Synthesis of Practice

Performance Evaluation Mechanisms for Transportation Research Programs

Doug Williams
The ARA Consulting Group Inc.

Transportation Association of Canada
Association des transports du Canada

No. 4

2323 St. Laurent Boulevard
Ottawa, Canada K1G 4K6
Telephone (613) 736-1350
Fax (613) 736-1395

ISBN 1-55187-104-1

2323, boulevard Saint-Laurent
Ottawa, Canada K1G 4K6
Téléphone (613) 736-1350
Télécopieur (613) 736-1395

TAC REPORT DOCUMENTATION FORM

Project No.	Report No.	Report Date	IRRD No.
1327		MAY 1996	

Project Manager

Christopher Hedges

Title and Subtitle

Performance Evaluation Mechanisms for Transportation Research Programs
TAC Synthesis of Practice Series - No. 4

Author(s)	Corporate Affiliation(s)
Doug Williams	The ARA Consulting Group Inc.

Sponsoring/Funding Agency and Address	Performing Agencies Names and Addresses
Research and Development Council Transportation Association of Canada 2323 St. Laurent Blvd. Ottawa, ON K1G 4K6	The ARA Consulting Group Inc. Suite 350, 355 Burrard Street Vancouver, BC V6C 2G8

Abstract

The objective of this study was to produce a synthesis of evaluation practices used by organizations conducting transportation-related research and development (R&D). The project was intended to determine which evaluation methods are currently being used to assess R&D programs and the degree of satisfaction engendered by these methods.

A second purpose of the study was to provide some "how to information" on evaluating the impacts of transportation-related R&D.

The work, carried out in three stages, involved: 1) conducting a brief review of the literature regarding R&D evaluation methodologies; 2) interviewing representatives of organizations involved in carrying out transportation-related R&D; and 3) preparing illustrative information on evaluation methodologies.

The report provides examples of the use of user surveys, cost-benefit methods, case studies, and performance indicators for evaluating transportation-related R&D. It also provides a summary matrix outlining the applicability of the various evaluation methods to transportation-related R&D at different stages of the R&D process, as well as some technical information on how to structure user surveys and how to carry out cost-benefit analyses. The study presents an ideal evaluation model for an R&D program using a combination of the various evaluation methods.

Keywords (IRRD)

Canada 8018
Research Project 8557
Organization
(Association) 9057
Administration 0145
Interview 0107
Evaluation
(Assessment) 9020

No. of Pages	No. of Figures	Language	Price
30 p		English	

Supplementary Information

FICHE DE RAPPORT DE L'ATC

Projet n°	Rapport n°	Date du rapport	DIRR n°
1327		MAI 96	

Gestionnaire du projet

Christopher Hedges

Titre et sous-titre

Performance Evaluation Mechanisms for Transportation Research Programs
TAC Synthesis of Practice Series - No. 4

Auteur(s)	Affiliation(s)
Doug Williams	The ARA Consulting Group Inc.

Nom et adresse de l'organisme parrain	Nom et adresse de l'organisme exécutant
Conseil de la recherche et du développement Association des transports du Canada 2323, boulevard Saint-Laurent Ottawa (ON) K1G 4K6	The ARA Consulting Group Inc. Suite 350, 355 Burrard Street Vancouver, BC V6V 2G8

Résumé

L'objective premier de cette étude était de dresser une synthèse des pratiques d'évaluation employées par les organisation exécutant des travaux de recherche et de développement (R-D) dans le domaine des transports. Concrètement, l'étude avait pour but de cerner les méthodes courantes d'évaluatuer les incidences de la R-D en transports.

Les travaux d'étude ont été exécutés en trois étapes, lesquelles sont décrites ci-après une brève analyse des documents traitant des méthodes courantes d'évaluation des incidences de la R-D la tenue d'entrevues avec des représentants d'organisation oeuvrant dans le domaine de la R-D en transports d'un précis sur les méthodes d'évaluation analysées.

Mots-clés

Canada 8018
Projet de recherche 8557
Organisme 9057
Administration (Gestion) 0145
Enquete 0107
Evaluation 9020

Nombre de pages	Nombre de figures	Langue	Prix
30 p		Anglais	

Renseignements supplémentaires

Foreword

There is always a delay before the best and most current research information is transferred into common use. The practical value of new information results only after dissemination and technology transfer mechanisms enable practitioners to transform that information into knowledge, and then to use that knowledge to solve problems or implement improved practices.

In the transportation sector, working professionals are often faced with problems for which solutions already exist, either in published reports or in the undocumented experience and practice of others working in the field. The volume of information being produced in the world today makes it very difficult to keep fully apprised on the most current data and practices. In Canada, the sharing of information is further complicated by the decentralized jurisdictional responsibility for transportation and vast geographical distances. The TAC Synthesis of Practice series has been initiated to help alleviate the problem by compiling and disseminating state of the art information on topics of current interest to the Canadian transportation community.

For each topic selected, the project objectives are:

1. To locate and assemble all relevant information on the topic.
2. To identify the most current practices for addressing problems within the scope of the topic.
3. To identify all relevant ongoing research on the topic.
4. To learn what problems remain largely unsolved.
5. To organize, evaluate, synthesize and document the useful information that is acquired.
6. To evaluate the effectiveness of the synthesis after it has been in the hands of its users for a period of time.

The overall mission of the Transportation Association of Canada (TAC) is to promote the provision of safe, efficient, effective and environmentally sustainable transportation services in support of the nation's social and economic goals. The national, non-profit association acts as a neutral forum for the discussion of transportation issues and concerns, and acts as a technical focus in the roadway transportation area. Its corporate members include all levels of government, other associations, consultants, contractors, manufacturers, distributors, shippers, goods carriers, passenger transport services, and academic and research institutes.

The Synthesis of Practice series is sponsored by TAC's Research and Development Council. The role of the R&D Council is to foster innovative, efficient and effective research and technology transfer in support of Canadian transportation. Its responsibilities include the identification of national research priorities, the development and management of a national cooperative R&D program, and the monitoring and dissemination of transportation research information in Canada and abroad.

Avant-propos

Il s'écoule toujours un certain laps de temps avant que les résultats de recherches les plus à propos et les plus à jour ne puissent être mis en application. L'information nouvelle obtenue dans ce contexte n'a de valeur concrète qu'une fois que les mécanismes appropriés de diffusion et de transfert de technologie ont été mis en place afin de permettre aux praticiens de convertir cette information en connaissances qui seront elles-mêmes utilisées aux fins de résoudre des problèmes ou d'instaurer des pratiques améliorées.

Les professionnels oeuvrant dans le secteur des transports se heurtent souvent à des problèmes auxquels on peut d'ores et déjà apporter des solutions, solutions qui sont soit décrites dans des rapports publiés antérieurement, soit issues de l'expérience et de la pratique non documentée d'homologues du domaine. De nos jours, la quantité d'information produite dans le monde ajoute considérablement à la difficulté de demeurer au fait des données et des pratiques les plus récentes. Au Canada, l'échange d'information n'en est d'ailleurs rendu que plus complexe en raison de la décentralisation des compétences et responsabilités en matière de transport et de l'immensité du pays. Désirant avant tout atténuer ce problème, l'ATC a entrepris de constituer et de diffuser une Synthèse des pratiques, une série de rapports contenant l'information la plus actuelle sur divers sujets auxquels la collectivité canadienne des transports accorde présentement beaucoup d'intérêt.

Pour chaque sujet retenu, les objectifs poursuivis sont les suivants :

1. localiser et réunir toute l'information documentée pertinente;
2. cerner les plus récentes pratiques applicables à la résolution des problèmes ressortissant au sujet retenu;
3. répertorier tous les travaux de recherche pertinents en cours sur le sujet;
4. cerner les problèmes qui demeurent en bonne partie non résolus;
5. agencer, évaluer, documenter et faire la synthèse de l'information utile réunie au fil des étapes précitées;
6. évaluer l'utilité de cette synthèse une fois que les utilisateurs visés en auront été saisis depuis un certain temps.

La mission de l'Association des transports du Canada (ATC) est de promouvoir la sécurité, l'efficience, l'efficacité et le respect de l'environnement dans la prestation de services de transport, en vue d'appuyer les objectifs sociaux et économiques du pays. Organisme d'envergure nationale et sans but lucratif, l'ATC offre une tribune neutre pour la discussion des enjeux et des problèmes liés aux transports et sert de centre d'études techniques dans le secteur des transports routiers. Ses membres comprennent tous les paliers du gouvernement ainsi que d'autres associations, des experts-conseils, des entrepreneurs, des fabricants, des distributeurs, des expéditeurs, des transporteurs de marchandises, des exploitants de services de transport de voyageurs, des établissements de recherche et le milieu universitaire.

La série *Synthèse des pratiques* est parrainée par le Conseil de la recherche et du développement de l'ATC. Le rôle de ce conseil est d'encourager l'exécution de recherches innovatrices, efficientes et efficaces et le transfert connexe de la technologie qui en est issue, le tout pour le compte du secteur canadien des transports. Ses responsabilités comprennent notamment la détermination des priorités nationales de recherche, l'élaboration et la gestion d'un programme coopératif national de R-D de même que le repérage et la diffusion des résultats des travaux de recherche sur les transports exécutés au Canada et à l'étranger.

ACKNOWLEDGEMENTS

This project was conducted with funding provided by TAC's Research and Development Council. The views, opinions and conclusions expressed or implied in the text are those of the authors and do not necessarily reflect the position or policies of the Transportation Association of Canada.

TAC would like to express its appreciation to the members of the project steering committee who volunteered their time to provide advice, guidance and direction, and to those individuals and agencies who contributed to the success of the study by providing input and responding to telephone surveys.

Project Steering Committee:

Mr. John Hosang, Chair	Manitoba Highways and Transportation
Mr. Keith Belinko	National Research Council
Mr. Imants J. Deme	Shell Canada Products Company
Mr. Shyam Kubchandani	Transport Canada
Monsieur Pierre Toupin	Ministère des Transports du Québec
Mr. Robert Valenti	New York State Department of Transportation
Ms. Michèle Le Blanc (Project Manager)	Transportation Association of Canada

Project Consultants:

Mr. Douglas Williams	The ARA Consulting Group Inc.

Executive Summary

The main objective of this study was to produce a syntheses of evaluation practices used by organizations which carry out transportation-related research and development (R&D). The project was intended to determine what evaluation methods are currently being used to assess R&D programs and the degree of satisfaction with these methods.

A second purpose of the study was to provide some "how to" information on evaluating the impacts of transportation-related R&D.

The work was carried out in three stages:

(1) the project began with a brief review of the literature regarding methodologies which are available for evaluating the impacts of R&D and some consultations with experts in this field;

(2) the second stage of the project involved interviews with representatives of organizations that are involved in carrying out transportation-related R&D - four federal (US and Canadian) agencies, four provincial agencies, two municipalities, three industry associations, and three other organizations;

(3) the third stage involved preparing the illustrative information on evaluation methodologies - both examples of the use of these methodologies and some technical information on how to apply the methodologies.

The methods which are available for assessing the impacts of R&D can be categorized as follows:

- expert opinion - this method involves obtaining the opinions of people who are knowledgeable about the particular research field, the importance of the R&D being evaluated, and/or the likely usefulness and impact of the R&D;
- user or client opinion - this method involves obtaining the opinions of the primary intended user of the research results or the clients for the research (users who are involved with the research-performing organization);
- cost benefit methods - the assessment of R&D on a project by project basis which seeks to quantify each project in terms of the economic and social benefits generated for a particular "referent group," as well as the economic and social costs incurred by the referent group to carry out the R&D and implement the R&D results;
- case studies - the thorough documentation of the relationship between the R&D and its impacts; and
- performance indicators - the collection of information on certain specified variables, each of which provides some insight into the extent of the impact resulting form the R&D.

The main finding from the review of the current practices was that most of these organizations are carrying out relatively little formal evaluation of their R&D. Most of the evaluation is conducted at the beginning of the R&D process and involves the review of potential projects by advisory committees composed of representatives of the primary intended users of the R&D and/or direct contact with the primary intended users. There is very little evaluation of the R&D during the R&D process, and there is also little evaluation of the R&D after is has been completed.

The specific findings can be summarized as follows:

- At the beginning of the R&D process most organizations consider the cost of the R&D and its probability of success and carry out some assessment of the likely impact/payoff of the R&D. The most common method used for the latter is client/user opinion (eight of the 18 organizations), followed by expert opinion (four organizations) and some form of cost-benefit analysis (four organizations).

- About half the organizations interviewed carry out some sort of informal monitoring of the progress of the R&D during the R&D process.

- Relatively little evaluation of R&D is carried out by these organizations after the R&D has been completed. There was only one formal system in use for post-project evaluation.

Regarding the degree of satisfaction of the organizations interviewed, almost all of them were generally satisfied with the evaluation methods they are currently using. On the other hand, about half of the interviewees said these methods could be improved.

The report provides examples of the use of user surveys, cost-benefit methods, case studies, and performance indicator for evaluating transportation-related R&D. It also provides a summary matrix outlining the applicability o the various evaluation methods to transportation-related R&D at different stage of the R&D process, as well as some technical information on how to structure user surveys and how to carry out cost-benefit analyses. The study suggests an ideal evaluation model for an R&D program, which involves the use of a combination of the various evaluation methods.

Sommaire

L'objectif premier de cette étude était de dresser une synthèse des pratiques d'évaluation employées par les organisations exécutant des travaux de recherche et de développement (R-D) dans le domaine des transports. Concrètement, l'étude avait pour but de cerner les méthodes courantes d'évaluation des programmes de R-D et le degré de satisfaction suscité par chacune d'elles.

Le deuxième objectif de l'étude était de réunir de l'information sur les façons d'évaluer les incidences de la R-D en transports.

Dans ce contexte, les travaux d'étude ont été exécutés en trois étapes, lesquelles sont décrites ci-après :

(1) le projet a débuté par une brève analyse des documents traitant des méthodes courantes d'évaluation des incidences de la R-D ainsi que par un certain nombre de consultations auprès d'experts du domaine;

(2) la deuxième étape du projet prévoyait la tenue d'entrevues avec des représentants d'organisation oeuvrant dans le domaine de la R-D en transports, en l'occurrence des représentants de quatre administrations fédérales (canadiennes et américaines), de quatre administrations provinciales, de deux municipalités, de trois associations de l'industrie et de trois autres organisations;

(3) la troisième étape portait sur la préparation d'un précis sur les méthodes d'évaluation analysées, exemples et renseignements techniques à l'appui.

Les méthodes d'évaluation des incidences de la R-D peuvent être regroupées selon les catégories suivantes :

- opinions d'experts — cette méthode permet de recueillir les opinions de personnes possédant une connaissance approfondie d'un domaine de recherche en particulier, de l'importance de la R-D évaluée ou de l'utilité et des incidences probables de la R-D, ou encore de toute combinaison de ces éléments;

- opinions des usagers ou des clients — cette méthode permet de réunir les opinions des principaux utilisateurs des résultats de recherches ou des clients à qui les résultats des recherches sont destinés (utilisateurs entretenant des rapports avec l'organisme de recherche);

- méthodes coûts-avantages — évaluation de la R-D par projet dans le but de quantifier les avantages économiques et sociaux de chaque projet pour un «groupe de référence» donné de même que les coûts économiques et sociaux devant être acquittés par ce groupe à l'appui de l'exécution de la R-D en question et de la mise en oeuvre de ses résultats;

- études de cas — examen approfondi des liens entre la R-D et ses incidences;

- indicateurs de rendement — collecte d'information sur certaines variables précises dont chacune permet jusqu'à un certain point de mesurer l'importance des incidences de la R-D.

La principale conclusion issue de l'examen des pratiques courantes en la matière était que la majorité des organisations ici visées se préoccupaient assez peu d'évaluer le rendement de leurs activités de R-D. Le cas échéant, cette évaluation est en bonne partie exécutée au début de l'instauration d'un processus de R-D et se limite

essentiellement soit à un examen des projets à l'étude par des comités consultatifs composés de représentants des principaux utilisateurs des résultats de la R-D, soit à des contacts directs avec ces utilisateurs. Peu d'activités d'évaluation sont exécutées au cours des travaux de R-D proprement dits ou même une fois ceux-ci terminés.

Plus spécifiquement, les conclusions de l'étude peuvent se résumer comme ci-après.

- Au début d'un processus de R-D, la plupart des organisations examinent le coût des travaux visés, leurs probabilités de succès et, dans une certaine mesure, leurs incidences/retombées probables. La méthode la plus courante utilisée dans ce contexte est la collecte d'opinions auprès de clients/d'utilisateurs (8 organisations sur 18), la collecte d'opinions auprès d'experts (4 organisations) et certaines formes d'analyses coûts-avantages (4 organisations).

- Environ la moitié des organisations interviewées ont indiqué qu'elles exerçaient une certaine forme de surveillance informelle des progrès de la R-D en cours d'exécution.

- Assez peu d'activités d'évaluation de la R-D sont exécutées par les organisations une fois les travaux en question terminés. L'exercice a permis d'établir que seule une organisation appliquait un système d'évaluation après coup de la R-D.

En ce qui a trait au degré de satisfaction des organisations interrogées, presque toutes ont indiqué qu'elles étaient généralement satisfaites des méthodes d'évaluation présentement appliquées. Près de la moitié des personnes interrogées ont toutefois fait valoir à cet égard que ces méthodes pourraient être améliorées.

Le rapport fournit des exemples concrets d'enquêtes auprès des usagers, de méthodes coûts-avantages, d'études de cas et d'indicateurs de rendement servant à évaluer la R-D en transports. Il contient également une synthèse graphique des possibilités d'application des diverses méthodes d'évaluation aux différentes étapes d'un projet de R-D. Ce rapport fournit en outre certains renseignements techniques sur la façon de structurer les enquêtes auprès des usagers et de procéder à des analyses coûts-avantages. L'étude propose enfin un modèle idéal d'évaluation des programmes de R-D en transports, modèle qui dans les faits s'inspire d'une combinaison d'éléments tirés des différentes méthodes d'évaluation analysées.

Table of Contents

1. Introduction

1.1 Purpose of the Study

Program evaluations have been carried out in Canada for many years, particularly since the mid-1970's when the practice of program evaluation was formalized by the federal government. The main purposes of program evaluations are:

- to provide information regarding a program's efficiency and effectiveness that can be used for reporting purposes—to sponsoring agencies and other interested stakeholders, and;
- to provide information that can be used by the program managers for improving the structure or operation of the program.

Research and development (R&D) programs have been among the last types of programs to be subjected to program evaluations, primarily because of the nature of research. Some of the difficulties associated with evaluating R&D programs are:

- R&D produces impacts by generating technological innovations. However, the connections between R&D and innovations are often long-term, indirect, and unpredictable. Studies of technological innovations have shown them to often depend on research results that are decades old and, in many cases, in seemingly unrelated fields.
- Even when the impacts of R&D are known, the methods available for measuring these impacts are often not very satisfactory. This is particularly true of R&D which is undertaken in order to produce "public goods"—that is, goods which are not bought and sold in the marketplace, such as clean air, improved quality of life, and so on. Because prices do not exist for public goods it is difficult to quantitatively measure their value.

At the same time, research organizations are under increasing pressure to demonstrate the benefits of their research, and, as a result, evaluations of R&D programs have become increasingly frequent. A large number of successful R&D program evaluations have been carried out since the mid-1980's, and the methods used and results achieved in these evaluations have gained widespread acceptance. Program evaluation is the main tool that is available to R&D program managers to justify or value their programs.

The main objective of this project was to produce a synthesis of program evaluation practices used by governments, agencies, and private firms to assess the value of their transportation-related R&D programs. In particular, the project was intended to address the following questions:

- What mechanisms or practices have been used to evaluate transportation-related R&D programs?
- Which of these have been found to be the most effective and successful?
- To what extent are organizations satisfied with present evaluation approaches to R&D?

Program evaluations traditionally address three categories of evaluation questions:

- Program Rationale—Does the program make sense? Is it needed?
- Program Impacts—To what extent has the program achieved its objectives? What have been the other significant impacts of the program, both intended and unintended?
- Program Delivery—How efficient and effective are the program's structure and operation? Are there any alternative ways of better meeting the objectives of the program?

The focus of this project was to obtain information regarding practices used to address the second category — i.e., the impacts of R&D programs.

Another purpose of this project was to provide some "how to" information on assessing the impacts of transportation-related R&D. Many of the organizations interviewed in this study said they would like to have more information regarding the methods that can be used for evaluation. These organizations expressed particular interest in methods that can be used for evaluating the economic impacts of R&D (at all stages of the R&D cycle), and a number of the organizations said they would like to see some standardization of the economic impact assessment methods which are used by different organizations. It is hoped that the preparation of some information regarding how to apply such methodologies might be a first step in filling this gap.

1.2 Summary of Work Carried Out

This project began with a brief review of the literature regarding methodologies which are available for evaluating the impacts of R&D. The purpose of this review was to update the literature review carried out in our previous work on R&D impact assessment methods[1] (referred to in the remainder of this report as the "impact methodology study"). The literature review involved a computer search of the literature on this topic contained in the University of British Columbia and Simon Fraser University library databases.

In addition to reviewing literature, we consulted with several experts in research program evaluation regarding available methodologies and participated in a day-long workshop at the November joint meeting of the Canadian and American Evaluation Societies. The workshop dealt with methods for evaluating the impacts of R&D, and we consulted with a number of the R&D evaluation practitioners who attended, including practitioners from the United States, Australia, the UK, and Scandinavian countries.

The second stage of the project involved interviews with representatives of organizations that are involved in carrying out transportation-related R&D. A total of 18 people were interviewed representing the following types of organizations:

- Canadian federal agencies—two interviewees;
- US federal agencies—two interviewees;

---

1 *Methods for Assessing the Socioeconomic Impacts of Research and Development*, The ARA Group Inc., May 1993.

- Canadian provincial agencies—four interviewees;
- Municipalities—two interviewees;
- Industry associations—four interviewees;
- Private companies—three interviewees; and
- Universities—one interviewee.

A list of the people interviewed is contained in Appendix A. Following the preparation of the descriptions of the evaluation practices of the various organizations, we confirmed the accuracy of these descriptions with each organization.

The third stage of the project involved preparing the illustrative information on evaluation methodologies. This was done on the basis of our past experience with these methodologies, combined with the review of several recent studies in which the methodologies have been applied to transportation-related R&D. These studies included:

- *Review of the Alternative Transportation Fuels Task*, The DPA Group (now the ARA Group), August, 1990.
- *Evaluation of Transport Canada's Central Research and Development Program*, Young and Wiltshire, March, 1992.
- *New Technology Research: Costs and Benefits*, University of California, Irvine, June, 1993.
- *Impacts of Canada's Heavy Vehicle Weights and Dimensions Research and Interprovincial Agreement*, Transportation Association of Canada, October, 1994.

2. Overview of Evaluation Methods

The literature review indicated that there are no methods available for assessing the impacts of R&D other than those outlined in the impact methodology study. There have been some refinements to these methods, particularly in the procedures used to collect the data more efficiently,[2] but there are basically no new methods. As noted in a recent paper by the Director of Technical Assessment at the US Office of Naval Research:

> *"While the methods in the performance of research continually advance the state-of-the-art, the methods used for its identification and selection have changed little in decades. In evaluation and assessment of existing and completed research, not only have the methods in practice changed little with time, but the numbers of organizations which use any but the most rudimentary methods also remain a handful."*[3]

The available methods are briefly described in the following sub-sections.

It should be noted that the impacts of R&D programs are, of necessity, assessed on a project by project basis. The impact of the program as a whole is then determined by "adding up" the individual project impacts. This is a fairly straightforward exercise when the project impacts are expressed in quantitative terms, such as dollars. When this is not the case, individual project impacts generally have to be added up on a more judgmental basis.

2.1 Expert Opinion

The term "expert opinion" is largely self-explanatory—this method simply involves obtaining the opinions of people who are knowledgeable about the particular research field, the importance of the R&D being evaluated (to the advancement of the field), and/or the likely usefulness and impact of the R&D. The experts can be either internal to the organization or external, such as university faculty members.

Expert opinion can be solicited at any time in the R&D process, but it is most commonly solicited at the beginning of the process when a potential R&D project is being considered. The opinion can be provided on an unstructured basis, or it can be structured on the basis of "performance indicators" (discussed in Section 2.5). In the latter case either the experts would base their reports on a specified set of **individual indicators**, such as the quality of the research or the economic impact of the research; or they would base their reports on a system of **integrated indicators**—e.g., the number of points for the quality of the research plus the number of points for the economic impact of the research.

A specific method for obtaining expert opinion which has come into widespread use over the past several years is a "modified peer review". The term derives from the fact that this method

---

2 See, e.g., *Measuring the Impact of Publicly Funded R&D*, Keith Belinko and Jennifer Hollington, to be published in Optimum, Winter, 1995.

3 Kostoff, Ronald N. (1994), *Research Impact Assessment: Where Are We Now*, Office of Naval Research, Arlington, Virginia.

is a modification of traditional peer review (which involves the assessment of the quality [scientific merit] of the research by scientific experts [peers] in the specific research field). Modified peer review involves the joining of some form of impact assessment with traditional peer review. The simplest type of modified peer review involves the selection of peers who can comment not only on the scientific merit of the research but also on its potential economic and social impacts. The peers are then asked to address both issues.

It is sometimes impossible to find experts who can address both the quality of the research and its potential impacts. In these cases the standard practice is to split the assessment into two parts with two different sets of reviewers. Most commonly, the two reviews are carried out independently, and the results are then brought together in an integrated report by a third party. (This is the approach used by Canada's National Research Council for reviewing its research institutes.)

2.2 User or Client Opinion

This method involves obtaining the opinions of the primary intended users of the research results or the clients for the research. ("Clients" are a subset of the primary intended users and consist of those organizations which are involved with the research-performing organization in research collaboration or some other form of active interaction.)

The most common method for obtaining user/client opinion is through the formation of advisory committees consisting of users or clients. These committees are asked to provide their opinions regarding various aspects of the research, and, in particular, the importance of the research to their own organization. Like expert opinion, user/client opinion is most commonly sought when proposals for research projects are being considered. (Sometimes these opinions are solicited even earlier, when research needs are being identified and ideas for potential projects are being formulated.)

A method of obtaining user/client opinion which is often used following the completion of research projects is user surveys. In such surveys the primary intended users (or clients) are provided with information regarding the research results, and they are asked for their opinions about the likely impacts of the research (particularly its importance and usefulness for their organization). The way in which such surveys are structured and the types of questions that are asked are described in Appendix B.

2.3 Cost-Benefit Methods

Cost-benefit analysis is always carried out on a project by project basis, and it seeks to assess the project in terms of the economic and social benefits generated for a particular "referent group" (e.g., a province or Canadian society as a whole), as well as the economic and social costs incurred by the referent group to carry out the R&D and implement the R&D results.

The main principles associated with carrying out cost-benefit analyses of transportation-related R&D projects are summarized in Appendix C. As seen in the appendix, very specific definitions and methods of evaluation are used in cost-benefit analysis. Some of the key points are:

- There are three main types of costs associated with an R&D project that must be taken into consideration in the analysis — the costs of generating the research results, the costs of introducing and supplying the results to end users, and the costs incurred by the end users to implement the results.
- The benefits of the R&D project are valued at the price society is willing to pay for them. The assessment of benefits includes not only those for which prices are paid, but also benefits associated with increased educational and training opportunities, reduced environmental damage, improvements in health and safety, and so on, even though in many instances it may not be possible to associate an explicit value with such benefits.
- The expected value stream over time of annual costs and benefits must be discounted to their present values in order for the calculation of net benefits (gross economic and social benefits minus economic and social costs) to be carried out.
- The research project being analyzed must be **incremental** and the benefits must be **attributable** to the results of the research. The term "incremental" means that the research results would not have been available in the absence of the specific project being analyzed (e.g., from similar research being carried out elsewhere). "Attribution" deals with the extent to which the benefits are actually due to the research results—i.e., the extent to which the benefits might have been achieved even if the research results had not been available. If the R&D project is only partially incremental or if the benefits can only be partially attributed to the research results, these factors must be taken into consideration in the analysis.

Given the uncertainty of R&D, many evaluators find that cost-benefit analysis is impractical and far too technically demanding for most R&D projects, except possibly those that have been completed for some time and for which the benefits can be observed. On the other hand, cost-benefit analysis can be a useful method for deciding which potential R&D projects are most attractive, as long as consistent techniques and assumptions are applied to different projects.

As a point of interest, Canada is one of the two countries (Australia being the other) which have had by far the most experience in applying cost-benefit analysis to R&D projects.

2.4 Case Studies

Case studies often get short-shrift in discussions of methodologies for evaluating the impacts of R&D, but, in fact, they represent one of the most useful methods for examining and documenting the relationship between R&D and its associated impacts. Case studies involve a detailed and thorough analysis of particular R&D projects, and they seek to track and document the evolution of the impacts associated with the R&D. The advantage of case studies over other methods is that, when they are carried out in sufficient numbers and sufficient detail, they represent probably the best chance of fully identifying the relationship between R&D activities and impacts. The problem with this method is that, since case studies relate to specific R&D projects, it is difficult (generally impossible) to aggregate the results from a group of case studies in order to generalize to a larger set of R&D activities, such as an R&D program.

Case studies are only applicable, of course, to R&D that has been completed. An important point to be made about case studies in relation to transportation R&D is that they are the best method for analyzing and documenting the impacts of R&D that is oriented toward the public good (as opposed to, for example, developing a product for the marketplace). They can be far more useful than cost-benefit analyses that assign dubious values to impacts for which there is no common consensus regarding appropriate values, such as the value of a human life.

2.5 Performance Indicators

There are two main categories of performance indicator methods — partial indicators and integrated partial indicators. The first method simply involves the collection of a certain number of information items, each of which provides some insight into the extent of the impacts resulting from the R&D. For example, the information can include information on inputs (e.g., program funding, number of people involved in running the program), program activities, program outputs, or program impacts themselves. In effect, one sets up an information collection system for the program, and, once the information has been collected, it is organized and presented in a way that enables people who are reviewing the information to draw conclusions regarding the impacts of the program.

The method of integrated partial indicators involves the collection of the same sort of information, with the difference being that the information is integrated in some way. Generally speaking this method involves a system for "adding up" the partial indicators and arriving at a "bottom line score" for each R&D project. The most common approach is to evaluate each project with reference to a specific set of criteria/questions (the partial indicators). Each criterion is then assigned a numerical weight, which enables the array of R&D projects to be ranked in order of priority according to the sum of the numerical values assigned to the various criteria. For example, potential R&D projects might be evaluated by assigning a score of 1-10 to each of the following indicators: cost, feasibility of the R&D, likely impact/payoff, and consistency with the mandate of the organization. The overall score for each project would then be between 4 and 40.

3. Current Practices

3.1 Summary of Current Practices

In this section we summarize the results of the interviews of R&D-performing organizations. The practices of these organizations are described on an individual (organization by organization) basis in Section 3.2.

With regard to factors considered at the **beginning of the R&D process**, all the organizations interviewed consider the estimated cost of the R&D, but the estimates used are based in almost all cases solely on budgets of research managers internal to the organizations or the budgets submitted by organizations proposing research. There was only one case of an attempt to more rigorously estimate the costs of successfully completing the R&D. (In this case R&D costs were estimated based on historical cost information for similar projects.) At first glance this is a bit surprising, given that the cost of much R&D greatly exceeds the initial estimates of the costs. However, it should be kept in mind that virtually all of the R&D carried out by the organizations interviewed is in the category of applied research or development, in which the uncertainties associated with R&D are much less than with basic or fundamental research. As one interviewee said: "The cost is a given."

Similarly, although most of the organizations interviewed consider the probability of success of the R&D, their assessment is based almost entirely on the opinions of the research managers. One organization said that they carry out a "qualitative risk analysis", but this too relies solely on the researchers' opinions.

All of the organizations interviewed consider the likely impact/payoff of the R&D when they are deciding what R&D to carry out. The most common method for doing this is to seek the opinions of the intended clients or the "users" of the R&D results regarding the benefits of the R&D. Five of the organizations solicit the opinions of client groups on an informal basis, and three of the organizations have a more formal system involving advisory committees of client representatives. Thus, about half the organizations surveyed involve the clients for the R&D in the selection process. In two cases the advisory committee uses a formal rating system for assigning priorities to potential R&D projects. In one case the research proposals are actually formulated by client groups, and a senior level committee of other client representatives subsequently evaluates these proposals.

Four organizations base their assessments of likely impact/payoff on expert opinion, generally the opinions of their research staff and/or their research managers, supplemented by the opinions of external experts when necessary. One of these organizations has an annual R&D needs exercise which feeds into the planning process.

Four of the organizations interviewed carry out some sort of cost-benefit analysis when considering what R&D to carry out. Only one of these, the Ontario Ministry of Transportation, conducts what we would call a formal cost-benefit analysis, in which there is an attempt to quantify all the benefits, including the benefits of environmental improvements and improved health and safety. As would be expected, the private companies consider the expected returns

from products or processes which may be developed as a result of the R&D. This is also the case for one of the industry associations.

Very few of the interviewees mentioned any other factors (i.e., other than cost of the R&D, probability of success, and potential impact/payoff) that are taken into consideration when deciding what R&D to carry out. A couple of the government interviewees did mention that the fit of the R&D with the department's overall objectives is explicitly assessed.

Very little evaluation of the R&D is carried out by the respondent organizations **during the R&D processes** itself. Half the organizations said they did nothing at all. The other half carry out some monitoring, but this is generally relatively informal monitoring of research progress (and to a lesser extent research costs and likely impacts) by the research managers and/or other organization officials. Two organizations (actually two branches of the same organization) have on-going research progress monitored on a regular basis by client advisory committees, and one other organization constitutes a technical committee for each on-going project to monitor the quality of the research.

There is also relatively little evaluation of R&D by these organizations **after the R&D has been completed**. It should be noted, however, that about half these organizations are themselves the primary intended users of the research results. Consequently, the research managers are generally well aware of the extent to which the research results are used and useful. In several other cases, the organizations may not be the primary intended users themselves, but they are very close to the users and, therefore, are aware of the use and usefulness of the research. As one representative of the Forest Engineering Research Institute said: "If the companies keep providing the funding for membership, that is our most important indicator of the usefulness of the research."

The only formal system for regular post-project evaluation is conducted by the Ontario Ministry of Transportation, which carries out a final cost-benefit analysis to update their pre-project cost-benefit analysis.

Other post-project evaluations that have been carried out include:

- The R&D Directorate of Transport Canada carried out a full evaluation of its R&D program several years ago as part of the normal cycle of evaluations of Transport Canada programs. This study included a client survey and case studies of the impacts of a selection of R&D projects.
- Alberta Transportation conducted a user survey several years ago to attempt to determine the extent of use and usefulness of its R&D results, but the response rate to the survey was unsatisfactorily low.
- The Quebec Ministry of Transportation forms a committee for its major R&D projects at the end of the project to evaluate the quality of the research and the contribution of the research to its overall research program objectives.

Finally, it should be noted that several of the organizations interviewed carry out cost-benefit analyses of the implementation of the R&D results (e.g., what would be the costs and benefits associated with using a new pavement mixture), and this information is disseminated to their

clients along with the R&D results. This information could be used in a more formal way as part of post-project cost-benefit evaluations (see Appendix C).

With regard to their degree of **satisfaction with the methods** being used by their organization for R&D impact evaluation, almost all of the respondents indicated that they are generally satisfied with the methods they currently use. Seven of the respondents, however, said the methods could be improved. The following two quotes represent the views of most of these people:

> *We need better methodologies to estimate the economic impacts of the R&D. This is very difficult in some cases — for example, R&D intended to develop standards and guidelines or to improve safety. The politicians want this, but we don't have any in-house economics capability in our Department. Everybody seems to evaluate the economic impacts of R&D differently. There is a need for some sort of manual.*
>
> *One of the hardest things to do — and the most important — is to evaluate the economic benefits of R&D. I would like to see a better methodology developed, and there is a real need for consistent methodologies. TAC would be well advised to fund the development of guidelines for evaluating the benefits of R&D projects.*

Other more specific comments were:

- There is a need for more methodological work on valuing the impacts of environmental and safety improvements and on performance indicators.
- We need a better way of estimating benefits because some of the benefits take a long time to pan out and they are difficult to evaluate without long-term testing.
- We need to improve the methods we use for risk assessment at the beginning of projects, and we also need to develop project selection criteria which include good measures of impact and payoff. Also, we haven't figured out how you measure the performance of public good-oriented R&D.

3.2 Practices of Organizations Surveyed

3.2.1 Transport Canada Research and Development Directorate

This Directorate administers the Central R&D program of Transport Canada. Almost all of the R&D within this program is implemented by the Transportation Development Centre (TDC) in Montreal through contracts with the private sector, universities, etc. The budget of the central R&D program is approximately $15 million per year plus about $2.5 million for salaries. R&D is carried out in the following areas:

- safety and security(30-35%);
- energy and environment(20%);
- transportation efficiency, productivity, and competitiveness(15%);
- operations(15%);
- policy(10%); and
- technology transfer(5-10%).

About 80% of the total research effort falls under the category of applied research, 15% is development, and 5% is exploratory or basic research. The primary intended users for the R&D are the program and operations managers in Transport Canada.

Much of the evaluation work for the program's R&D is carried out at the beginning of the R&D process when deciding what R&D should be undertaken. There is an extensive planning process which is based on consultations between the researchers and the clients (Transport Canada managers). The two groups reach agreement regarding what R&D is high priority. The factors considered in reaching a decision are the cost of the R&D, the probability of success (based on a qualitative risk analysis), and the pay-off from the R&D if it successful. The Directorate is beginning to use more formal project selection criteria which include specified impact/payoff factors. As a supplement to this process the Department has R&D councils for each mode of transportation which serve as overall sounding boards.

R&D is not evaluated in a formal way during the actual R&D process. There is a project team which monitors the progress of the R&D.

After the R&D has been completed, the researchers are required to prepare a project completion memo which summarizes the R&D results. The purpose of this is mainly to have a record of what has been accomplished.

A major external evaluation of this program was carried out in 1992. It included about 15 detailed case studies of specific R&D projects in which there was an attempt to identify (and in some cases to quantify) the impacts of the R&D. This evaluation, which was part of the regular Departmental evaluation cycle, had some impact on how Transport Canada downsized its R&D program and on formalizing the rationale for Transport Canada involvement in R&D. It also influenced the methods used for project selection, including bringing about a greater focus on Transport Canada priorities.

The Directorate is fairly well satisfied with the evaluation methods that are currently used, with two exceptions:

- There is a feeling that it needs to improve the methods for risk assessment at the beginning of projects; and
- There is a need for better methods for measuring the impacts and benefits of public-good oriented R&D. (Case studies are seen as the only method currently available for doing this.)

3.2.2 Transport Canada Road Safety and Motor Vehicle Regulations Directorate

This Directorate spends about $2 million per year on R&D, most of which (80%) is in the area of vehicle design regulations and standards. About 10% of the work is devoted to intelligent transportation systems, and about 10% to environmental issues (e.g., standards for emissions). All of the R&D would be classified as applied research. The primary intended users for the R&D are Transport Canada officials involved in preparing regulations and standards. The general public is considered as a secondary client.

The selection of R&D projects is based to some extent on international trends in research and to some extent on expert opinion, with the latter obtained informally from researchers (university researchers and researchers employed by vehicle manufacturers) and medical departments and collision investigators involved in compiling information on accidents. There is no formal evaluation process.

There is also no formal evaluation process during the conduct of the R&D or after the R&D has been completed, except as part of the R&D management process. Informal feedback from users and general public opinion provides a sort of post-project evaluation. Data on collisions plays the same sort of role.

The Directorate is satisfied with the evaluation methods currently being used.

3.2.3 Federal Highway Administration

The FHWA has an annual R&D budget of approximately $350 million, which supports R&D in the following areas:

- infrastructure design;
- pavement design;
- vehicle design;
- road safety;
- economics;
- maintenance;
- traffic;
- intelligent transportation systems (ITS); and
- environment.

About 15 percent of FHWA's R&D program is directed at exploratory or long term research projects which are likely to be completed in 10 years or longer; 50 percent is directed at applied research projects which are likely to be completed within 2-5 years; and 35 percent is directed at the refinement and delivery of research products for use by the transportation community. ITS accounts for the largest share of the funding (57%), followed by pavement design (10%). The primary intended users for almost all of the R&D results are state and local transportation officials. Some of the R&D is directed toward internal FHWA policy makers.

There is no formal, systematic evaluation of the R&D which is carried out. Evaluation was described as "an informal part of research management." The Research and Technology Executive Board is chaired by the FHWA's Executive Director, the agency's most senior career position. Its members also include eight other senior managers, including one regional administrator. This Board meets periodically to provide policy direction for the R&D program, reach agreement on priorities, and review progress in meeting program goals, accomplishments, priorities, and milestones. Their meetings coincide with the federal government budget cycle so they can adjust resources to reflect any changes in priorities.

Research and technology coordinating groups in each area (pavements, safety, planning, etc.) develop the details of proposed R&D programs and initiatives. These groups consist of mid-level managers from offices responsible for conducting the research as well as those who use R&D results when providing technical assistance to state and local transportation officials, developing technical guidelines, or assessing the implications of policy options. FHWA staff provide technical oversight of individual R&D projects. Future programs are adjusted based on research results from ongoing R&D. Each group makes presentations to the Board on R&D accomplishments and priorities for upcoming budget.

The Federal Highway Administration is developing performance goals and indicators in response to the Government Performance and Results Act of 1993. Some of the indicators under consideration include:

- state and local highway practices changed as a result of R&D activities;
- numbers of papers or studies accepted for publication or presentation at conferences;
- number and percentage of initiatives that are supported by outside funding.

The FHWA is satisfied with the current evaluation system, but the organization is "continuing to look for better ways to evaluate R&D program performance."

3.2.4 US Transportation Research Board

The Transportation Research Board (TRB) was established in 1920 to facilitate the exchange of information about highway research and technology among state highway agencies, the federal government, and universities. The TRB administers two contract research programs—one dealing with highways (National Cooperative Highway Research Program) and the other dealing with transit (Transit Cooperative Research Program). The budget for these two programs combined is approximately $23 million per year. The total TRB budget is about $37 million per year, with the majority of the additional amount allocated to core activities (annual meetings, technology transfer activities, and so on). There are 180 technical committees which identify research needs and sponsor technical sessions at TRB's annual meeting. These committees cover all transportation modes, but there is a heavy concentration on highway technology, for which TRB's clearinghouse role is of longest standing. A committee of the American Association of State Highway and Transportation Officials (AASHTO) selects the NCHRP projects from the proposals submitted and allocates the budget. The TRB administers the program and distributes information resulting from the R&D to the states. A similar process is followed for the TCRP.

The primary intended users of the R&D are state highway construction and maintenance organizations and regional transit authorities. Seventy-five percent of the research would be classified as applied research and 25% would be classified as development.

As noted above, the decisions regarding which NCHRP projects are approved are made by AASHTO, but these decisions are based on the rankings of proposed projects which are submitted by each state. Decisions are based on the cost of R&D, the probability of success (which has to be high because this is a very applied program), and the impact/payoff of the R&D if it is successful, but there are no formal criteria for these factors. Once a project has

been approved, an expert panel for that project is convened by the TRB. The panel writes the Request for Proposals for carrying out the work and evaluates the proposals that are submitted. The panel may also meet during the conduct of the research to review progress and offer guidance.

There is no evaluation of the R&D after it has been completed. The TRB publishes and disseminates the results of the research, but its feeling is that it doesn't need to get involved in its implementation, because this is a very applied program that is closely tied to the users.

There are some slight differences between the highway program and the transit program. The main one is that the highway program has more of a responsive orientation — i.e., it responds to the proposals of AASHTO technical committees and individual staff. The transit program, which is overseen by a body of transit operators, is more directive. In particular, there is a strategic planning process which results in the identification of areas of interest, and R&D proposals are then encouraged in these areas.

The TRB is satisfied with the informal evaluation methods which are used.

3.2.5 Ministère des Transports du Québec

The Quebec Ministry of Transportation has an annual R&D budget of $10 million, which supports R&D in the following areas:

- infrastructure (14%)—bridge loads, concrete/corrosion;
- pavement design (10%)—pavement mixtures, rutting, use of recycled materials;
- vehicle design (4%);
- road safety (8%);
- economics and administration (23%)—competitiveness, statistics;
- maintenance (19%)—pavement management systems, material testing, road repairs and rehabilitation;
- traffic (3%);
- intelligent transportation systems (14%)—automatic weather information system, GPS, traffic control system;
- environment/sustainability (2%); and
- planning (3%).

The $10 million R&D budget includes salaries and operating costs of the program, as well as $5 million in contracted work. Almost all this R&D is intended to support the Ministry's mission. Therefore, although the Ministry is in some regards the primary user, the ultimate users are transit organizations, entrepreneurs, road users, and municipalities. Forty percent of the R&D is applied research, 55% is development, and 5% is basic research.

The Ministry carries out an R&D needs exercise every year, and this is used as input to the planning process. Based on the results of this exercise, the various divisions submit proposals for research projects. The divisions are responsible for estimating the costs of the projects and

identifying the benefits. Proposals are evaluated by senior managers in the Ministry who take the following factors into consideration in deciding what R&D should be carried out:

- the cost of the R&D;
- the probability of success;
- the impact/payoff of the R&D if it successful; and
- the conformity of the R&D with the needs of the Ministry (as specified in the needs assessment).

There is no formal evaluation system.

Once a project has been approved, an internal committee is set up to monitor the quality of the research on an ongoing basis. In the case of the Road Safety Program these committees are made up of outside experts. They examine progress reports submitted by the researchers once a year, and at the end of three years they carry out a more global review, in which senior Ministry staff are also involved. Major projects are also evaluated at the end of the project to assess the quality of the R&D and its contribution to the objectives of the Ministry's research program. Some R&D is also subjected to actual testing in real conditions (e.g., testing of concrete mixtures which have been developed).

The Ministry is basically satisfied with the priority assessment method it uses for the annual programming of research projects. This is regarded as a simple and efficient method. There is some interest in exploring economic evaluation methods.

3.2.6 Alberta Transportation

The R&D budget of this Department was $5.9 million in 1994-95, but only $780,000 of this was for research, with the remainder going for "related scientific activity" (e.g., the collection of traffic data). The projected budget for 1995-96 is $4.9 million. R&D is carried out in the following areas:

- infrastructure(15%)
- pavement design (30%)
- vehicle design (5%)
- road safety (5%) (The Ministry's involvement in both this area and the previous area was much larger in the past.)
- economics and administration (5%)
- maintenance (10%)
- traffic (5%)
- intelligent transportation systems (20%), and
- environment/sustainability (5%)

The Department is the primary intended user of all the R&D—either for engineering purposes, to set standards and specifications, to provide input to decisions regarding maintenance, or to assist with the enforcement of regulations. Sixty percent of the research would be classified as applied research, 35% as development, and 5% as basic research.

Proposals for R&D projects are developed in consultation with the clients for the R&D within the Department. They are then evaluated by the Departmental Research Advisory Committee, based on a point system which considers the cost of the R&D, the probability of success, its impact/payoff, and the fit of the project with Departmental priorities. During this process the clients for the R&D within the Department are asked for information regarding these factors to support their proposals.

During the R&D process, projects are reviewed by Departmental staff to ensure that they are working out in line with the initial assumptions regarding the factors noted above. (If not, they may be modified or stopped.) There is no formal system for evaluating R&D after it has been completed, although there is informal feedback on the impact of the R&D on the Department's operations.

The Department is not particularly satisfied with the evaluation methods it uses, particularly for post-project evaluations. The Department feels that there is a need for a better evaluation system. It attempted to carry out a survey of intended R&D users a couple of years ago, but the response rate was very low. It feels there is a need for guidelines on how to estimate the economic value of the impacts of R&D. The politicians would like to see this, but it's difficult for this Department to carry out economic analysis for a number of reasons, the main one of which is that most of the research is intended for internal Department use. As a result, the value of the impacts—such as use of R&D results to develop standards and guidelines or to improve safety—is difficult to determine. It was noted that there is a need for a manual on evaluating the economic impacts of transportation-related R&D, because everybody does this differently.

3.2.7 Ontario Ministry of Transportation

The R&D budget of the Research and Development Branch of the Ontario Ministry is $5.5 million per year. It is devoted to the following areas:

- infrastructure design;
- pavement design;
- road safety (including road-side safety, such as guard rails and exit ramps);
- maintenance; and
- environment/sustainability (issues related to the use of roadways, such as effects of salt).

The Ministry is the primary intended user of all the R&D results, although it is recognized that some of these results are used by and useful to the general public. Ninety percent of the R&D is applied research, and 10% is development. Two-thirds of the research is done in-house, and one-third is contracted out to outside consultants.

The Ontario Ministry began doing formal cost-benefit analysis about one year ago as an aid to priorizing research projects. The cost-benefit results are not the only factor taken into consideration when deciding which projects to carry out, but the analysis is attached to each research proposal, and this is becoming an increasingly influential consideration. It is our understanding that these are rigorous cost-benefit analyses, in which both the costs and benefits are quantified in dollar terms whenever possible. The benefits often arise as a result of

reduced costs (e.g., reduced costs of maintenance). As would be expected, the Ministry has some difficulty in expressing environmental and safety benefits in dollar terms because of controversy over values associated with these benefits—e.g., the value of reduced injuries and, especially, reduced numbers of deaths. As a result, these benefits are expressed in both quantitative and qualitative (physical) terms.

There is no evaluation of the R&D during the R&D process. After the R&D has been completed, the cost-benefit analysis is updated to reflect more accurate estimates of benefits and costs. In addition to R&D costs, the likely costs of implementing the results are also better known at this time, and there is a better idea regarding the extent of implementation that is likely to occur (e.g., the probability that new infrastructure or new standards are subsequently developed). The Ministry is generally satisfied with the evaluation methods it is using, but feels these methods can be improved. It is currently in the process of developing performance indicators to add to its evaluation package, and it is also trying to improve the methods used for estimating the costs of implementing R&D results.

3.2.8 BC Ministry of Transportation and Highways

This Ministry had an R&D budget of $3.1 million in 1994-95, which dropped to $2.5 million in 1995-96. R&D is carried out in the following areas (the numbers in parenthesis are for 1995-96, but the percentages for 1994-95 were similar):

- infrastructure design (13%);
- pavement design (1%);
- road safety (7%);
- economics and administration (4%);
- maintenance (2%);
- traffic (55%);
- intelligent transportation systems (11%); and
- environment/sustainability (7%).

The Ministry and its consultants are the primary intended users of the research results, with municipalities and other transportation agencies being considered secondary users. About 70% of the research would be classified as applied, with about 30% being classified as basic.

R&D proposals are evaluated on the basis of the cost of the R&D, the probability of success, and the impact/payoff if successful. The Ministry primarily relies on expert opinion for these evaluations. (User surveys and performance indicators have also occasionally been used.) There is no formal evaluation either during or at the end of the R&D process, but projects are monitored to ensure that their objectives are met. The Ministry is generally satisfied with the evaluation methods it uses, but there is some interest in exploring other methods of evaluation. Constraints on staff and financial resources are considered to be limiting the use of some methods, such as economic analysis.

3.2.9 Municipalities

The responses of interviewees at the City of Calgary and Municipality of Metropolitan Toronto were similar, so they are described together here. Both municipalities carry out work in the areas of:

- infrastructure design
- pavement design
- maintenance, and
- traffic.

The work is divided more or less equally among these four areas. The City of Calgary also carries out some work in road safety, economics, intelligent transportation systems, and light rapid transit. The budgets of both municipalities are on the order of several hundred thousand dollars. Their own organizations are the primary intended users of the R&D—in particular, departments that deal with capital works, operations, and maintenance. Almost all of the work would be classified as either applied research or development.

When deciding what R&D to carry out, the factors considered include the cost of the R&D, the probability of success, and the likely impact/payoff. Potential R&D projects are assessed with regard to these factors by internal staff. There is no evaluation of the R&D during the R&D process. After the R&D has been completed, there is some attempt by both organizations to monitor the extent to which the R&D results are used.

Both organizations carry out some work to document the cost-effectiveness of some of their research results in terms of testing (e.g., for new pavement designs) and more detailed analysis of implementation costs. Both organizations are generally satisfied with the relatively informal evaluation methods used, but the City of Calgary noted that it would like to be able to estimate the economic benefits resulting from research more definitively. It noted the difficulty of estimating benefits which are uncertain until the R&D has been applied over a fairly long period of time: "For R&D dealing with streets, you have to observe the benefits—there aren't any short cuts."

3.2.10 Forest Engineering Research Institute of Canada

Interviews were held with both the Eastern and Western Divisions of FERIC. The responses are combined here, since they were quite similar.

The budgets of FERIC's Eastern and Western Divisions for transportation-related R&D are approximately $700,000 and $400,000 respectively. The fields of R&D are somewhat different for the two divisions. The primary focus of the Eastern Division is on vehicle design, maintenance, and infrastructure design, followed by some work on pavement design and economics. The main focus (for about half the R&D) of the Western Division is road safety (primarily heavy vehicle dynamics), and about a third of the total effort is devoted to economic analysis (primarily trucking productivity). The primary intended users of the R&D carried out by both divisions are forestry companies, truckers, and manufacturers of forestry-related vehicles (e.g., log trailers). The R&D is split about 60%/40% between applied research and development.

The principal evaluation of R&D projects is carried out at the beginning when deciding what R&D should be undertaken. The staff provides information regarding the costs of potential projects (based, to some extent, on historical cost information for similar projects), the probability of success, the likely impact/payoff (with particular attention in the Western Division being given to environmental impacts) to an industry advisory committee which meets twice a year. The advisory committee rates each potential project on a zero to ten scale based on its views regarding the importance of the project to the industry. FERIC then funds the highest ranked projects up to the point that their R&D budget is exhausted. (Some attention is also given to regional priorities, so that the projects not disproportionately represent the interests of one particular region.)

During the R&D process FERIC has a management information system which is used to monitor the costs of the R&D in comparison with the percentage completion (e.g., if the project is 40% complete, are the costs roughly equal to 40% of the original estimate?). In addition, the industry advisory committee reviews all ongoing projects every six months. Some projects are re-oriented (and some are even dropped) as a result of these reviews. There is no formal evaluation process after the R&D has been completed, but FERIC makes an active effort to transfer the results of the R&D to its members. It circulates reports of all completed R&D projects to the members (and other organizations), and in general, feels it is close to the industry that more formal evaluation is not necessary. It does include reply cards regarding the usefulness of the R&D with every report (although these do not garner a high response), and it has carried out some surveys of the members regarding the usefulness of past projects (e.g., for software products). Both FERIC representatives indicated that if the forest companies continue to supply the funding for membership, this is the most important indicator of the value of the R&D. FERIC is generally well satisfied with the advisory committee process — it feels this process keeps it well focused on the issues that are important to the industry.

3.2.11 Canadian Trucking Research Institute

The Canadian Trucking Research Institute has an annual R&D budget of approximately $1 million. R&D is carried out in the following areas:

- vehicle design (10%)
- road safety (30%)
- economics and administration (25%)
- intelligent transportation systems (5%), and
- environment/sustainability (30%)—primarily in support of the development of a code of conduct for trucking companies.

The primary intended users of most of the R&D are trucking companies and suppliers to trucking companies. Government is the primary intended user of some of the policy-oriented research. Ninety percent of the R&D would be classified as applied, with 10% classified as development.

Decisions regarding what R&D to carry out are made by the staff, in consultation with outside experts if necessary, based on the cost of the R&D, the probability of success, and the likely impact/payoff. In some cases potential users are also surveyed to evaluate the likely usefulness of the research results and, occasionally, to gain support for the R&D if insufficient funding is

available. With the one exception discussed below, there is no evaluation of R&D after it has been completed. The Institute is generally satisfied with the evaluation methods it uses, but it would like to have a broader view of the needs of the industry. Given that there are 60,000 trucking companies in Canada, it feels it would benefit by having more information on industry opinions regarding R&D priorities.

The Institute was involved in a major cost-benefit evaluation of R&D results carried out in 1994. That study estimated the net benefits to the Canadian economy associated with regulatory changes which were introduced as a result of R&D. It is discussed further in Section 4.2.

3.2.12 Société de l'assurance automobile du Québec

The Quebec automobile insurance corporation has an annual R&D budget of approximately $3 million, which includes funding for related scientific activities such as the processing of data on accidents. Sixty percent of the work deals with road safety—analysis of accident data, health data, and so on. Forty percent of the work is specifically related to the costs of providing automobile insurance, such as research on helping people to recover from accidents. The Corporation is its own client for this R&D, all of which would be classified as applied research.

Decisions regarding what R&D to carry out are made by the Board of Directors following recommendations by the staff. The staff prepares a memo to the Board for all new projects outlining the cost of the R&D, the probability of success, the likely impact/payoff, and the relation of the R&D to the mission of the Corporation. A cost-benefit approach is used to quantify the benefits of the research if this is possible—e.g., reduced costs to the insurance industry from accidents as a result of increased safety due to R&D. There is little evaluation during the R&D process or after the R&D has been completed. The researchers submit interim and final reports, but these are not used in a formal way (except that, for research conducted by the universities, the final reports may be used in deciding whether to fund particular university researchers again). The Corporation is generally happy with what it is doing, although it did express a desire to know more about more formal evaluation methods. It noted that it is particularly difficult to evaluate longer-term research.

3.2.13 Private Sector

Three private sector companies were interviewed. The research budgets of these companies were all on the order of several hundred thousand dollars. One of them devotes most of its R&D resources to monitoring R&D being carried out by other similar companies and "expropriating" the results of this R&D. The responses of the other two are summarized below.

The primary intended users of the R&D in both these cases were the marketing and production divisions of their own company. Each potential R&D project is developed in consultation with these users and is assessed in terms of its cost, probability of success (both technical success and market success) and, especially, the expected return. If justified by these factors, or in some cases by other strategic reasons, the project is undertaken.

In both cases on-going projects are monitored by teams consisting of researchers and users from the company (and in some cases customers). After the R&D has been completed, the research department gets involved with the users in estimating the benefits and costs of implementing the results of the R&D (sometimes in quantitative terms and sometimes in qualitative terms, for example, if the R&D is oriented toward environmental benefits). Both organizations are satisfied with the relatively informal evaluation techniques they use—basically involving and staying close to the intended users. Because of the involvement of the users (and sometimes the customers) the R&D has a high level of acceptance and the right questions are asked when projects are being carried out.

3.2.14 Waterloo Department of Civil Engineering

This section relates to the transportation group within the Civil Engineering Department. The R&D budget of this group is approximately $500,000 per year plus faculty salaries. Work is carried out in the following areas:

- infrastructure design (10%);
- pavement design (20%);
- road safety (15%);
- economics and administration (10%);
- maintenance (30%);
- traffic (10%); and
- intelligent transportation systems (5%).

The transportation industry and its suppliers (of both products and services) are the primary intended users of most of the R&D. Public agencies are also an important focus for some of the work. Ninety percent of the R&D would be classified as applied research, and 10% as basic research.

The primary evaluation method used at the beginning of projects is the peer review of research proposals by panels of experts constituted by the research funding agencies. Peer review is also used at the end of projects to assess the suitability of research results for publication in journals and presentation at conferences. Very little evaluation is done in the course of the R&D process. After R&D projects have been completed, there is some informal follow-up—for example, contacts with industry—but generally not anything that would be called evaluation. As the interviewee explained, the real measure of the quality and impact of the R&D carried out is the extent to which their group gets ongoing grants and contracts and attracts good graduate students.

The Department noted that one of the hardest things to do—and also the most important—is to evaluate the economic benefits of R&D. They would like to see a better methodology developed for doing this, one which is consistently applied by all transportation-related R&D performers.

3.2.15 Conclusions

As reported above, the organizations interviewed carry out little formal evaluation of their R&D. The most common method used is the review of potential and on-going projects by advisory committees composed of representatives of the primary intended users of the R&D and/or direct contact with the primary intended users. This makes perfect sense in view of the applied nature of most of this R&D.

4. Examples of Applications of Evaluation Methods

The two most methodologically complex of the evaluation methods discussed in Section 2.0 — user surveys and cost-benefit analysis — are discussed further in Appendices B and C. Those appendices are intended to provide sufficient "how to" information to enable readers to understand what is involved in implementing these methods.

In this section we provide examples of the application of user surveys, cost-benefit analysis, case studies, and performance indicators to transportation-related R&D.

4.1 User/Client Surveys

Our example of the use of user surveys is taken from the *Review of the Alternative Transportation Fuels Task*[4]. The Alternative Transportation Fuels Task is the Canadian government's R&D program for alternative transportation fuels. It is one of seven components of the federal Energy Research and Development Program (commonly called PERD). The budget for the Task is approximately $20 million per year.

The user survey was carried out in accordance with the procedures outlined in Appendix B. The R&D projects which comprise the program were subdivided into thirteen project groups for the purpose of this survey — conversion of natural gas to liquid fuels, hydrogen production and utilization, etc. For each of these groups an average of five reviewers commented on the R&D projects within the group.

Exhibit 4.3 in Appendix D provides an illustration of the typical kind of information that can be obtained from a user survey. Some of the conclusions drawn from this exhibit were:

- The results of the R&D in most of the project groups are used fairly heavily as a source of general information and for reference purposes.
- With the exception of the sewage sludge project and the Environment Canada projects, this is also true for the use of the results as input to user organizations' R&D programs.
- Generally the R&D has not been heavily used as a basis for investment decisions by the user organizations.
- The use of the R&D as a basis for modifying the operational procedures of the user organizations is generally rated as low.
- The three groups of projects that are intended to supply information which will be used as input to government regulations (groups 8, 12, and 13) are all rated as having been of medium usefulness for this purpose.

Similar data were obtained regarding the predicted future usefulness of the R&D.

---

4 *Review of the Alternative Transportation Fuels Task,* The DPA Group (now the ARA Group), August, 1990.

A second important set of data obtained in this survey involved the identification of those R&D projects for which the user organizations have made a high amount of use of the results or found the results especially useful. A page from Exhibit 4.4 of the study which is reproduced in Appendix D provides a sample of the results.

In addition to specific questions regarding the use of the R&D results, the respondents to the user survey were also asked: "In general, do the projects in the specified group of projects address research needs which are important to your [the user] organization?" The average response for each project group is shown in Exhibit 4.7 in Appendix D.

The survey also obtained data regarding the extent of harmfulness for user organizations if the Task did not exist or were to discontinue its activity and the extent of benefits for user organizations if the Task were to support twice as much R&D as it does now.

Finally, important information was obtained in this survey regarding some of the specific uses of the R&D results. A page which provides an example of this kind of information is reproduced in Appendix D.

4.2 Cost-Benefit Methods

We give two examples of the applications of cost-benefit analysis. Readers of this section should first read Appendix C, which lays out the main issues associated with the use of cost-benefit analysis.

The first example is from a study carried out by the University of California, Irvine, for the California Department of Transportation (Caltrans).[5] That report contains several case studies, one of which deals with a proposal by the City of Los Angeles to implement advanced, computer-based traffic surveillance and control systems in order to alleviate the central city gridlock. The City's Department of Transportation carried out a study of the expected costs and benefits of the proposed system, with the following results:

Projected Annual Benefits of ATSAC	
Reduction in stops ($.03/stop)	$4,411,500
Reduction in fuel consumption ($1/gallon)	$1,337,000
Reduction in time travel ($2/hour)	$2,091,000
Total Annual Benefits	$7,839,500
Projected ATSAC Annualized Costs	
Construction and engineering costs	$654,200
Operation and maintenance costs	$148,400
Total annualized costs	$802,600

As can be seen from these data, the City's study projected the following categories of benefits:

[5] *New Technology Research: Costs and Benefits,* University of California, Irvine, June, 1993.

- Reduction in stops and delays (estimated to be in the range of 13-17%);
- Reduction in fuel consumption (estimated to be in the range of 6-9%); and
- Reduction in travel time.

These are all legitimate benefits, but there are several problems with this study:

- The most serious problem is that the with-the-project improvements are not compared to a realistic base (with-the-project) case. The base case in this instance could have included replacement of the existing electromechanical fixed-time controllers with variable-time controllers, which, based on the time of day, could have altered signal timing to facilitate the smooth flow of traffic. In addition to these operational improvements, ride-sharing and short-term transit improvements could have been implemented in the downtown area. By not including the comparison of the with-the-project impacts with realistic without-the-project impacts due to prudent management and operation of the system that would have occurred anyway, the benefits of the proposed improvements are overstated.
- Benefits are not discounted in the same way as costs, with the effect that benefits are overstated.
- The $2/hour for travel time savings is regarded by Caltrans as low, thereby understating benefits.
- The estimated reduction in fuel consumption would be accompanied by a reduction in exhaust emissions (hydrocarbons and carbon-monoxide), but the benefits of this are not included in the annual benefit calculations.

Our second example of the use of the cost-benefit analysis is from the TAC-sponsored study on the impacts of Canada's revised heavy vehicle weights and dimensions regulations.[6] The focus of that study was the memorandum of understanding (MOU) on vehicle weights and dimensions signed by the provinces, territories, and federal government in 1988. This agreement allowed larger and heavier trucks to operate across Canada on designated highways, introducing a greater degree of uniformity than had existed previously. It was preceded by a TAC-supported research program on heavy vehicle weights and dimensions, which dealt specifically with performance and safety issues associated with various truck configurations (for example, the impact of truck weights on pavement durability or on bridge load design, the impact of truck configurations on the rollover threshold or on braking efficiency).

The study estimates the net quantifiable benefits due to the MOU as 1.87 billion 1992 dollars. The calculations involved in deriving this estimate are summarized below, because they provide a useful example of how to carry out a cost-benefit analysis.

The most complex calculation involved estimating the impacts of the MOU on trucking costs. This was done in accordance with the following steps:

---

6 *Impacts of Canada's Heavy Vehicle Weights and Dimensions Research and Interprovincial Agreement*, IBI Group, October, 1994.

(1) The first step was to estimate the changes in annual vehicle-kilometres by configuration type and vehicle weight for each province and territory. Since this was an estimate of the changes **due to the MOU**, two estimates were necessary — annual vehicle-kilometres by configuration type, etc. that would occur with the MOU in place and annual vehicle-kilometres that would occur if the MOU were not in place.

(2) Truck operating costs per vehicle-kilometre for the different configuration types and weights were then estimated for each province and territory.

(3) Estimated changes in annual trucking costs due to the MOU were estimated by multiplying the changes in annual vehicle-kilometres from step (1) by the cost per vehicle-kilometre for each configuration type from step (2).

The MOU was implemented in 1989. The study was carried out in 1994. The annual impacts of the MOU on trucking costs were estimated by carrying out the above three steps for three years:

1992 — estimated actual impacts that had occurred;

1997 — estimated impacts that would occur; and

2002 — estimated impacts that would occur.

Then impacts for all years between 1988 and 2002 were interpolated on a straight line basis. Trucking cost savings due to the MOU (resulting from the shift to larger, heavier, and more efficient truck configurations for interprovincial movements allowed as a result of the MOU) were estimated at just under $40 million (1992 dollars) in 1989 to over $220 million (1992 dollars) in 2002.

A number of other potential impacts of the MOU, both positive and negative, were also considered in the study. These included:

- impacts on pavement life;
- bridge strengthening costs;
- costs of upgrading weigh scales;
- savings to shippers as a result of reduced trucking rates (offset, to some extent, by capital costs to modify terminals and loading facilities to accommodate the larger truck configurations); and
- impacts on Canadian manufacturers of trailers (for whom a niche was developed as a result of the MOU).

Those impacts which could be quantified amounted to costs of about $2.75 million per year, primarily for bridge strengthening. These costs were then subtracted from each year's estimate of benefits (trucking cost savings) to yield the net benefits for each year from 1989 through 2002.

The net benefits for each year were then discounted to 1994 using a 5% discount rate, and the cost of the R&D program (also discounted to 1994) was subtracted, resulting in an overall net benefit of $1.86 billion (1992 dollars).

Also included in the study are:

- a discussion of the impacts of the MOU which could not be precisely quantified, such as those listed above and those due to reduced truck operating costs on roads outside of the national highway system (the numbers presented above are only for trucking on the national highway system);
- a discussion of qualifications to the study findings, especially qualifications related to data limitations and small sample sizes of key data sources; and
- tests of the sensitivity of the results to alternative assumptions regarding traffic growth rates.

The analysis in this study appears to be correctly done. The main problem with the study—or at least with the way the study is being interpreted—is that it deals with the impacts of the MOU, but it is interpreted as dealing with the impacts of the R&D program. The study itself leads readers to make this conclusion. For example, under the heading "Benefit/Cost Assessment of the TAC Research Program" the study computes the ratio of the net benefits reported above to the net present value of the research program cost ($5.7 million) to obtain a benefit/cost ratio of 328/1. The study notes that this is "an extremely handsome rate of return".[7] Indeed it is—a benefit/cost ratio like this would make this the most attractive R&D program ever carried out in the history of the western world! The problem, of course, is the problem of attribution. All of the benefits of the MOU in this calculation are attributed to the TAC research program, even though the MOU was based on other research as well, and many other political and economic elements contributed to the formulation of the MOU. Related to this is the fact that the study doesn't seriously consider a base case—i.e., in the absence of this R&D program, is it obvious that nothing at all would have been done to improve the situation?

4.3 Case Studies

Our example of the use of case studies is the evaluation of Transport Canada's Central R&D program.[8] That study was largely based on 30 case studies of transportation-related R&D projects. A case study methodology was selected rather than cost-benefit analysis because of the fact that most of the R&D in this program is oriented toward public benefits, which are difficult to quantify. As stated in the study: "...quantification of costs and benefits is difficult and based on numerous assumptions. When assessing benefits, a description of the benefits derived from the projects is often more useful than a simple quantification."[9] The study includes descriptions of benefits and costs for all 30 case studies.

---

7 Ibid., page S.6.

8 *Evaluation of Transport Canada's Central Research and Development Program*, Young and Wiltshire, March, 1992.

9 Ibid., page 31.

The most important element of the methodology for carrying out case studies is that the data for all the case studies be gathered in a consistent manner and reported consistently. The format would generally include a general description of the case, a discussion of the intended outputs and objectives, a detailed description of the activities carried out, and a description of the apparent impacts/likely impacts. Appendix E contains an example case study from the Transport Canada study.

As noted in Section 2.4, case studies are the best method for identifying and documenting the impacts of R&D oriented toward the public good. The table below summarizes some of the impacts identified through case studies in the Transport Canada study.

Examples of Public Benefits of Transport Canada R&D

Project	Public Enterprise Benefits
Microwave Landing System Antenna Development (Project #4880/4977) TDC cost: $300,000	This project is one of a series of MLS projects which have resulted in a recent decision to install MLS at 42 runways in Canada. The MLS results in a more efficient use of runways and airspace.
Shipboard Multi-Task Ice Data Analysis System (Project #6086) TDC cost: $481,900	The Star-vue system is on-board all eight Coast Guard ice breaking ships and installed in all three ice centres. There has been fuel savings for ships as they are able to navigate through ice more effectively. It has also reduced the time required for Coast Guard ships to reach their destinations in ice conditions.
End of Train Monitoring (Project #4924/6271) TDC cost: $70,000	CN could save up to $30 million/year. Due to labour agreements, the company will not be able to obtain full cost savings of $60 million. The cost impact on the railroads with the removal of the cabooses is significant when considering the caboose operating costs (estimated at 65-70 cents per mile) and the capital cost of a new caboose (estimated at $80,000: 1985 costs).

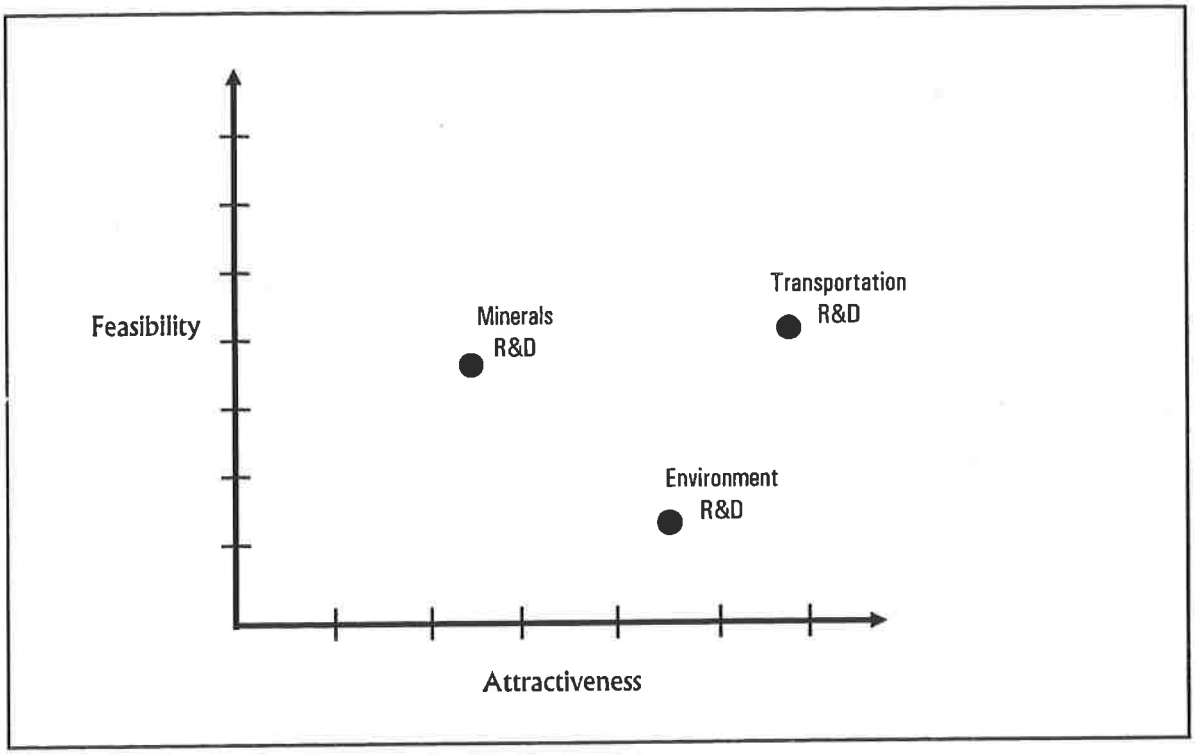
4.4 Performance Indicators

We were unable to find any particularly interesting example of the use of performance indicators in assessing transportation-related R&D. An integrated partial indicator method that is used by the Commonwealth Scientific and Industrial Research Organization (CSIRO) in Australia for assigning relative priorities to broad research fields is described below. This is the most effective performance indicator system for R&D which we have seen.

In this method each research field is ranked on two criteria, "feasibility" and "attractiveness". Feasibility is an R&D factor which is intended to incorporate consideration of the R&D potential (i.e., the technical potential of the relevant research fields) and CSIRO's R&D capacity (i.e., their capability to carry out the R&D and Australia's international research competitiveness in the field). Attractiveness is a socioeconomic factor which incorporates consideration of the potential benefits of the R&D (both commercial, such as size of market, and non-commercial, such as health and safety improvements) and also Australia's ability to capture these benefits (for example, the receptor capacity of Australian industry for

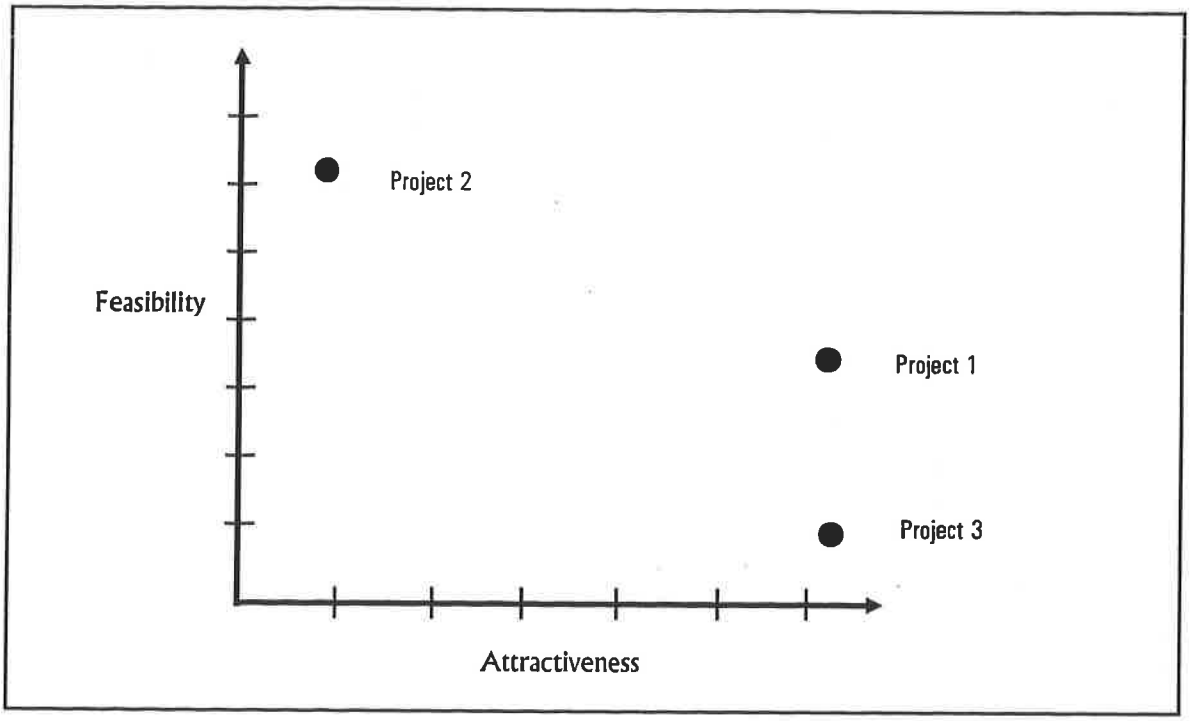
commercially oriented research, and the likely implementation of the relevant research by public sector bodies for non-commercial research).

For each research field the feasibility rating and the attractiveness rating are determined through a consensus process involving the senior managers of all of CSIRO's research establishments. The highest priority is assigned to research fields which are the furthest away from the origin in the following schematic.



This method could be useful to organizations in selecting among alternative transportation-related R&D projects. For example, an organization might be considering the following three projects:

- Project #1 — a project to develop extra-strength concrete mixtures, of medium feasibility (challenging R&D but not too risky) and high attractiveness (because of the potential cost savings);
- Project #2 — a project to develop better methods for carrying out road repairs, of high feasibility (relatively straightforward R&D) but low attractiveness (potential for only modest cost savings); and
- Project #3 — an automated traffic control system project, of low feasibility (tricky R&D) but high attractiveness (huge potential benefits because of reduced traffic times).



Project 1 would rank the highest overall, with projects 2 and 3 ranking about the same.

This system could be further refined by dividing each project's overall ranking (distance from the origin) by its estimated cost, for a cost-effectiveness type of rating.

5. Conclusions

The review of the current practices of organizations carrying out transportation-related R&D which is summarized in Section 3 indicated that most of these organizations are carrying out relatively little formal evaluation of their R&D. Most of the evaluation is conducted at the beginning of the R&D process and involves the review of potential projects by advisory committees composed of representatives of the primary intended users of the R&D and/or direct contact with the primary intended users. There is very little evaluation of the R&D during the R&D process, and there is also little evaluation of the R&D after it has been completed.

This is understandable in view of the applied nature of most of this R&D and the close connections in many of these organizations between the R&D performers and the intended users of the R&D results. Almost all of the respondents in this study indicated that they are generally satisfied with the evaluation methods they currently use.

We would like to offer a note of caution, however. R&D programs, like all programs, are coming under increasing scrutiny. Formal evaluations which document why the R&D was carried out, the results of the R&D, and, most importantly, its usefulness and impacts have become extremely valuable for defending programs. We are familiar with a number of government organizations which up until recently did relatively little formal evaluation of their R&D programs other than obtaining advisory committee input and expert opinion. These programs were good programs and were well managed, and the R&D had a high degree of impact. However, when the program managers were asked to produce evidence of the impact, they couldn't do so because of the lack of formal evaluation. Some of these organizations were able to "rescue" their programs by carrying out formal evaluations at this point; but even in these cases we have seen some close calls, and the evaluations were much more expensive than they need have been (because of the cost of having to collect historical data which had not been maintained in any sort of systematic way).

Program managers no longer have the excuse that R&D programs cannot be evaluated. Since the mid 1980s there have been numerous successful evaluations of R&D programs, and the methods used and results achieved in these evaluations have gained widespread acceptance.

The Exhibit on the following page shows which of the evaluation methods described in this report are best suited for certain situations.

An ideal evaluation model for an R&D program would be:

- select the R&D on the basis of user or client opinion supplemented by expert opinion or information from performance indicators;
- use experts to monitor the technical progress of the R&D (cost and achievement of technical objectives); and

Applicability of Evaluation Methods to Transportation R&D

Method	*At the beginning – when deciding what R&D to conduct*	*During the R&D process*	*At the end – after the R&D has been completed*
Expert opinion	A good supplement to user/client opinion (to provide them with information) and performance indicators (to value the indicators). Not particularly useful on its own.	Good way to monitor the technical progress of the R&D.	Good way of obtaining high quality information regarding the quality and potential usefulness and impacts of the R&D, with relatively little effort.
User/client opinion	The best method for deciding what R&D to conduct, especially when supplemented by expert opinion or information from performance indicators.	Limited usefulness.	A fairly easy way of finding out if the R&D has been/is likely to be useful; but the results are more useful for program management purposes than reporting purposes.
Cost-benefit methods	Can be a useful way of priorizing potential projects. Also, forces decision makers to think about the critical success factors. However, fairly time consuming.	Can be useful for monitoring if a C-B analysis has been done at the beginning.	The best way of documenting the impacts of R&D whose benefits can be identified and quantified. Assumptions need to be clearly documented and, in general, the most challenging method to use correctly.
Case studies	Not useful.	Not useful.	The best way of documenting the impacts of R&D whose benefits can be identified but not quantified. Not particularly challenging.
Performance indicators	A good supplement to user/client opinion.	Can be useful in structuring the monitoring process.	Limited usefulness.

- conduct a formal post-project evaluation for each project to document the R&D results, the use of the results, and the resulting impacts. If resources are available, cost-benefit methods (for R&D which has quantifiable benefits) and case studies (for R&D whose benefits cannot be quantified) should be used. If not, user/client surveys should be used.

The methods described in this report are not perfect. For example, there are no particularly good methods for evaluating R&D which is intended for use by government bodies; it is difficult to quantitatively value health and safety benefits; there are numerous challenges associated with the use of cost-benefit analysis; and so on. However, these methods do provide a lot of useful information — both for management purposes and for reporting purposes. Also, it should be kept in mind that, as noted at the beginning of Section 2, any attempt to carry out formal evaluation is much better than no attempt.

A number of the people interviewed for this study indicated that they would find additional information on R&D evaluation methods useful — both for their own purposes and as a means of ensuring greater consistency in evaluation practice. If, following the publication of this report, there is a high degree of interest in this among TAC members, TAC may wish to consider taking the lead in preparing some sort of "how-to" manual.

Appendix A

List of People Interviewed

Appendix A
List of People Interviewed

Interviews Completed

- Rob Draper—US Federal Highway Administration
- Robert Skinner—US Transportation Research Board
- Ralph Haas—Waterloo University
- George Gera—Ontario Ministry of Transportation
- Helen Tetteh-Wayoe—Alberta Transportation
- Pierre Toupin—Ministère des Transports du Québec
- A. Viel—Société de l'assurance automobile du Québec
- Yves Provencher—Forest Engineering Research Institute of Canada (Eastern Division)
- Eric Amlin— Forest Engineering Research Institute of Canada (Western Division)
- John Pearson—Canadian Trucking Research Institute
- Judy MacDonald—3M Canada Inc.
- Les Morgan—Shell Canada Limited
- T.W. Mulligan—Municipality of Metropolitan Toronto
- Arnie Andreeson—City of Calgary
- A. Gus Pokotylo—Research and Development Directorate, Transport Canada
- Harvey Layden — Road Safety and Motor Vehicle Regulation Directorate, Transport Canada
- Pierre Berthiaume—CN Rail
- John Shaw—BC Ministry of Transportation and Highways

Declined to be Interviewed

- Francis Francois—American Association of State Highway and Transportation Officials
- John Coleman—National Research Council
- Jean Levere—Bombardier Inc.

Appendix B

Structure of User Surveys

Appendix B
Structure of User Surveys

The main elements of the survey plan for a user survey are described below.

Identification of project groups. The first step is to subdivide the program into groups of like projects. The most important consideration in organizing these groups is that, for every group, the primary intended users of the research results from each project in that group should be the same—e.g., automobile manufacturers, organizations involved in formulating regulations.

Identification of users and experts. The next step is to identify representatives of the primary intended user organizations who can comment knowledgeably on how useful the R&D has been or is likely to be for their organization. There may be some project groups for which the primary intended users are not sufficiently familiar with the research to be able to answer the questions. For these groups, experts in the research areas can be used, and they can be asked to comment on the usefulness of the R&D for the "intended user organizations".

The number of reviewers selected for each project group depends on the breadth of the research included in the group. All reviewers should be able to comment on the total group of projects, but, in addition, for each project there should ideally be at least one reviewer who is very knowledgeable about the state of research in that area and its potential applications.

Questionnaire. In general in user surveys, respondents are asked two sets of questions—questions about the specific group of projects they are reviewing and questions about the program as a whole. The main items addressed in relation to the specific group of projects are:

- Ratings of the extent to which the results of the projects have been useful to the user organizations to date for various purposes;
- Which projects have been highly useful;
- Ratings of the extent to which the results of the projects are likely to be useful to the user organizations in the future for various purposes;
- Which project are likely to be highly useful in the future;
- Reasons for projects not being useful;
- Extent to which the projects address important needs of the user organizations;
- Benefits to the user organization if more work in this area were carried out/harm if less work were carried out;

The main items addressed in relation to the program as a whole are:

- Importance of the work in each program area to user organizations;
- Contribution of the work in each area to the objectives of the program;
- Items regarding the structure and operation of the program (appropriateness of the relative amount of work carried out in each area, adequacy of the degree of user (client) input, extent to which the research results have been effectively disseminated to users, and so on).

Appendix C

Principles of Cost-Benefit Analysis

Appendix C
Principles of Cost-Benefit Analysis

C.1 General Principles

Cost-benefit analysis is concerned with the net effect of a given investment of productive resources (i.e., natural resources, labour, capital) on the overall welfare of society. Conceptually it is not significantly different from the types of analysis employed by private firms in the evaluation of their investment projects. The economist conducting a cost-benefit appraisal is, in essence, asking the same sorts of questions asked by an analyst in a private firm. The basic difference is one of perspective, with the cost-benefit analyst asking the same questions but of a much larger collection of individuals—society as a whole. Thus, in the place of private revenue, the economist is concerned with social benefits. For the costs accruing to a private firm, the economist substitutes the concept of opportunity costs—the social value foregone when resources are shifted from one use and redeployed in an alternative use. For the profit of the private firm, the economist substitutes the concept of excess social benefits over social costs, or net societal benefits.

Some of the important general principles that need to be kept in mind when conducting any cost-benefit analysis are briefly listed below.

1) Cost-benefit analysis is carried out on the basis that the economic costs and benefits of relevance are those that accrue to a particular **referent group**, which defines the bounds for the analysis. The referent group may involve a particular region, the total country, or some other group of individuals. The starting point for the analysis is to specify the referent group. After that, all costs and benefits are calculated as costs and benefits which accrue to this particular group.

2) Costs are treated as the costs of a project to society—the economic benefits that are foregone when resources are shifted from alternative uses and invested in the project in question. This definition of the cost of an economic resource is referred to as the **opportunity cost**. It represents the true value of productive resources to society, and it may differ from the costs that would actually be incurred by the private or public organization responsible for the project being analyzed. Under certain conditions the market prices of labour, capital, materials, and so on reflect the opportunity costs of these factors to society. However, this is only true in certain cases and always needs to be checked.

3) The same considerations apply to economic benefits—i.e., their market prices may reflect the net increase in society's welfare as a result of the project or they may not (in which case, as with costs, some way of better measuring the true value of the benefits needs to be found). A common situation is that no markets exist for the benefits being generated—such as benefits associated with improvements in air quality or quality of life. In these cases, the benefits are valued according to what society would be willing to pay for them (or simply described qualitatively).

Implementation costs also include costs to the end user to implement the product/service such as:

- costs of purchasing the product;
- costs of installing the product; and
- costs of operating the product.

Not every one of these costs is applicable to each R&D project, but they need to be checked.

As noted in Section B.1, estimated costs and benefits have to be discounted to their present values before they can be compared. The appropriate discount rate to use in a cost-benefit analysis of an R&D project is the social discount rate. The social discount rate differs from the interest rate a private investor may use in that it reflects the present generation's weighting of benefits and costs to be borne by future generations. There is considerable debate over the "correct" value for the social discount rate. We suggest using the social discount rate suggested by the federal Treasury Board.[10]

Additional considerations that frequently arise in conducting cost-benefit analyses of transportation R&D are:

- the value of time, and
- the value of health and environmental benefits.

Among the benefits occurring as a result of transportation R&D, the value of time saved for travellers is often one of the most important. There is currently no consensus regarding the best way to quantify the value of time saved. The most common method is to use a percentage of the wages of the people whose time is saved.

The valuation of health effects, especially the valuation of human life, is even more controversial. The most common approach is to use the projected economic contributions of individuals — for example, the value of a life saved would be equated to the individual's projected lifetime earnings — but this method is far from being fully accepted.

The quantification of environmental benefits can sometimes be based on comparisons between similar items that are and are not affected. For example, the benefit of reduced freeway noise might be estimated by comparing the values of comparable houses that are near to freeways with those that are far from freeways. Estimates of the willingness of people to pay for environmental benefits are also often used.

In all the above cases our recommendation is that, when the quantification of benefits is highly uncertain, it is best to not attempt to quantify them and simply describe them qualitatively.

Finally, one should analyze the sensitivity of the results to critical assumptions affecting costs, benefits, and the discount rate. Sensitivity analysis should provide a reliable assessment of the risk and uncertainty inherent in the anticipated research results.

---

[10] To obtain Treasury Board's recommendation regarding the most appropriate social discount rate(s) contact the Financial Management Policy Branch, (613) 957-9692.

In addition to all the "usual" difficulties associated with cost-benefit analysis, it needs to be recognized that the problems of forecasting and capturing benefits and identifying linkages between research results and ultimate benefits are particularly severe for R&D. However, there have now been a number of successful cost-benefit analyses of R&D projects and programs carried out since the mid-1980's, and, properly applied, this can be a very useful technique.

Appendix D

Sample Output from a User Survey

EXHIBIT 4.3: RATINGS OF THE EXTENT OF USEFULNESS TO DATE OF THE R&D

Type of Use		Information and Reference	Input to own R&D Programs	Basis for Investment	Basis for modifying Operational Procedures	Basis for Decisions Regarding Government Regulations
Project Group						
(1)	Coprocessing/Liquefaction	H	M	L	L	L
(2)	Sewage Sludge	M	L	M	N	L
(3)	Primary Upgrading	H	M	L	L	(H)
(4)	Materials	H	H	M	M	(M)
(5)	Secondary Upgrading	H	M	L	L	(M)
(6)	Natural Gas Conversion	H	M	L	N	M
(7)	Bitumen/HO Recovery	H	M	M	L	(L)
(8)	5.5 Emissions	H	M	(L)	L	M
(9)	5.5 Performance	H	H	M	M	M
(10)	Hydrogen	M	M	M	M	(L)
(11)	Electrochemistry	H	M	M	L	M
(12)	HWC Projects	H	M	(N)	L	M
(13)	EC Projects	M	L	(N)	L	M

Key: H = High, M = Medium, L = Low, N = None

Note: Parentheses indicate that ratings may not be meaningful.

- For the question dealing with the use of the results as a basis for investment decisions by the user organizations, the ratings of the extent of usefulness of the results in project groups 8, 12, and 13 should be regarded as very suspect, since the majority of the reviewers for these project groups were responding on behalf of organizations that would not generally be involved in making investment decisions (e.g., government departments). In addition, this question does not apply very well to groups 8, 12, and 13.

- For the question dealing with the use of the results as a basis for recommendations or decisions regarding government regulations or

Group 5: Secondary Upgrading of Synthetic Crudes

A number of reviewers commented that this research provides a good overview of the processing of Canadian synthetic crude distillates, as well as the awareness of catalysts and properties of catalysts for processing them and analytical techniques for analyzing some of the components (e.g., nitrogen aromatics). Some of the specific uses and benefits of this research are described below.

Nova Husky Research found the research entitled "The impact of nitrogen compounds on the processing of synthetic gas oil" particularly useful. Their synthetic distillates' nitrogen content had to be lowered to meet fuel specifications. The research informed them of the impacts of high nitrogen content on their catalyst's life. The Fluid Catalytic Cracking (FCC) unit would coke up if the nitrogen content were not lowered. This information has been beneficial in maintaining equipment and producing marketable synthetic fuels.

The knowledge gained from project work entitled "Catalyst activity and deactivation in the hydrodenitrogenation of gas oil derived from hydrocracked Lloydminster/Cold Lake residue" and "Improving diesel fuel quality of Cold Lake/Lloydminster synthetic crude" is crucial to the development of the Biprovincial Upgrader in which the provinces of Alberta and Saskatchewan, the federal government and Husky Oil are participants. Once the upgrader is in place, application of the results of these projects will be made to the commercial unit. This will involve selecting a catalyst that will actively hydrodenitrogenate the gas oil fraction of the synthetic crude distillate and using the proper catalyst to meet the required government specifications on diesel fuel.

The research project "Compositional analysis of hydrotreated middle distillates from synthetic crudes by mass spectrometry" was used by Petro-Canada to plan future processing of synthetic crudes, particularly middle distillates, to meet specification

APPENDIX E

SAMPLE CASE STUDY

1. CASE OVERVIEW

Case:	Air Cushion Icebreaking Bow Evaluation Program
Project #(s):	4794, 6110
Project Officer:	J. Laframboise
Contractor:	German and Milne Inc., Montreal, Quebec, contact: Phil Markham 232-9391
Client:	Transport Canada, Contact: Terry Maluish, Head of Aviation of Marine
Beneficiary:	Canadian Coast Guard, Contact: Ron Wade 998-0660
Start/Finish:	August 1982 - August 1983 (4794) December 1983 - June 1984 (6110)
Publication:	1983 publication
Sector:	Exploratory
Mode:	Marine
Cost:	(4794) TDC $450,000 (6110) T.C. Energy Program $114,000

Case Description:

Since the early 80s, Transport Canada has been actively developing air cushion icebreaking technology in order to explore the technical, economic and commercial implications of this innovative icebreaking phenomenon. The Air Cushion Icebreaking Bow (ACIB) features a flexible notch structure designed to fit closely to the bow of several Coast Guard ships.

The purpose of the bow is to add to the ice breaking capacity of a ship. With the bow, a ship can break ice ten times as fast. This is a good design for the St. Lawrence seaway because ice does not get any thicker than 32". The bow would also allow smaller ships the ability to break ice that they otherwise would not be able to under their own capacity.

2. CASE PROFILE

2.1 Deliverable

- TP 4446E Air cushion icebreaking bow (ACIB) trials report: 1982/83, German and Milne Inc., 1983
- TP 5497E Air cushion icebreaking bow (ACIB) operation report, 1983/84, German and Milne Inc., 1984

2.2 Objective

The objectives of the 1982/83 trials were:

- To explore and define, in quantitative terms, the performance parameters of the ACIB.
- To gain operational experience with the ACIB to the greatest extent practical during the 1982/83 winter season.

The objectives of the 1983/84 operations were:

- To obtain data on hardware, performance and operations of the ACIB during the 1983/84 ice management period in Thunder Bay for an adequate assessment of its effectiveness under the following conditions:
  - At beginning of the winter season;
  - Under severe winter conditions (cold, wind, snow, etc.);
  - Icebreaking up to 1 meter of ice thickness (design max.).
- To characterize the performance of the ACIB when it is pushed by a small ship (Thunder Cape).
- To monitor and document the operational performance and the maintainability of the ACIB.
- To perform all necessary maintenance and minor repairs required for proper functioning.
- To collaborate with and advise the CCG in operating the ACIB craft and/or resolve problems.

2.3 Intended Benefits

- Reduce operational costs for Coast Guards.
- Reduce capital costs for Coast Guards.

3. SEQUENCE OF EVENTS

3.1 Chronology of Projects

- In 1979, the Canadian Coast Guard sponsored the construction of a specially designed air cushion icebreaking bow (ACIB), built by Hoverlift Systems Limited of Calgary. The notch design, was not without problem and TDC was asked to take over operations of the ACIB for the 1981/82 and 1982/83 seasons.
- It was moved from Calgary to Thunder Bay in the Fall of 1981, and erected at the Port Arthur Shipbuilding Company, following which limited tests were carried out late in the 1981/82 winter season. These tests achieved a performance similar to that of the earlier icebreaking platform, ACT-100, and also revealed a number of deficiencies.
- Late in 1982 a contract was placed for repairs, modifications and further testing with the tug THUNDER CAPE and the CCGS ALEXANDER HENRY. A mild season permitted the modification and maintenance to be done, but restricted the scope of the trials. Nevertheless, a lot of information was obtained and experience gained.

- Late in 1983 a further contract was placed for repairs, modifications and engineering support for the ACIB during ice management operations by the CCG. For this task the host ship was to be the CCGS ALEXANDER HENRY, but it was intended also to conduct trials with the tug THUNDER CAPE to explore the limits of its capability.

- Due to the lateness of the contract, the ACIB was not ready for operations until 22 February 1984, but after that successful ice management tasks were conducted until 4 April, when the Master of the ALEXANDER HENRY was satisfied that the ACIB was no longer required.

- Problems were experienced with damage to skirt and, particularly, to notch segments. This was the result of a number of circumstances: deterioration of the material, poor quality control, design deficiencies, and inability to adjust cushion pressure and speed to ice conditions. Also the ACIB was operated in some situations where the ALEXANDER HENRY alone would have been equally effective; in very thin ice and in broken ice. Much was learned and lessons will be applied.

3.2 Series of deliverables, outputs

- Modifications made to the bow to make it more streamline.

- Put into operations by the Coast Guard attached to Alexander Henry in Thunder Bay.

- Results:

  - ships can break ice ten times as fast with the bow
  - little damage to the hull
  - save in fuel consumption (5%)
  - allows smaller ships the ability to break ice that they otherwise would not be able to do under their own capacity.