mininum Landing Fee** | **Alternative Airports & $100 Minimum Landing Fee** |
| **Project-Related Costs (incremental to Base Case)** | | | | | |
| Capital costs | 19.0 | 35.0 | 48.0 | 48.0 | 2143.0 |
| O&M costs | 9.0 | 15.5 | 19.0 | 19.0 | 667.0 |
| Total Incremental Costs | 28.0 | 50.5 | 67.0 | 67.0 | 2810.0 |
| **Benefits (incremental to Base Case)** | | | | | |
| Savings in operating costs to air carriers | 367.0 | 1834.0 | 1890.0 | 2214.0 | 817.0 |
| Time savings to passengers | 439.0 | 2021.0 | 2136.0 | 2136.0 | 878.0 |
| Total Incremental Benefits | 806.0 | 3855.0 | 4026.0 | 4350.0 | 1695.0 |
| **Negative Effects (incremental to Base Case)** | | | | | |
| Noise costs to third parties | 34.7 | 43.4 | 43.4 | 43.4 | 10.0 |
| **Net Present Value (Incremental Benefits less Project-Related Costs) less Negative Effects** | 743.3 | 3761.1 | 3915.6 | 4239.6 | -1125.0 |

(1) The actual BCA also included sub-options for the base case involving $25 and $100 minimum landing fees, and a sub-option (i.e., $100 minimum landing fee) for the 9940 foot parallel runway.

## 9.4 Dealing With Uncertainty

As discussed in Section 9.3, the selection of a preferred option is based on an assessment of benefits and costs, in the presence of a number of uncertainties.

There are uncertainties that the most cost-beneficial option has either not been identified or has been discarded. These concerns can be addressed by ensuring that the problem or opportunity is correctly stated, a wide range of options is identified and a careful screening of options is carried out.

There are uncertainties with respect to forecasts, assumptions, relationships between variables, and judgements concerning parameters such as the discount rate and the value of travel time savings used to calculate benefits and costs to society.

There are also uncertainties associated with benefits which are conditional on the outcome of related actions which could not be incorporated into the options analysis.

Uncertainties need to be assessed in all BCA for three reasons:

> First, a check is needed to make sure that the option being selected is a robust choice, that is, the same option would be selected over a reasonable range of assumptions;
>
> Second, decision-makers need to know, and be in a position to assess, the risks associated with the choice of an option; and
>
> Third, explicit analysis of uncertainty is needed to build confidence in the analysis and to facilitate the development of a stakeholder consensus around a decision.

The assessment should be aimed at deriving a best estimate of probabilities and outcomes; an overly pessimistic or optimistic view of the risks serves only to bias the analysis and cloud the issues. The approach to the assessment is to recognize all uncertainties explicitly and to gauge their impact on the merits of the options systematically.

The first step of an assessment is a **sensitivity analysis**. There are two elements:

- identifying the risk factors (key variables) which are uncertain and establishing the range of uncertainty;
- for each risk factor, determining the outcome of the options analysis over the range of uncertainty.

If sensitivity analysis indicates that the results of the options analysis would remain the same over a broad range of values or assumptions for risk factors (i.e., the selection of the preferred option is robust), a decision on the preferred option can be made with relative confidence.

However, if sensitivity analysis indicates that different options would become more cost-beneficial under certain circumstances, a more detailed assessment is needed of the risk that the best option is being selected (i.e., the option risk). An assessment of the **option risk** involves:

- a determination of the circumstances that would have to prevail for particular options to be the most attractive and the likelihood of these circumstances being realized.

Finally, assessing uncertainties involves the **management of risk** - ensuring a favourable outcome for the project. Management needs to know about the likelihood of adverse outcomes, the steps that might be taken to mitigate their severity and the actions required for the harvesting of benefits.

It may be useful for a panel of experts to assist in the assessment of uncertainties. In some cases, panels can be extended to include stakeholders to make sure that all points of view are considered in the evaluation of options.

Sections 9.4.1 through 9.4.3 discuss different kinds of tests which can be undertaken to fulfil the above guidelines on assessing uncertainties.

### 9.4.1 Sensitivity Analysis

Sensitivity analysis shows how outcomes differ under a range of circumstances.

As a checklist, the following risk factors may be appropriate for sensitivity analysis:

- **demand**. Traffic forecasts are always key variables;

- **prices**. For example, fuel prices have shown unexpected and significant movement in real terms several times in the past two decades;

- **technology**. There may be unexpected advancements in vehicle, vessel, or information technology;

- **logistics**. Changes may occur in trade flows, traffic growth and mix, scheduling patterns or modal preferences;

- **technical performance**. For projects involving new or advanced technology, there may be a significant design risk associated with the estimates of cost and performance;

- **cost estimates**;

- **standard values**. These values include the value of fatalities, injuries and environmental damage avoided and the value of time savings;

- **timing**. Changes in the implementation schedule of a project may have a material impact on project benefits and costs;

- **discount rate**. Results should be tested using real discount rates of 7.5% and 12.5%;

- **conditions for the accrual of benefits**. Assumptions affecting the accrual of benefits, including the behaviour of stakeholders or the presence of certain conditions or complementary actions, should be tested; and

- **accrual of full benefits**. In some circumstances, it may be appropriate to test the sensitivity of results to the accrual of less than full benefits.

Sensitivity analyses on the final two factors is particularly important for dealing with uncertainties arising from conditional benefits.

In some cases it may be appropriate to consider particular combinations of circumstances. For example, an alternative scenario for a port development project might involve a major shift in global shipping patterns combining changes in traffic volume, traffic mix, vessel technology and fuel prices.

A review of uncertainties may prompt a quick look back at discarded options to be sure that they have not regained their feasibility under some "what-if" conditions being considered.

The conclusions of a sensitivity analysis should focus on whether the selection of the preferred option is robust. If not, then the risk factors and the range of values or assumptions which affect the selection of the preferred option should be identified.

### 9.4.2 Assessing Option Risk

The issue is whether the best option has been selected.

The basis of the assessment is the systematic consideration of each element of uncertainty and a judgement as to the likelihood of the circumstances affecting the selection of the preferred option.

A threshold (or break-even) analysis may assist in formulating the judgement.

**A threshold analysis** is designed to establish the quantity of a variable or parameter value required to make a particular option the most cost-beneficial. In using this technique, a judgement is required on the likelihood that the quantity or value would exceed these thresholds. These thresholds are also known as "switching values", because they are the values at which the decision could switch from one option to another. An example of a threshold analysis is discussed in Section 9.5.1.

No matter how intricate or sophisticated the formulation of a threshold analysis, there is no escaping the requirement for a judgement on the likelihood of circumstances.

In some projects, the assessment of option risk may lead to a decision to widen the scope of the options or to collect more information.

### 9.4.3 Probability Analysis

Probability analysis is an extension of the basic benefit-cost investment criteria. By calculating a probability distribution for the NPV, on the basis of assumed probability distributions for key variables, it is more comprehensive and sophisticated than single variable sensitivity tests or scenario approaches discussed above.

A probability analysis allows for variations in all key variables to be tested simultaneously using a Monte Carlo simulation technique. By contrast, in a scenario approach, several variables could be varied at the same time but with only one future outcome being predicted.

Probability analysis provides decision-makers not only with the NPV of an option but an indication, given the uncertainties identified, as to the likelihood that the NPV will be realized. For example, in an evaluation of the economic merits of adding runway capacity to Vancouver International Airport, it was concluded that while there is a chance that the NPV for the most cost-beneficial solution will diverge from expectations, there is virtually zero probability that it will be negative.

The greater the uncertainty associated with a project, or the more complex a project, the more cost effective the use of a quantified approach becomes to deal with uncertainties.

While software is widely available for probability analysis work, it should be emphasized that, as for threshold analysis, there is no escaping the requirement for judgements on the likelihood of circumstances.

## 9.5 Cost-Based Comparisons of Options

The analysis discussed in Section 9.3 is an example of a comprehensive BCA. There are situations, however, where a comprehensive BCA cannot be done, because important benefits are not quantifiable. There may also be a few instances where a BCA is not necessary, because the benefits are the same for all options.

Techniques exist for dealing with essentially cost-based comparisons of options. They should be used in a very few cases, and only with considerable care.

### 9.5.1 Dealing With Unquantifiable Effects

It is important that the basic evaluation process for a BCA be retained, even when there are significant unquantifiable effects. Unquantifiable effects should be explicitly addressed, not glossed over just because a dollar value cannot be readily assigned to them.

Decision-makers should be provided with sufficient information to allow them to make a judgement as to whether the benefits, that have been quantified and used in the estimation of the project's NPV, reflect the true value of the investment.

For example, in the IDFS project, information was provided on unquantified benefits, including the value of enhanced management information systems, improved level of service to suppliers/customers, and the adaptability of the system to future changes in technology.

The attribution of unquantified benefits should be supported by a clear linkage between the outputs of the project and the results of the claimed benefit.

In some projects, the main benefits may be unquantifiable. For example, in a BCA of alternative levels of service (LOS) provided to commercial fishermen by short-range marine aids to navigation along the south-east coast of Newfoundland, the main benefit was the number of accidents avoided. The incremental project-related costs of each LOS option were measurable, but it was not possible to estimate the number of accidents that would be associated with each LOS. However, knowing the project-related costs of each LOS, and applying standard values for the economic effects of accidents (e.g., fatalities, injuries and property damage avoided), it can be determined how many accidents would have to be avoided with a higher LOS to justify the incremental costs of providing it. This is an example of a **threshold analysis** (Section 9.4.2).

A threshold analysis was also used to show how great the benefits would have to be from detecting oil spills in order to justify various options for an expanded aerial surveillance for the Canadian Coast Guard's Pollution Prevention Program. Such an analysis was necessary, because it was not known how many spills are occurring, and what the deterrent effect of aerial surveillance might be.

**Cost-effectiveness analysis** is another technique that may be used in a limited number of circumstances. In cost-effectiveness analysis, a measure of output is used as a proxy for benefits, where quantification of the latter in dollars is a problem.

In the majority of cases, there is no single measurable unit of output. Typically, the nature of the output lends itself better to qualitative description or to more formalized judgement-based quantifications.

For example, a cost-effectiveness analysis of the Aviation fleet presented a cost analysis of options including jet aircraft versus options without. In this analysis, the cost implications of incorporating jet aircraft into the fleet could be compared to the advantages in qualitative terms.

Where more formalized judgement-based quantification is used, it involves the building up of a composite output measure. This is accomplished by assigning scores to a number of dimensions or characteristics of the output. Each characteristic is given a particular weighting in order that a composite score can be calculated. The scores and weights are generally selected by groups of experts.

An example of cost-effectiveness analysis was the Canadian Airspace Management Simulator (CAMSIM) study. Effectiveness of the ATC simulators under consideration was measured in terms of various functions, such as the number of aircraft that could be handled at one time.

The weakness of cost-effectiveness analysis is that outputs are rarely a good proxy for benefits. Benefits may not move in step with changes in the number of units of output.

### 9.5.2 Least-Cost Analysis

When the benefits of identified options are the same in both quantity and quality, a least-cost analysis is acceptable. With no differences in benefits, it remains only to determine the least costly option.

Renovation projects are a possible application for least-cost analysis. Wherever the state of an existing facility requires it to be replaced by one of essentially the same size or capacity, and <u>where the consequences of a "no replacement" option have been determined as uneconomic</u> (see Section 4.3.1), the issue is whether the least costly option has been selected.

It is essential that least-cost analysis not proceed directly from the statement of the problem. The issues associated with the problem and a range of possible solutions, as set out in Sections 4.3 and 4.3.2, need to be considered. Only if the benefits from all of the options are indeed the same should a least-cost analysis be used.

Least-cost analysis may be used in the screening of options. An option may be screened out in the early stages of a BCA if it involves higher costs than another option to generate the same benefits.

It could also be used to determine particular elements of larger projects. It might be useful, for example, to employ least-cost analysis to assist the choice between two heating systems for an air terminal building project.

## 9.6 Presentation of Results

The results of a BCA must be presented both numerically and narratively.

Numerically, the net present value (NPV) of each option should be presented using a central set of "most likely" assumptions and values.

The present value associated with each of the categories of costs, benefits and negative effects leading to the NPV should be itemized. Material unquantifiable benefits and negative effects should be included in the itemization, even though numerical values would not be available. This separate display allows decision-makers to see the significance of each component to the bottom-line NPV.

Because of the special uncertainties associated with small travel-time savings and conditional benefits, these effects should not be included in the NPV for each option. Instead, senior management should be invited to decide whether and to what extent to count these effects, case by case.

To assist senior management in making a decision, the present value of these effects should be reported separately, together with a narrative discussion of the nature of the effect. In the case of small travel-time savings, the likelihood of combinability with other small time savings outside the project could be discussed. Another consideration could be the average time saving per individual one-way trip.

The separate reporting of conditional benefits is also helpful in drawing management's attention to any need for special action to ensure the accrual of such benefits.

Numerical results should then be tested under variations in the key assumptions and values. The presentation should be tailored to the nature and extent of uncertainties associated with the project and specific options. At a minimum, a sensitivity analysis would be required using different values for key variables such as traffic growth.

If the results were to be the same over a broad range of values and assumptions (i.e., one option had the highest NPV in all cases), a preferred option could be identified with some confidence. However, if the results were different, a judgement would be required on the more likely outcome.

A narrative summary of the uncertainties, including a discussion of any small travel-time savings, conditional benefits and unquantified benefits and costs, would be helpful to decision-makers in exercising such judgement. The narrative could be supplemented by a calculation of the percentage of any such benefits or costs that would have to be realized to change the preferred option (i.e., a threshold analysis).

### 9.7 Summary

- Transport Canada uses the net present value (NPV) investment criteria for identifying the preferred option, from an economic standpoint.

- NPV estimates assist, but do not automate, decision-making.

- Uncertainties can and should be assessed and reported. The approach is to recognize all uncertainties explicitly and to gauge their impact on the choice of option systematically.

- Sensitivity analysis is the first step in the assessment of uncertainties.

- Unquantified benefits and other effects have to be recognized and taken into account.

- The NPV for each option should be presented without small travel-time savings and conditional benefits, which should be described and valued separately.

- Comparisons of options based solely on costs should be used infrequently, and only with considerable care.

- Figures 9.2 and 9.3 discuss the comparison of options for the two case studies presented in previous chapters.

**Figure 9.2**

Case Study 1:
Installation of a CAT II ILS Precision Approach for Runway 07 at Ottawa International Airport

Comparison of Options

The discounting spreadsheet (Figure 8.6) shows net present values (1991/92 $) for options 1, 2 and 3 of $1,565.7k; $999.4k; and -$46.6k, respectively, indicating that Option 1 is the most cost beneficial based on the best estimate value of the key variables. Uncertainty associated with these values should be considered in a sensitivity analysis.

The discount rate and traffic growth rates are routinely considered in sensitivity analysis:

- At a 7.5% discount rate, the net present values (NPVs) of options 1, 2, and 3 are $2942.1k, $1987.2k and $981.5k, respectively. At 12.5%, they are $668.4k, $368.3k and -$711.5k.

- Reducing growth rates for aircraft and passenger traffic by 50% yields NPVs of $231.3k, $41k and -$667k for options 1, 2, and 3, respectively.

These figures show that the conclusion is not sensitive to changes in discount rate and traffic assumptions.

In addition to these routinely considered assumptions, the analyst should consider any key issues that may affect the project's economic viability. The key issues in this project are the timing of Option 1 and the transition to MLS.

A delay in the implementation of the project would decrease the payback period and would make Option 1 less attractive. A sensitivity analysis shows that delaying implementation by one year reduces the NPV of Option 1 to $1420.5k.

Postponing the ICAO MLS transition date would increase the payback period for ILS and would make Option 1 even more attractive relative to Option 2.

This analysis indicates that the project should proceed immediately and not be postponed. Further, this conclusion is not sensitive to a postponement of the ICAO MLS implementation date.

## Figure 9.3

Case Study 2:
Replacement of the West Berth at Sydney Marine Terminal (Sydney, N.S.)

Comparison of Options (93/94 $)

The discounting spreadsheet (Figure 8.7) indicates that, at a 10% discount rate, the net present value (NPV) of option 1 (relative to the base case) is $8.1 million, indicating that this option is the most cost beneficial based on the best estimate values of the key variables. Uncertainty associated with these values should be addressed in a sensitivity analysis.

The discount rate and traffic growth rates are routinely considered in sensitivity analysis:

- Substituting discount rates of 7.5% and 12.5% into the discounting spreadsheet yields NPVs of $10.4 & $6.3 million, respectively.

- If cargo traffic were to remain constant, trucking cost savings would remain at $420k a year, and the NPV at a 10% discount rate would be $7.8 million.

These figures show that the conclusion is not sensitive to changes in discount rate and traffic assumptions.

In addition to these routinely considered assumptions, analysts should consider any key issues that may affect the project's viability. A key issue in this project is the availability of alternative facilities, i.e., Sydport. Ideally, planning for the Marine Terminal and Sydport should be coordinated, but this is not achievable for a number of reasons. Therefore, the analysis has to assume certain behaviour on the part of SDC in response to TC decisions on the Marine Terminal. These assumptions need to be tested.

In the base case, it was assumed that SDC would spend $16 million on rebuilding their docks if the Marine Terminal were to be decommissioned. If this amount were to be reduced, at some point the most cost-beneficial solution would switch from Option 1 to the base case. Threshold analysis indicates that Option 1 remains the preferred option as long as the cost of rehabilitating the Sydport docks exceeds $3.6 million. It is almost certain that rehabilitating Sydport docks would cost more than $3.6 million.

A decision by SDC not to spend anything on rehabilitation, and actually close their docks, would make Option 1 highly cost-beneficial, as the cost of serving Sydney from other ports was more expensive than Option 1 and the lack of a facility would reduce the attractiveness of Sydney to the cruise ship industry.

On the other hand, if SDC were to replace their docks, regardless of TC's decision on the Marine Terminal, Option 1 would not be a good economic choice. It would be better to take advantage of rebuilt facilities at Sydport. However, given the low level of demand, it seems unlikely that SDC would act without considering the available capacity at the Marine Terminal. Therefore, barring an uneconomic response by SDC, Option 1 is a robust choice.

# 10.0 STRUCTURE OF A BCA REPORT

This chapter offers a few ideas on presenting the results of a BCA. It is not intended, however, to serve as a template into which all study reports should be forced to fit.

The one guideline that seems applicable to all studies, however, is that the resulting report should be organized along the lines of the evaluation process followed. Figure 10.1 contains an example of a possible table of contents for a BCA report. This example follows the evaluation process outlined in this guide.

| **Figure 10.1** |
|---|
| POSSIBLE TABLE OF CONTENTS FOR A BCA |
| Executive Summary<br>Introduction<br>Benefit-Cost Framework<br>Base Case Option<br>Other Options<br>Estimation of Project-Related Costs<br>Estimation of Benefits and Other Effects<br>Evaluation of Options<br>Assessment of Risks and Uncertainties<br>Conclusions |

The Introduction would include a clear statement of the problem or opportunity.

The Benefit-Cost Framework would identify the issues relevant to the project. It would also identify the main benefits and costs requiring evaluation.

The sections on the Base Case Option and Other Options would follow from the issues. The latter section would identify and describe the options retained for detailed evaluation. It would also briefly discuss other options that were identified but screened out of further study. The reasons for rejecting these options would be given.

The Estimation of Project-Related Costs would cover the identification of the costs and a description of the methodology and assumptions for forecasting future cost streams. The results would be set out in constant dollars and present values.

The Estimation of Benefits and Other Effects would cover the identification of benefits and other effects, as well as a description of the methodology and assumptions used in their estimation. Separate sub-sections would likely be presented for the individual benefits and other effects quantified. Unquantified effects would be discussed in qualitative terms in other sub-sections. Numerical results would be provided in constant dollars and present values.

The Evaluation of Options section would focus on the Net Present Value (NPV) for each option, without small travel-time savings and conditional benefits. The main factors contributing to these NPVs should be itemized and quantified in present value terms.

Assessment of Risks and Uncertainties would test the results under variations in the key assumptions and critical values. At a minimum, this section should include a sensitivity analysis using different values for key variables (e.g., traffic growth). More extensive analysis would be necessary to deal with special kinds of uncertainties, such as those concerning small travel-time savings and conditional benefits.

The Conclusions would summarize the findings of the economic evaluation, as well as the considerations covered on the previous two sections. The impact of unquantified benefits and other effects on the outcome would be presented, to assist management in weighing their importance. A threshold analysis might be used in this regard.

The report might also include one or more appendices to make it a more stand-alone document. For example, there might be appendices presenting key forecasts or detailing the estimation of particular costs and effects. A glossary of terms and/or acronyms might be a worthwhile addition to a BCA report as well.

## PART IV - FINAL SUMMARY

### Final Summary

- The first step in the evaluation process is the statement of the problem or opportunity. This statement sets up the issues, which in turn shape the options to be studied. The more specific the statement is in identifying performance deficiencies or opportunities for improvement, the more helpful it will be guiding the formulation of options.

- A broad range of realistic options needs to be identified. "Can the problem be solved to different extents" and "Are there different ways of tackling the problem" are two generic questions/issues that are relevant to the identification of options.

- A base case option, reflecting the best that management can do without significant investment, is essential as a reference point against which to compare other options.

- A full scale analysis of all options is not necessary. Options should be screened to ensure that the most promising options are considered at a reasonable level of effort.

- A common framework must be established for the comparison of options. This framework requires that:

    - all options be self-contained (i.e., include all of the actions necessary to make the option work) and independent (i.e., ensure that incremental benefits and costs are attributable solely to the project);

    - all of the future benefits, costs and other effects associated with particular options be identified, regardless of who accrues, incurs or experiences them;

    - once identified, benefits, costs and other effects be quantified as much as possible, provided that it makes sense. What is possible is largely determined by the availability of data. What makes sense is determined by the level of precision required to distinguish among options; and

    - the analytical timeframe coincide with the economic life of the most durable asset under consideration (generally not to exceed 30 years).

- The level of effort is a matter of judgement dependent on factors such as the nature and magnitude of the project, the expected payoff from incremental effort and the availability of relevant data.

- Project-related costs are the costs to plan and implement a project, as well as to operate and maintain it throughout its useful life.

- There are three main principles relevant to the measurement of project-related costs:

    - all costs that differ among the options should be included, no matter who incurs them;

- costs solely attributable to a project must be included; and
- costs should reflect opportunity costs.

- Benefits are primarily the intended effects of a project. In the evaluation of transportation projects, the three main types of benefits are:

  - safety;
  - efficiency to users and operators of transportation services; and
  - productivity gains.

- Small travel-time savings (i.e., under five minutes per one-way trip) should be separately identified.

- Some benefits are conditional upon separate decisions and actions that are beyond the scope of the BCA in question. Unless there is a high degree of confidence that such benefits will be achieved, they should be clearly identified as conditional benefits. Conditional benefits should not be included in the calculation of the net present value.

- Other effects are primarily the unintended outcomes of a project. Typically, these are negative and experienced by third parties (e.g., environmental impacts).

- Benefits and other effects may be either on-going over the life of the project or transitional (i.e., experienced only during the implementation phase of a project).

- The values of benefits and other effects of a project are normally based on an estimate of how much the people affected are willing to pay either to receive a benefit, or avoid a negative effect.

- Economic impacts or multiplier effects must be excluded from a BCA, unless they are incremental to the economy as a whole (rather than redistributional from one sector to another).

- Discounting is the means to put all costs, benefits and other effects, relating to different time periods on a comparable basis (i.e., present value).

- A 10% real discount rate (i.e., using constant dollars) should be used as a standard value. Sensitivity analysis should be done at 7.5% and 12.5%, again in real terms.

- The net present value (NPV) investment criterion should be used to identify the preferred option, from an economic standpoint.

- The NPV for each option should be presented without small travel-time savings and conditional benefits, which should be described and valued separately.

- The present value associated with each of the categories of costs, benefits and negative effects making up the NPVs should be itemized.

- Unquantified benefits and other effects have to be recognized and taken into account.

- Uncertainties should be reported and assessed. The approach is to recognize all uncertainties explicitly and to gauge their impact on the choice of an option systematically.

- Sensitivity analysis tests the results of a BCA under different assumptions for key factors in the analysis. A sensitivity analysis is an essential part of every BCA:

  - if sensitivity analysis indicates that the results would remain the same over a broad range of values for key factors (i.e., the analysis is robust), a decision on the preferred option can be made with relative confidence; or

  - if sensitivity analysis indicates that another option would become more cost-beneficial under certain circumstances, a judgement would be required on the likelihood that those conditions would occur.

- Projects that depend heavily, for their economic justification, on benefits involving material uncertainties should be looked at especially carefully.

- Figure 11.1 depicts the entire evaluation process for a BCA.

**Figure 11.1**

| Evaluation Process | Considerations |
|---|---|
| 1. State Problem or Opportunity | • Is there a specific description of the deficiency or opportunity for improvement?<br>• Does the statement deal with the underlying cause rather than symptoms?<br>• Is the problem statement broad enough to capture the full range of options to resolve the problem? |
| 2. Identify Issues | • What kinds of issues arise from the problem or opportunity (e.g., need, scope, timing, technology)? |
| 3. Identify Base Case Option | • Does the base case make the most out of existing facilities, i.e., is it the best that managers could do without major investment?<br>• Has a "no replacement" base case been considered for a replacement project? |
| 4. Identify Other Options | • Has a wide range of options been considered?<br>• Have options that consider different degrees of problem resolution been considered?<br>• Have non-investment options (e.g., regulation, pricing, operational changes) been considered?<br>• Have strategic options (e.g., redistribution of responsibility) been considered? |
| 5. Screen Options | • Are some options clearly less cost-beneficial than others, from the outset of the estimation process?<br>• Can options be screened out on the basis that they are just not possible because of physical, legislative, technological or other constraints? |
| 6. Establish Options for Comparative Analysis | • Has a common framework for comparison of options been established?<br>• Are the options self-standing, i.e., self-contained and independent of other options or projects?<br>• Have options been evaluated over a consistent timeframe that is sufficient to capture the benefits and costs of each option?<br>• Would expending more effort on estimating the benefits and costs likely change the decision or reduce uncertainty surrounding the most economic choice (i.e., is the level of effort appropriate)? |
| 7. Estimate Project - Related Costs | • Have all future costs that differ among options been included, regardless of who incurs them?<br>• Do the costs reflect the concept of the opportunity costs of the resources required by each option?<br>• Are costs properly attributed to other projects excluded? |
| 8. Identify & Estimate Benefits & Other Effects. | • Have all incremental benefits and effects been considered, regardless of magnitude, to whom they accrue and whether they are on-going or transitional?<br>• If benefits are conditional on events beyond the project scope, have these conditions been identified?<br>• Have small travel-time savings been separately identified?<br>• Has consideration been given to unquantifiable effects? |
| 9. Evaluate Options & Compare Results | • Has a Net Present Value been calculated for each option, and have any small travel-time savings and conditional benefits been shown separately?<br>• Have unquantifiable benefits, costs and other effects been taken into account in recommending an option?<br>• Has there been an assessment of the risks and uncertainties associated with each option, including sensitivity analysis on key variables? |

## APPENDIX A - ILLUSTRATIVE APPLICATIONS OF BENEFIT-COST ANALYSIS

TABLE OF CONTENTS

**Illustrative Example**

1. Restoration of Runway 12/30 and Taxiway "K" at Regina

2. Construct a bypass taxiway at the west edge of Apron VI northward from taxiway "X" at Vancouver International Airport

3. The expansion and refurbishment of the Air Terminal Building Complex (ATB) at Halifax International Airport

4. Acquisition and installation of Air Navigation Integrated Maintenance System (AIMS)

5. Replacement of Type 300 Life Boats/"S" Class Cutters

6. Acquisition of two hydrographic depth sounding catamarans in the CCG Laurentian region.

7. Acquisition of a widely disseminated, semi-distributed, integrated departmental financial/materiel management information system (IDFS)

**Illustrative Example 1: Restoration of Runway 12/30 and Taxiway "K" at Regina**

Statement of Problem/Opportunity

- The condition of Runway 12/30 and Taxiway "K" at Regina is deteriorating below standards.

Economic Issues

- Is the runway still required, given the nature and level of forecast traffic?
- What are the consequences of deferral, with or without interim repair work?
- Should the runway be repaved with exactly the same length and width? What is the critical aircraft? Has it changed over the years? Is it justified?
- Are there feasible resurfacing design alternatives, with differing upfront capital expenditure requirements, or trade offs between capital and O&M expenditures, or trade-offs between overall cost and level of service?
- Is a special construction schedule warranted to lessen disruption to users?

Base Case Option

- Restore runway, with reduced width, and taxiway five years hence (Note: the non-restoration option, closing the runway, was rejected early, on the basis of large forgone benefits).

Main Options Retained

- Restore runway and taxiway.
- Reconstruct foundation along centreline with either:
  - hot mix asphaltic concrete; or
  - portland cement concrete.
- Overlay without reconstruction of foundation along centreline with either:
  - 100 mm thick overlay; or
  - 250-300 mm thick overlay.

Note: All options involve reduced runway width and reflect designs based on the A320 as the forecast critical aircraft (the B727 was the critical aircraft for the existing facilities).

The implementation of all options to begin five years before the base case.

The options with the highest net present value to be tested using both daytime and overnight construction schedules.

Other Options Dealt With

- Close the runway.
- Resurface entire existing runway (i.e., no reduction in width).
- Design for existing critical aircraft (i.e., B727).

Project-Related Costs

- Upfront capital expenditures to repave/restore runway and taxiway.
- Periodic capital expenditures and/or annual expenditures to maintain surfaces.
- Annual operating expenditures.
- Expenditures associated with night construction.

Benefits

- Differences in airline operating costs with and without the runway in service (quantified).
- Differences in airline operating costs and aircraft safety due to foreign object damage under the base case (unquantified, because the difference in cost alone provided sufficient quantified information to establish the economic merits of the options).

**Illustrative Example 2: Construct a bypass taxiway at the west edge of Apron VI northward from taxiway "X" at Vancouver International Airport**

Statement of Problem/Opportunity

- Aircraft are delayed as a result of traffic along the west edge of Apron VI. Likewise, aircraft push-backs delay the high volume of aircraft movements to and from the north apron.

Economic Issues

- Is a taxiway necessary to alleviate the problem?
- Is it preferable to delay the investment?
- Are there feasible expansion or other configurations for a taxiway with differing upfront capital expenditure requirements?
- Is a special construction schedule warranted to lessen disruption to users?

Base Case Option

- Implement only the already planned north-east finger expansion with none of the described inefficiencies/safety problems alleviated.

Main Options Retained

- Expand the west perimeter of Apron VI to permit ease of aircraft movement and improve safety.
- Construct bypass taxiway at the edge of Apron VI northward from taxiway "X" at Vancouver to permit ease of aircraft movement and improve safety.

Other Options Dealt With

- The impact of different traffic level assumptions on the economic merits of the proposed investment.

Project-Related Costs

- Upfront capital expenditures to construct the taxiway.
- Periodic capital infusions directly related to the construction and maintenance of the new taxiway.
- Operating expenditures to maintain the new taxiway.

Benefits

- Reduction in airline operating costs and travellers' time savings as a result of: continuous two-way traffic flow; reduced apron congestion; and reduced push-back delays (quantified)

- Improvement in safety of aircraft movements on taxiway and apron due to the positive separation of traffic flows (not quantified)

**Illustrative Example 3: The expansion and refurbishment of the Air Terminal Building Complex (ATB) at Halifax International Airport**

Statement of Problem/Opportunity

- The inadequate capacity and condition of a high number of components of the Halifax International Airport ATB is resulting in additional user time spent in the ATB, reduced retail potential, high maintenance costs and higher airline operating costs.

Economic Issues

- Is there a requirement for a major capital infusion to address the capacity and condition deficiencies of the ATB?
- Would implementing the expansion over a number of phases be more cost beneficial?
- What is the most appropriate configuration, location and size for the ATB?
- Would expanding and renovating the existing ATB be more cost beneficial than building a new one?
- Would a two-level curb be preferable to a single level curb?

Base Case Option

- The minimum capital investment, with appropriate operational adjustments, so as to keep the building functional throughout the life-cycle period.

Main Options Retained

- The expansion and renovation of the existing ATB, with a "Y" configuration and one level curb, over three stages.
- The expansion and renovation of the existing ATB, with a "Y configuration and one level curb, with a large initial stage followed by two much later stages.
- The building of a new ATB in the existing quadrant but to the south of the existing ATB, with a "Y" configuration and two level curb, over two stages.

Other Options Dealt With

- The building of a new ATB in any of the other three quadrants of the airport.
- The building of a new ATB in the existing quadrant, but to the north of the existing ATB.
- The building of a new ATB at the existing site, with various configurations or over three phases.

<u>Project-Related Costs</u>

- The capital investments for the apron, ATB and groundside components, including planning, design, project management, site supervision, construction costs.

- The costs of temporary facilities.

- The apron, ATB and groundside O&M costs.

<u>Benefits</u>

- The reduction in the time spent by users in the ATB, made possible by the higher processing capabilities or reduced distances of the proposed solutions (quantified).

- The changes in airline operating costs including, for example, the costs for luggage handling, passenger ticketing as well as aircraft apron operations (partly quantified).

- The increased value of concession services (quantified).

- The increased user comfort due to the reduced level of crowding in the ATB (not quantified) and the improved aesthetics (not quantified, due to the difficulty of assessing credible values).

- The reduction in time spent by well-wishers and greeters (quantified).

**Illustrative Example 4: The acquisition and installation of the Air Navigation Integrated Maintenance Systems (AIMS)**

Statement of Problem/Opportunity

- The existing time-based maintenance practices and the lack of remote maintenance and monitoring capabilities are resulting in a requirement for a high number of maintenance workcentres in support of major air navigation electronic systems.

Economic Issues

- What benefits will flow from an integrated remote maintenance monitoring system?

- To what extent should the workcentres maintaining the ANS electronic systems be consolidated, i.e., what is the optimal trade off between, on the one part, the travelling costs and the remote maintenance monitoring capital costs, and on the other part, the labour costs and the other avoided costs?

- What is the most appropriate level of remote maintenance monitoring capability for different types of equipment and sites?

- Is the project justification dependent on other projects being implemented?

Base Case Option

- The continued reliance on the current maintenance practices and the replacement of the existing systems with the latest technology, incorporating the use of remote maintenance and monitoring practices where appropriate.

Main Options Retained

- The implementation of AIMS with an associated consolidation of the ANS maintenance workcentres to:

  (a) 62 workcentres
  (b) 52 workcentres
  (c) 44 workcentres
  (d) 31 workcentres

Other Options Dealt With

- Different levels of Remote Maintenance Monitoring capability for different types of sites and electronic equipment.

- The replacement of ground systems to be supported by AIMS with satellite-based systems.

Project-Related Costs

- The upfront capital expenditures to implement the options
- The periodic capital expenditures and annual O&M expenditures of the options

Benefits

- Labour cost savings associated with the shift to performance-based maintenance and with remote maintenance monitoring capabilities (quantified)
- Travel cost savings made possible by the shift to performance-based maintenance and with remote maintenance monitoring capabilities (quantified)
- Other avoided costs made possible by the reduction in the number of workcentres (quantified)
- Improvement to staff morale, consolidation of maintenance workstations, reductions of paperwork and reductions in outages (unquantified, as the quantified benefits demonstrated the economic merits of the options).

**Illustrative Example 5: Replacement of Type 300 Life Boats/"S" Class Cutters**

Statement of Problem/Opportunity

- The deteriorating condition of the Type 300 lifeboats and the "S" Class Cutters is resulting in declining Search and Rescue (SAR) performance and escalating maintenance costs.

Economic Issues

- Are the lifeboats still required given the current level and location of marine activity?
- Are the benefits greater than the costs at all proposed bases? Could the number of boats be reduced by combining or reallocating SAR zones?
- Are there other SAR resources which could provide the services more cost beneficially?
- Are there design alternatives for lifeboats with differing upfront capital costs or trade-offs between overall cost and operational performance/level of service?

Base Case Option

- Retirement of lifeboats without replacement.

Main Options Retained

- Replacement of lifeboats with either:
    - lifeboats with the same capability as the existing Type 300 lifeboats; or
    - enhanced capability lifeboats of either ARUN or MEDINA design[(1)].

Other Options Dealt With

- Expansion of alternative SAR resources (helicopters or air cushion vehicles) to fill the gap left by the retirement of the lifeboats.
- Rationalization of SAR zones to reduce the number of lifeboats required.
- Operation of lifeboats with alternative crewing assumptions.

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(1) The question as to which of the two designs would be most cost beneficial for each SAR zone was not addressed (i.e., one design was determined a priori to be preferable for each zone. As a switch in designs did not affect the global outcome of the analysis, resolution of the issue was left to a subsequent phase).

Project-Related Costs

- Differences in upfront capital expenditures to acquire replacement lifeboats.
- Differences in annual crewing, operating and refit costs.

Benefits

- Differences in the number of fatalities avoided (quantified)
- Capital and O&M costs of expanding alternative SAR resources (quantified)
- Differences in the avoidance of property loss, reduction in the severity of injuries, and in assistance to mariners in non-distress incidents (not quantified, because other quantified benefits were sufficient to establish the relative economic merits of the options)
- Differences in the cost of using existing alternative SAR resources (not quantified, because the quantified benefits were sufficient to establish the relative economic merits of the options).

**Illustrative Example 6: The acquisition of two hydrographic depth sounding catamarans in the CCG Laurentian Region**

Statement of Problem/Opportunity

- The proposed decommissioning of two hydrographic depth sounding vessels, as part of the Fleet Restructuring Plan, is compromising the delivery of the hydrographic depth sounding program in the St. Lawrence River and its tributaries.

Economic Issues

- To what extent could the remaining vessels be able to take over the workload of the decommissioned vessels?
- How many catamarans are required?
- What types of catamarans are needed?
- Would extending the life of the decommissioned vessels and replacing them later be more cost effective?
- To what extent would the options considered be able to meet the sounding program requirements, and what would be the consequence of not meeting these requirements?

Base Case Option

- The non-replacement of the decommissioned vessels and the discontinuance of the hydrographic depth sounding program.

Main Options Retained

- The refit and operation of one of the decommissioned vessels, and the subsequent replacement of this vessel at the end of its extended life.
- The acquisition of one catamaran.
- The acquisition of two catamarans.

Project-Related Costs

- The upfront capital costs of acquiring the vessels to implement the options
- The periodic capital costs and the annual crewing and operating costs

Benefits

- The decreased commercial shipping costs as a result of the removal of the draft restrictions.

- The decreased risk of groundings with the associated damage costs and environmental effects (both effects were unquantified, as they were qualitatively assessed to be greater than the program costs).

**Illustrative Example 7: The acquisition of a widely disseminated, semi-distributed, integrated departmental financial/materiel management information system (IDFS)**

Statement of Problem/Opportunity

- The multitude of existing non-integrated systems are difficult and costly to maintain, result in unproductive efforts to perform tasks dependent on financial/materiel/asset management information and cannot meet current and future information needs.

Economic Issues

- Is there a requirement for an integrated system?
- To what extent should the departmental information flows be integrated within IDFS?
- At what level of the organization should the system be disseminated?
- Should the system be based on a central or semi-distributed architecture?

Base Case Option

- The replacement and maintenance of the existing 15 systems as required, without integration.

Main Options Retained

- The acquisition of an information system meeting the Financial Information Strategy (FIS) requirements, disseminated to the Accounting Offices only, by buying and modifying:
    - the Common Departmental Financial System (FIS-CDFS)
    - a commercial off-the-shelf package (FIS/Off-the-shelf)
- The acquisition of an information system meeting the FIS requirements and supporting additional functionality (e.g., materiel management), disseminated to all responsibility centres, through:
    - a centralized architecture (IDFS-Centralized)
    - a semi-distributed architecture (IDFS/Semi-distributed)

Other Options Dealt With

- The FIS-CDFS option disseminated to all responsibility centres.
- The IDFS-Centralized option disseminated to the Accounting Offices only.

- The modifications of the existing systems or the in-house development of the system to meet the stated requirements.

Project-Related Costs

- The software/hardware acquisition, installation, modification and support costs; the production and distribution costs of documentation for users and support personnel; the project management costs

- The training costs.

- The operating costs of the system (Informatics Directorate's fully allocated costs as per the Service Level Agreement -SLA) and the communication costs.

Benefits

- The enhanced management information, potentially leading to better, faster decisions (unquantified, due to difficulties in assessing reliable values)

- The productivity improvements resulting from the reduced amount of resources necessary to perform management functions dependent on financial data (quantified to a limited extent, as other quantified benefits were sufficient to justify scope of the project)

- Improved level of service to TC suppliers/customers, resulting from more timely or better performance of service (unquantified)

- Other benefits, such as improved job satisfaction and adaptability of the system in response to future technological changes, or to changes in TC organization such as divestiture (unquantified).

## APPENDIX B - TABLE OF DISCUOUNT VALUES

Discount Rates

| **Year** | **7.5 %** | **10 %** | **12.5 %** |
|---|---|---|---|
| 0 | 1.0000 | 1.0000 | 1.0000 |
| 1 | 0.9302 | 0.9091 | 0.8889 |
| 2 | 0.8653 | 0.8264 | 0.7901 |
| 3 | 0.8050 | 0.7513 | 0.7023 |
| 4 | 0.7488 | 0.6830 | 0.6243 |
| 5 | 0.6966 | 0.6209 | 0.5549 |
| 6 | 0.6480 | 0.5645 | 0.4933 |
| 7 | 0.6028 | 0.5132 | 0.4385 |
| 8 | 0.5607 | 0.4665 | 0.3897 |
| 9 | 0.5216 | 0.4241 | 0.3464 |
| 10 | 0.4852 | 0.3855 | 0.3079 |
| 11 | 0.4513 | 0.3505 | 0.2737 |
| 12 | 0.4199 | 0.3186 | 0.2433 |
| 13 | 0.3906 | 0.2897 | 0.2163 |
| 14 | 0.3633 | 0.2633 | 0.1922 |
| 15 | 0.3380 | 0.2394 | 0.1709 |
| 16 | 0.3144 | 0.2176 | 0.1519 |
| 17 | 0.2925 | 0.1978 | 0.1350 |
| 18 | 0.2720 | 0.1799 | 0.1200 |
| 19 | 0.2531 | 0.1635 | 0.1067 |
| 20 | 0.2354 | 0.1486 | 0.0948 |
| 21 | 0.2190 | 0.1351 | 0.0843 |
| 22 | 0.2037 | 0.1228 | 0.0749 |
| 23 | 0.1895 | 0.1117 | 0.0666 |
| 24 | 0.1763 | 0.1015 | 0.0592 |
| 25 | 0.1640 | 0.0923 | 0.0526 |
| 26 | 0.1525 | 0.0839 | 0.0468 |
| 27 | 0.1419 | 0.0763 | 0.0416 |
| 28 | 0.1320 | 0.0693 | 0.0370 |
| 29 | 0.1228 | 0.0630 | 0.0329 |
| 30 | 0.1142 | 0.0573 | 0.0292 |

NOTA : Chaque inscription représente la valeur actualisée de 1 $ reçue ou dépensée durant l'année n au taux d'actualisation r.

## APPENDIX C - SUGGESTED REFERENCES

### Further Reading

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## APPENDIX D - ACRONYMS

| Anglais | Francais | |
|---|---|---|
| ADS | | Automated Dependence Surveillance |
| | SSAV | Système de suivi automatique des vols (*antérieurement Surveillance dépendante automatique)* |
| AIMS | | Air Navigation Integrated Maintenance System |
| | SEIA | Système d'entretien intégré des aides à la navigation |
| ATB | | Air Terminal Building |
| | --- | Aérogare |
| ATC | | Air Traffic Control |
| | ATC | Contrôle de la circulation aérienne |
| BCA | | Benefit-Cost Analysis |
| | ACA | Analyse coûts-avantages |
| CAATS | | Canadian Automated Air Traffic System |
| | --- | Système canadien automatisé de contrôle de la circulation aérienne *(antérieurement Automatisation du système canadien de la circulation aérienne)* |
| CAMSIM | | Canadian Airspace Management Simulator |
| | CAMSIM | Simulateur de gestion de l'espace aérien du Canada |
| CAT I | | Category 1 |
| | CAT1 | Catégorie 1 |
| CAT II | | Category 2 |
| | CAT II | Catégorie 2 |
| CCG | | Canadian Coast Guard |
| | GCC | Garde côtière canadienne |
| CDFS | | Common Departmental Financial System |
| | SFMC | Système financier ministériel commun |
| DRS | | Department of Supply and Services Financial Reporting System |
| | SRM | Système de compte rendu financier du ministère des Approvisionnements et Services |

| | | |
|---|---|---|
| EARP | | Environmental Assessment and Review Process |
| | PEEE | Processus d'évaluation et d'examen en matière d'environnement |
| EPA | | Effective Project Approval |
| | ADP | Approbation définitive du projet *(antérieurement Approbation effective de projet – AEP)* |
| FIS | | Financial Information Strategy |
| | SIF | Stratégie en matière d'information financière |
| GDP | | Gross Domestic Product |
| | PIB | Produit intérieur brut |
| GST | | Good and Servies Tax *(previously Gov't Sales Tax)* |
| | TPS | Taxes sur les produits et services |
| ICAO | | International Civil Aviation Organization |
| | OACI | Organisation de l'aviation civil internationale |
| IDFS | | Integrated Departmental Financial System |
| | SFIM | Système ministériel intégré de gestion des finances et du matériel *(antérieurement Système financier intégré du Ministère)* |
| ILS | | Instrument Landing System |
| | ILS | Système d'atterrissage aux instruments |
| IRR | | Internal Rate of Return |
| | TRI | Taux de rendement interne |
| IT | | Information Technology |
| | TI | Technologie de l'information |
| LOS | | Levels of Service |
| | NDS | Niveaux de service |
| MLS | | Microwave Landing Systems |
| | MLS | Systèmes d'atterrissage hyperfréquences |
| NPV | | Net Present Value |
| | VAN | Valeur actualisée nette |
| O&M | | Operating and Maintenance |
| | F et E | Fonctionnement et entretien |
| PPA | | Preliminary Project Approval |

| | | |
|---|---|---|
| | APP | Approbation préliminaire de projet |
| RAMP | | Radar Modernization Program |
| | RAMP | Projet de modernisation des radars |
| SAR | | Search and Rescue |
| | SAR | Recherche et sauvetage |
| SDC | | Sydney Development Corporation |
| SLA | | Service Level Agreement |
| | ENS | Entente sur le niveau de service |
| SSP | | Sheet Steel Pile |
| | --- | Palplanches d'acier |
| STS | | Small Travel-Time Savings |
| | PED | Petites économies de temps de déplacements |
| TC | | Transport Canada |
| | TC | Transports Canada |
| U.K. | | United Kingdom |
| | R.-U. | Royaume-Uni |
| U.S. | | United States |
| | É.-U. | États-Unis d'Amérique |
| VTS | | Vessel Traffic Services |
| | STM | Services du trafic maritime |