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Development of a Project Evaluation Methodology Framework for Canadian Intelligent Transportation Systems

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16. Abstract

The evaluation methodology presented in this report provides a framework to ensure consistency and validity of results across regions and across types of ITS investments, and will help Canadian local and provincial agencies select and manage ITS programs. The focus is on describing the project and benefits, and on developing guidance on how to interpret the results.

The framework is based on four evaluation steps: evaluation planning, data collection, data analysis, and recommendations and reporting. The main body of the report presents the details of each step, including a discussion of the challenges that are typically encountered. Two Transport Canada projects serve as sample cases to test the framework. In both cases, the four evaluation steps are followed and results, limitations, and assumptions are discussed.

Next steps include:

- using the framework to complete some evaluations
- collecting feedback regarding the evaluation framework and how it performs in practice
- summarizing the results from the evaluations to help provide access to others
- integrating the Canadian evaluation material into one of the existing databases in the UK or the U.S.
- generating a "lessons learned" report to provide guidance regarding which projects perform well and to identify the implications for future programs
- mandating that individual evaluations and the "lessons learned" report both address the synergistic impacts of interactions among groups of ITS investments and between ITS and the underlying transportation infrastructure

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16. Résumé

La méthode d'évaluation présentée dans ce rapport offre un cadre de travail qui favorise la cohérence et la validité des résultats, quel que soit l'emplacement et le type d'investissement STI, et aidera les municipalités et les provinces canadiennes à choisir et administrer les programmes STI. La méthode met l'accent sur la description du projet et de ses avantages, et sur l'élaboration de critères pour l'interprétation des résultats.

L'évaluation se compose de quatre étapes : planification de l'évaluation, collecte de données, analyse des données, et recommandations et rapport. Le corps du présent rapport décrit chaque étape en détail, y compris les obstacles habituellement rencontrés. Deux projets STI réalisés sous l'égide de Transports Canada servent de cas types pour la mise à l'essai du cadre d'évaluation. Dans les deux cas, les quatre étapes de l'évaluation sont présentées, et les résultats, les limites et les hypothèses sont discutés.

Les prochaines étapes comprendront ce qui suit :

- utiliser le cadre pour réaliser certaines évaluations
- recueillir des commentaires sur le cadre d'évaluation et son utilité pratique
- résumer les résultats des évaluations pour les rendre disponibles à d'autres
- intégrer les données d'évaluation canadiennes à l'une ou l'autre des bases de données existantes au R.-U. ou aux É.-U.
- produire un rapport de type « leçons apprises » pour indiquer quels projets fonctionnent bien, et pour cerner les conséquences à prévoir pour les programmes STI futurs
- faire en sorte que les évaluations individuelles et le rapport sur les « leçons apprises » examinent les impacts synergétiques résultant des interactions entre plusieurs investissements STI, et entre les STI et l'infrastructure de transport sous-jacente

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Preface

ITS projects offer a cost-effective solution for many transportation problems. Individual projects are often not evaluated, and when they are, such evaluations can be restricted by limited data, by the ability of ITS to affect only a portion of the transport network, and by evaluation methodologies that were developed with more traditional transport investments in mind.

Evaluations that have been done often show a strong positive rate of return. Transport Canada sponsored this project to develop a methodology framework that can support evaluations for individual ITS projects. The primary goal is to better assess the benefits of ITS investments in Canada. In addition, the framework can help select projects that will improve the efficiency, safety, and sustainability of the Canadian transportation system. This framework builds on existing work in Canada, the U.S., and Europe.

Transport Canada's current funding program for ITS projects – the Strategic Highway Infrastructure Program (SHIP) – began in March 2000 and is drawing to a close. Since then, more than 100 ITS projects were funded under various funding arrangements representing a total investment of over $50 million. As considerations are made for renewed funding, there is an increasing need to measure the benefits derived from these projects and their success in meeting stated objectives. The methodology resulting from this project will serve as an ITS evaluation framework for past and future Canadian ITS projects.

Executive Summary

Overview

The evaluation methodology presented in this report provides a framework to ensure consistency and validity of results across regions and across types of ITS investments, and will help Canadian local and provincial agencies select and manage ITS programs.

The framework presented here is based on four evaluation steps. The main body of this report presents the details of each step, including a discussion of the challenges that are typically encountered.

Intended Audience

This framework is written from the perspective of creating an evaluation to be used by decision makers. Consequently, the focus is on describing the project and benefits, and on developing guidance on how to interpret the results.

Primary Challenges and Framework Limitations

Data availability: Gathering appropriate information about the benefits of an ITS project is undoubtedly the greatest challenge of evaluation. While it is impossible to collect enough information to quantify all the benefits of a project, a well planned and focused data collection effort will greatly increase the chances of capturing those benefits that represent the bulk of the project's overall impact.

Defining the base case: Determining the benefits of a project requires the comparison of a before and after situation. For projects that have already been implemented, gathering appropriate data for the "before" or "base" case may be extremely difficult. This also can be a problem for ITS projects that are integrated within much larger investments.

Evaluation process: The previous challenges underscore the importance of considering evaluation through all stages of a project, including (and especially) the early planning phase. This will ensure that the most appropriate measures can be identified and that data collection technology is built into the project wherever possible. This also supports consistent results.

This evaluation framework was designed with the budgetary and temporal constraints of a typical ITS project in mind. ITS projects generally have modest budgets relative to traditional transportation projects, leaving an even smaller pool of money for evaluations. As such, this framework focuses on producing effective and meaningful evaluation results with the most reasonable amount of work required.

In addition, in the interest of simplicity and practicality, this framework is intended only for the evaluation of individual ITS projects. ITS projects, however, are often designed to work in combination with each other, often with the entire system having a greater impact than each of the individual parts would have in isolation. Although a methodology to assess the interactions among projects is beyond the scope of this report, it is, however, possible to measure the additional impacts as each subsequent project is completed.

Evaluation Framework

Step 1: Evaluation Planning

In this step the evaluator should determine the critical impacts that need to be measured for an ITS project, i.e., what the project is intending to fix or improve and how, in practice, we can observe to what degree these goals are met. Each ITS project will have specific goals or categories of benefits that should be identified. This framework is built around six of them:

1. Safety
2. Mobility
3. Efficiency and Productivity
4. Energy and the Environment
5. Security
6. Customer Satisfaction

Following the identification of goal areas, specific measures of effectiveness should be selected based on relevance or value for the specific project, ability to collect primary measures, and relevance of secondary data from other evaluations. The ability to capture 100 percent of benefits is time consuming, expensive, and probably impossible. Thus, an important early step is to identify a limited number of measures that are most likely to capture the bulk of the benefits.

Step 2: Data Collection

Data for evaluation should be collected by the simplest and most cost-effective means. Primary methods of data collection include: Field Observation, Automated Data Collection Devices, Simulations, and Surveys. Data collection should begin as soon as possible, preferably before the actual implementation of the project. Evaluation is often only considered during or after an ITS implementation. At this point, an accurate evaluation becomes difficult because of missing or unreliable information about the "before" condition. The timeframe of the analysis is also important when collecting data after the deployment of the project as ITS installations typically require some time to pass for the system to stabilize and the appropriate level of benefit to be observable.

When data regarding specific costs or benefits are not available, it may be necessary to use information from similar projects in similar regions. While the framework suggests existing comprehensive databases of ITS benefits, it also emphasizes the importance of keeping in mind the scope of the project in the database relative to the project being evaluated and the need to interpret the data accordingly.

Step 3: Data Analysis

Traditional economic analysis tools exist to convert the benefit and cost data generated in the previous steps into summary measures. When evaluating the benefits of public sector investments, a benefit-cost framework provides a number of summary measures. Benefit-cost analysis is the process of weighing the total expected costs over time versus the total expected benefits over time. The framework provides a summary of the most common indicators used in project evaluation. It also suggests some unit values of resources (such as travel time, values to be assigned to crashes) to be used for the monetary quantification of benefits.

Step 4: Recommendations and Reporting

Evaluation serves multiple purposes. One, of course, is to review past projects to see how well funds have been spent. More importantly, however, is to use evaluation as a guide to designing and selecting more effective projects in the future. This requires examining which types of benefits are important, as well as the interactions between ITS and non-ITS projects, which can help stimulate higher levels of return. This systems view is not common within ITS (nor other parts of transportation) but would seem to offer significant value now that ITS has moved beyond the early stages of deployment.

While ITS evaluations have an immediate value by informing practitioners and decision makers about a particular project, they also add value by helping in the design and selection of ITS projects in the future. The final report also serves to preserve the methods, results, and insights gained through the evaluation of projects. To ensure consistency of reports and facilitate comparisons of evaluations across projects, a recommended report outline has been developed and is included in the framework.

Application of Framework to Sample Projects

Two projects financed by Transport Canada under the Strategic Highway Infrastructure Program have been selected to serve as sample cases to test the proposed evaluation framework. The first is an ITS project in the Commercial Vehicle Operations (CVO) area in the Province of New Brunswick. The second project is a Bus Rapid Transit investment incorporating ITS technologies such as Automatic Vehicle Location (AVL), Transit Signal Priority (TSP), and Real-Time Passenger Information in British Columbia. In both cases, the four evaluation steps are followed and results, limitations, and assumptions are discussed.

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1. Overview of Proposed ITS Evaluation Framework

The benefits of ITS projects are not as well understood as benefits from more traditional transportation projects. While ITS professionals are well aware of the significant impacts that ITS can have on a transportation network, others, including some decision makers and the general public, may find it more difficult to understand why, how, or when ITS investments can provide significant benefits.

ITS evaluation has received more attention in recent years as the number of projects has increased and as the total dollar volume of spending has grown. While transportation agencies often have standard analytic practices in place to evaluate major investments, these documents usually do not address the specific nuances of how best to evaluate ITS investments. These demands underscore Transport Canada's need for an ITS evaluation framework that will ensure consistency and validity of results across regions and across types of ITS, and that will help local and provincial agencies to select and manage ITS programs.

ITS evaluation frameworks have been in place in the United States and several European countries for more than a decade; however, a relatively small number of Canadian ITS projects have actually been evaluated. Even in other countries, only one or two efforts have been made to evaluate ITS programs or groups of projects. The specific detail of each evaluation framework varies, but the basic processes used are similar. That is, the analytic tools are common as are the underlying problems. The framework presented here is based on the evaluation steps shown below. The next section presents the details of each step, including appropriate modifications for ITS projects and the challenges that are typically encountered.

Step 1	**Evaluation Planning**
1a)	*Determine project classification and objectives*
1b)	*Select ITS impact measures*
Step 2	**Data Collection**
2a)	*Methods*
2b)	*Timeline*
2c)	*Dealing with unavailable data*
Step 3	**Data Analysis**
Step 4	**Recommendations and Final Report**
4a)	*Develop recommendations*
4b)	*Create final report*

1.1 Intended Audience of the Evaluation

The intended audience of the evaluation report should be considered through the entire evaluation process and especially during the creation of the final report. While the basic steps will not change whether the audience is decision makers or ITS professionals, local or national, different levels of technical detail will be required and different types of summary information will be needed for each group. This framework is written from the perspective of creating an evaluation to be used by decision makers. Consequently, the focus is on describing the project and benefits and on developing guidance on how to interpret the results.

1.2 Primary Challenges of ITS Evaluation

While a standard economic evaluation process is at the heart of evaluating ITS projects, the nature of these kinds of projects presents several challenges.

Limited Data Availability. Gathering appropriate information about the benefits of an ITS project is undoubtedly the greatest challenge of evaluation. The small size of ITS projects relative to transportation investment in general creates several problems:

- The absolute level of ITS benefits is usually quite small relative to the general level of transport benefits (of course, costs are also relatively small).
- The benefits that can be attributed directly to ITS are difficult to separate from transportation benefits in general.
- The limited level of funds for ITS projects often cannot accommodate significant data collection efforts.

While it is impossible to collect enough information to quantify all the benefits of a project, a well planned and focused data collection effort will greatly increase the chances of capturing those benefits that represent the bulk of the project's overall impact. As discussed in the data collection step of the framework, unavailable data can be estimated from simulations or by adjusting estimates of benefits observed in comparable ITS projects that have received more complete evaluations. These methods can be risky, however, because evaluators must ensure that the data are truly applicable to the project being evaluated.

Difficulties in determining the base case. Determining the benefits of a project requires the comparison of a before and after situation. For projects that have already been implemented, gathering appropriate data for the "before" or "base" case may be extremely difficult. This also can be a problem for ITS projects that are integrated within much larger investments.

Evaluation process often not started early enough. The previous challenges underscore the importance of considering evaluation as early as possible in the ITS deployment process. Often evaluation takes a low priority in the overall picture or is finally desired only after implementation has begun, or even after a system has been activated. In either case, the best opportunities for data collection may have already passed. Evaluation should be considered through all stages of a project, including (and especially) the early planning phase. This will ensure that the most appropriate measures can be identified and that data collection technology is built into the project wherever possible. This also supports consistent results.

1.3 Limitations of this Framework

This evaluation framework was designed with the budgetary and temporal constraints of a typical ITS project in mind. ITS projects typically have modest budgets relative to traditional transportation projects, leaving an even smaller pool of money for evaluations. As such, this framework focuses on producing effective and meaningful evaluation results with the most reasonable amount of work required. This requires tradeoffs, since a full and complete evaluation would require money and time beyond that of the average ITS project. These tradeoffs need not devalue the outcome, provided they are acknowledged and the user is aware of how the results were derived. This framework also provides the foundation for a more comprehensive evaluation, if desired.

Framework Is Intended to Evaluate Individual Projects

In the interest of simplicity and practicality, this framework is intended only for the evaluation of individual ITS projects. ITS projects, however, are often designed to work in combination with each other, often with the entire system having a greater impact than each of the individual parts would have in isolation. These types of network or system impacts have been found in traditional transportation investments. The ability to identify these network or system effects is complicated and usually requires a regional or national perspective. (For example, see the report on ITS program costs and benefits prepared by Apogee Research for the U.S. FHWA and ITS America[1]).

Figures 1 and 2 provide a hypothetical snapshot of how synergy effects can be created as a network of ITS projects is completed. The actual proportions of the “isolated” versus “synergistic” impacts will vary by type of project and according to the nature of the ITS network, but the underlying principle will still apply. In this example, each project has the same isolated impact of 1,000 “units” – that is, each project would provide the exact same benefit if it were built in isolation. However, as each additional project is built into the network, increasing synergy effects will be realized. Upon completion of the ITS program for a certain area (or at least a number of ITS components that have been linked together), the total impacts will be larger than sum of the impacts in isolation – in fact, synergy effects may be a significant proportion of the total impact. For example, the implementation of a series of signal timing projects in Phoenix, Arizona, showed a

[1] Apogee Research Inc., *Intelligent Transportation Systems National Investment and Market Analysis*, ITS America and U.S. Department of Transportation, Washington, DC, 1997.

significant increase in overall benefits once projects for individual communities were completed and their data coordinated.

Although a methodology to assess the interactions among projects is beyond the scope of this framework, it is possible to measure the additional impacts as each subsequent project is completed. Ultimately, a well-planned evaluation program could encompass the entire ITS program of a given region.

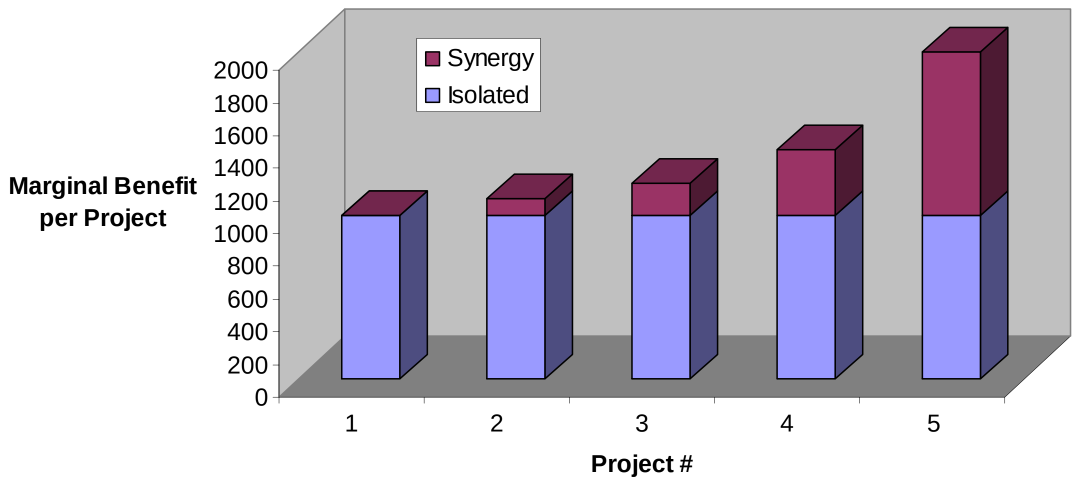

Figure 1 – Hypothetical Marginal Synergy Effects of Additional ITS Projects

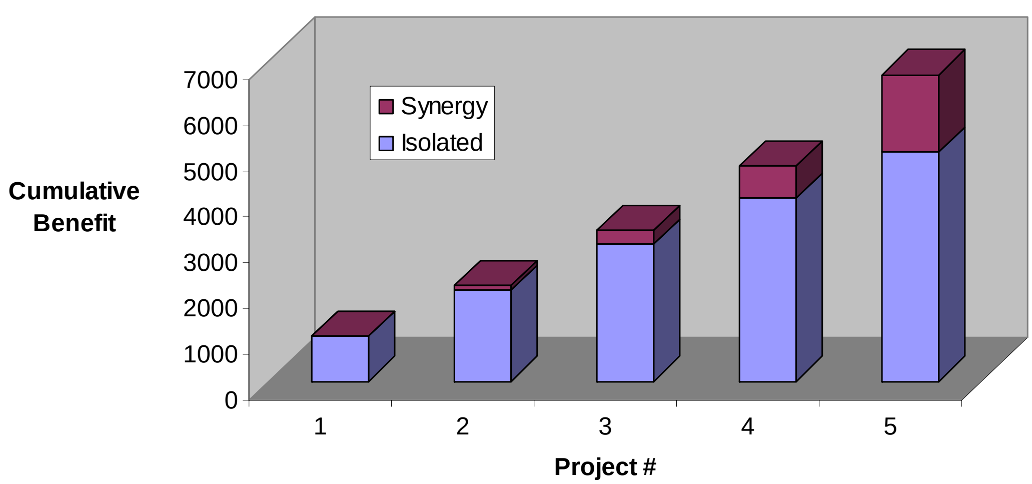

Figure 2 – Hypothetical Cumulative Synergy Effects of Additional ITS Projects

2. Proposed ITS Evaluation Framework for ITS Canada

2.1 Step 1: Evaluation Planning

1(a) Determine Project Classification and Objectives

Perhaps the most important, yet subjective, part of the evaluation process is determining the critical impacts that need to be measured for an ITS project. The evaluator needs to paint the picture of what the project is intending to fix or improve, and the way in which, in practice, we can observe how well these goals are met. The results of this step should be logical and intuitive; for instance, measures that relate to safety should be used for safety-oriented projects. Of course, secondary benefits may exist and should be addressed in the analysis and final report.

In this step, the evaluator should classify the project into one (or possibly more) of the ITS categories given in Table 1. From there, the user should refer to Appendix C for assistance in determining the most appropriate measures for this project. While the lookup table in Appendix C contains the most common measures associated with different types of projects, those presented may not be appropriate for each potential project being evaluated. Nevertheless, a decision must be made as to the most effective and practical measures to use. Ideally, a meeting should be held prior to concluding this step to help develop consensus about the chosen measure(s). Completing this step to the satisfaction of all interested parties will have a positive impact on the overall success of the evaluation.

Table 1 – ITS Project Classifications

Arterial Management	Freeway Management	Transit Management
Incident Management	Emergency Management	Electronic Payment Systems
Traveler Information	Information Management	Crash Prevention & Safety
Roadway Operations & Maintenance	Road Weather Management	Commercial Vehicle Operations
	Intermodal Freight	

1(b) Select ITS Impact Measures

Each ITS project will have specific goals or categories of benefits. These will differ by type of project. As described below, an important step in any evaluation is to identify the most significant benefits. Evaluation efforts can then focus on these benefits. This framework is built around six primary benefit categories:

1. Safety
2. Mobility
3. Efficiency and Productivity
4. Energy and the Environment

5. Security
6. Customer Satisfaction

An important step is to select specific measures for each category. These measures need to consider relevance or value for the specific project, ability to collect primary measures, and relevance of secondary data from other evaluations. Table 2 shows suggested performance measures for each of the six broad categories. Appendix A contains a more detailed compilation of possible measures from U.S., Finnish and Swedish government sources.

Table 2 – ITS Goals Areas and Common Benefit Measures[2]

Goal Area	Measure
Safety	• Reduction in the overall rate of crashes • Reduction in the rate of crashes resulting in fatalities • Reduction in the rate of crashes resulting in injuries • Reduction in secondary crashes
Mobility	• Reduction in travel time delay • Reduction in travel time variability
Efficiency and Productivity	• Increase in freeway and arterial throughput • Cost savings for users • Cost savings for agency
Energy and the Environment	• Decrease in vehicle emissions • Decrease in vehicle energy consumption
Security	• Reduction in acts of crime against passengers and property
Customer Satisfaction	• Increase in customer satisfaction • Link with mobility measures

1. **Safety**

   The most common performance measures regarding safety are those that deal with a reduction in crashes. Many evaluations also look more specifically for reductions in fatal or injury crashes. Crash statistics are also obtainable in many

[2] Security has been added to the five goal areas suggested by the U.S. Federal Highway Administration: http://www.its.dot.gov/evaluation/defs.htm.

areas since they are collected by public agencies, although the ability to link crashes (or the lack of them) to specific ITS projects is not a simple task.

2. **Mobility**

   Mobility and congestion are frequently used to describe the same condition in opposite ways. Mobility refers to the ability to reach a destination, whereas congestion describes the inability to do so. While travel time reduction is perhaps the most common measure of improved mobility (or reduced congestion), a reduction in travel time variability is also a direct measure of mobility improvement. While not easy to measure, this has a direct link with the economic and social value of transportation in today's economy. In the case of public transportation systems, waiting times or service frequency may be appropriate measures.

3. **Efficiency and Productivity**

   Efficiency and productivity measures reflect two different ideas, but both are based on how well available resources are used. Efficiency measures look at changes in throughput or how well existing capacity is utilized. For instance, a ramp-metering project can smooth traffic flows, resulting in approximately the same (or greater) traffic flows but at a higher level of service. Productivity is most often associated with public and/or private cost savings that, in turn, can create benefits beyond the scope of the immediate project. While these measures could reference a particular project, they usually provide a larger view of the "ripple effects" of savings having direct and indirect benefits on the economy. Cost savings for the transport agency has particular interest.

4. **Energy and the Environment**

   Energy and the Environment can include a number of different issues, and it should be noted that these terms refer to two separate issues. Noise and aesthetics performance measures are included in the Finnish and Swedish architectures (see Appendix B). The most common way to measure environmental impacts is by a reduction in emissions or pollutants. Ozone, volatile organic compounds (VOCs), nitrogen oxides (NOx), carbon monoxide (CO), and particulate matter are common pollutants that are used in air quality planning. Measurement, however, often depends on simulation models that may not effectively represent ITS projects. Energy use also relies on simulation models since acceleration characteristics are important.

5. **Security**

   Supporting or increasing security has recently become an important goal in some ITS applications, such as public transport and border crossing. Although appropriate measures of effectiveness are still being investigated, past studies and research projects in the public transport field have examined changes in the number of acts of crime against passengers or property, and changes in acts of vandalism and graffiti.

6. **Customer Satisfaction**

   Customer satisfaction is not always used as a measure of transportation success since it is hard to quantify. This does relate to improvements in mobility (average travel time and variability) as well as more subjective measures. The subjective aspect is difficult to assign a monetary value. Surveys and interviews are the most common ways to determine customer satisfaction. The Finnish architecture outlines several different areas in which satisfaction can be gauged, such as the user's willingness to pay for services, public image of the organization or business unit, and travel comfort. Appendix A contains a list of possible measures in this category.

The ability to capture 100 percent of benefits is time consuming, expensive, and probably impossible! Thus, an important early step is to identify a limited number of measures that are most likely to capture the bulk of the benefits. Focusing available funds and time on making the best possible estimate of these measures is an effective strategy.

Appendix C contains a table of recommended measures based on project type. While additional or substitute measures may be appropriate for certain projects, these measures are the most commonly used based on a survey of past evaluations.

2.2 Step 2: Data Collection

2(a) Methods

Data for evaluation should be collected by the simplest and most cost-effective means. However, the data collection effort should be carefully planned and designed so that requirements such as statistical representation, seasonal adjustments, and others can be adequately addressed. Primary methods of data collection include:

1. **Field Observation:** Field observations are necessary for certain measures, such as the number of accidents, or when automated data collection devices are not available (e.g., obtaining speed data at a particular location).

2. **Automated Data Collection Devices:** Ideally, data collection devices can be built right into the ITS project, thereby providing a continuous stream of data after (and possibly before) activation of the system. The reaction of the transportation system can be clearly observed over time.

3. **Simulation:** Simulations are useful for estimating data prior to the completion of an ITS project, for generating data to use in an evaluation that was planned after the implementation of a project, or for generating data when direct data collection is not possible.

4. **Surveys:** Surveys are necessary when customer satisfaction or other behavioural attributes related to an ITS project need to be measured. While benefits such as

"satisfaction" and "ease of use" are difficult to quantify in monetary terms, customer satisfaction has become a very important qualitative measure of the public's perception and acceptance of ITS projects. Customer satisfaction surveys provide important knowledge that can be used as feedback both prior to and following project implementation.

2(b) Timeline

A major challenge in ITS evaluation is gathering an adequate sample size of data. Data collection should begin as soon as possible, preferably before the actual implementation of the project. Evaluation is often only considered during or after an ITS implementation. At this point, an accurate evaluation becomes difficult because of missing or unreliable information about the "before" condition.

When using this framework to decide among several possible ITS projects, the "before" conditions may be all the data that can be measured directly in the field. The post-project conditions must be estimated by simulation or the use of historical data from comparable projects. Again this analysis requires accurate pre-project data, underscoring the need to begin data collection early in the ITS project life cycle.

Evaluation planners who intend to use actual data collected after the deployment of an ITS project need to consider carefully the timeframe of the analysis. ITS installations typically require some time to pass for the system to stabilize and the appropriate level of benefit to the transportation system to be observable. Stability, as used here, does not necessarily mean that the system has reached its maximum level of impact, but rather that the marginal increase from one day (week, month or other useful time period) to the next is not significant to the evaluation.

The greatest impact on the transportation network is expected in the time period that immediately follows activation of the ITS project, as approximated by the graph in Figure 3. The exact shape and scale of this curve depend on the type and magnitude of the ITS project and the nature of the underlying transportation network. Such a chart can provide an initial estimate of how long data should be collected before a project reaches maturity. This time frame, however, is shorter than for most construction projects and typically will be less than one year.

The Finnish ITS evaluation framework describes two points in Figure 3: "After I" (t_1) and "After II" (t_2). "After I" is a point representing the initial effects of activating the ITS system (t_0) and "After II" is a time when the transportation network has "reacted" to the new ITS component and stabilized. The exact amount of time elapsed between t_0, t_1, and t_2 will vary by project, but most ITS projects reach maturity relatively quickly.

2(c) Dealing with Unavailable Data

When data regarding specific costs or benefits are not available, it may be necessary to use information from similar projects in similar regions. This should always be done with caution, trying to match both the type of project and a location/transportation network with similar types of transportation problems – major metropolitan area, town, rural, similar traffic or congestion levels, etc. The U.S. Department of Transportation and the UK Department for Transport both maintain databases with costs and benefits for typical types of ITS projects. While both emphasize projects in their own country, they also include projects from other countries, primarily North America and Europe.

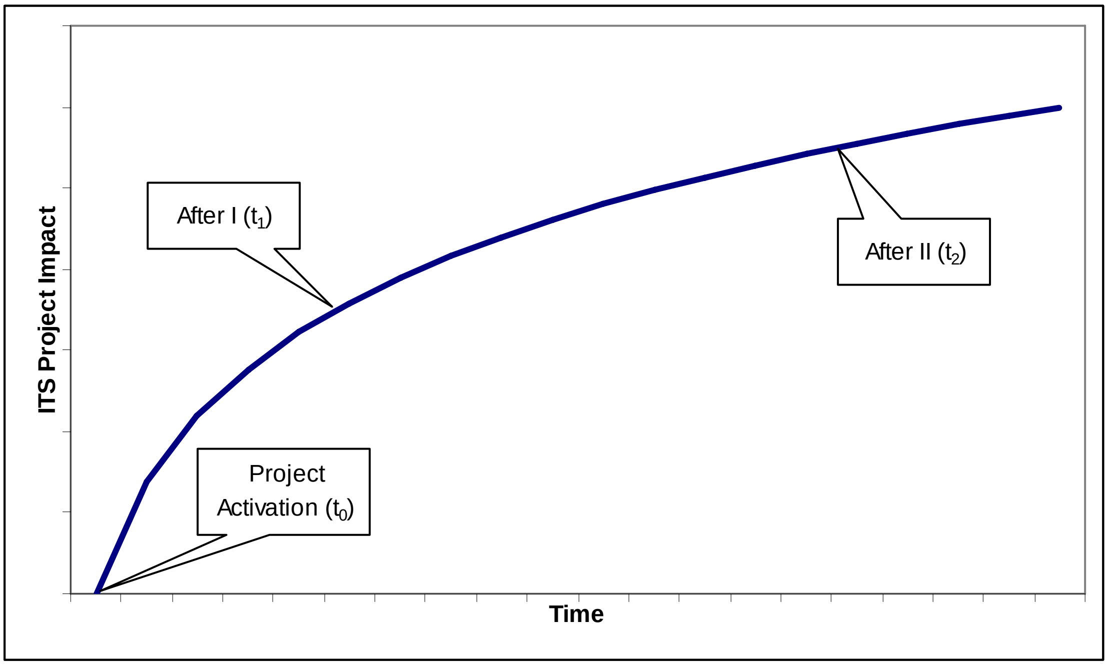

Figure 3 – Generic ITS Project Impacts over Time

Some documents within these databases are case-specific while others are general. The wide range of projects is beneficial when searching for a similar project evaluation; however, it is important to keep in mind the scope of the project in the database relative to the project being evaluated. Costs and benefits vary widely from one project to another; therefore, when using a database to obtain “missing” information, it is best to ensure that the project is as similar as possible to the one being evaluated.

A logical approach for searching one of these databases is to identify an area of interest and to search the benefits database for relevant documents. Once a document is obtained, search the cost database for related information. Since the database summary often does not provide adequate project background information, it may be necessary to obtain a full copy of the evaluation to be able to understand the data and apply it to a current project.

2.3 Step 3: Data Analysis

Traditional economic analysis tools exist to convert the benefit and cost data generated in the previous steps into summary measures. When evaluating the benefits of public-sector investments, a benefit-cost framework provides a number of summary measures. Benefit-cost analysis is the process of weighing the total expected costs over time versus the total expected benefits over time.

Since costs usually occur prior to benefits, the technique uses a discount rate to convert future costs and benefits into current values. The most common summary measures include benefit-cost ratio, net present value, and internal rate of return. The rest of this section describes these and related tools, along with their equations. Spreadsheet programs such as Excel have these formulas built in.

The user of this framework is expected to be familiar with these analyses, so this discussion is limited to the basic mechanics of each tool. Numerous reference manuals and textbooks are available on this topic if further information is needed. Tables 3 and 4 contain recommended unit values for these analyses.

Time Value of Money

The time value of money recognizes that society does not value expected future cash flows as highly as immediate cash flow. Very simply, current consumption is more valuable than future consumption. This is not the same as inflation. Therefore, in order to compare investments, future cash flows must be discounted to what they would be worth today. The discount rate is the percentage by which the present value of future cash flows is calculated.

The discount rate can vary widely depending on the type of investment or the state of the economy such as inflation rate and the prime lending rate. In 1976, the Canadian Treasury Board set the discount rate at 10 percent, with a sensitivity range of 2.5 percent on either side. Given today's economy, this number seems too high. For example, the United States Office of Management and Budget specifies a discount rate of 7 percent for economic analyses of federal programs. In recent past, the provinces have been setting their own discount rate for projects, typically in the 7 percent range.

Benefit-Cost Analysis

The first step in a benefit-cost analysis is to determine the benefits and costs associated with a project. This can be difficult, especially when determining benefits. Once the benefits and costs are determined, each should be given a dollar amount. These amounts should be net of inflation impacts. Tables 3 and 4 show standard units used for providing monetary values for major costs and benefits.[3]

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[3] Users of this evaluation framework should consult with federal and/or provincial government agencies as to the availability of more recent values at the time they intend to use them. Should more recent data not be available, then values shown should be updated to the base year selected for the evaluation in question.

Table 3 – Value of Injuries / Fatalities Avoided

Performance Measure	Monetary Value (1991 Dollars)		
	Average	Lower	Upper
Serious Injury Avoided	$75,000	$56,250	$93,750
Minor Injury Avoided	$30,000	$22,500	$37,500
Fatalities Avoided	$1,500,000	$500,000	$2,500,000

Table 4 – Values of Passenger Time (1990 base year)

Mode	Business Travel	Non-Business Travel
Auto	$24.00	$6.50
Air	$33.70	$6.50
Bus	$23.70	$6.50
Rail	$23.70	$6.50

Benefit-Cost Ratio

The benefit-cost ratio is one way of comparing the benefits generated by an investment with the costs to implement that investment. Very simply, using this method, a ratio of costs to benefits is determined and can be used to compare the alternatives. The method for computing the benefit-cost ratio is as follows:

1. Compute present value of both benefits and costs

$$PV_{Benefit} = \sum_{t=0}^{t} \frac{B_t}{(1+i)^t} \qquad PV_{Cost} = \sum_{t=0}^{t} \frac{C_t}{(1+i)^t} \tag{1}$$

Where: B = benefit
C = cost
t = year, starting with 0, which is the current year
i = discount rate

2. Determine the ratio of benefits to costs

$$\frac{B}{C} = \frac{PV_{Benefit}}{PV_{Cost}} \tag{2}$$

A ratio greater than one means the benefits exceed the costs. Simply having a benefit-cost ratio greater than one does not necessarily mean the project is a good one or should be carried out. When comparing two investments, the one with the larger benefit-cost ratio is generally more attractive. Other factors need to be considered as well, of course, including the absolute level of funds available.

Also, while benefit-cost ratios convert all costs and benefits into a single measure (dollars and cents), in practice not all benefits or costs may be equal. For example, in certain circumstances, safety benefits or environmental impacts such as a reduction in greenhouse gases might be considered as the driving force behind a particular investment. These issues can be addressed, in part, by focusing data collection efforts on a limited number of key benefits.

Net Present Value and Internal Rate of Return

The net present value (NPV) is the total value of the net benefits generated by a project – net after reducing for costs and net after adjusting for the time value of money. This measure reflects both the size of the investment and the value relative to its costs. NPV provides the best single estimate of the overall value of the project. The NPV is calculated as follows:

$$NPV = \sum_{t=0}^{t} \frac{CF_t}{(1+i)^t} \qquad (3)$$

Where: CF = cash flow
t = year, starting with 0, which is the current year
i = discount rate

Internal rate of return (IRR) is comparable to the rate of return on an investment. Mathematically, it is calculated as the discount rate that is high enough to generate a net present value of zero.

The IRR can be used as an investment decision tool in its own right and is often preferred over the NPV method since a discount rate does not have to be assumed at the beginning of the process. Calculating the IRR is an iterative process.

$$NPV = \sum_{t=0}^{t} \frac{CF_t}{(1+i)^t} = 0 \qquad (4)$$

Where: CF = net value cash flow in a particular year
t = year, starting with 0, which is the current year
i = internal rate of return

The investment alternative with the highest IRR is generally preferred. It also offers a way to compare an investment with standard benchmark investments, such as rate of return on a bond or even to compare ITS investments with other transport projects.

Other Types of Analysis

Break-Even Analysis

The break-even point for a project is the point where total benefits received equals total costs expended. That is, how soon will the project begin to generate a net value? The point in time at which the benefits received equal the costs for a given investment can be determined by solving the following equation for t:

$$\sum_{t=0}^{t} B_t - \sum_{t=0}^{t} C_t = 0 \qquad (5)$$

Where: B = benefits
C = costs
t = years

More attractive investments will have a smaller value of t, meaning that the benefits will equal the costs in fewer years. Of course, a higher overall return may mean that a project that takes longer to mature is still a better one.

First-Year Return

As the name implies, the first-year return reflects the benefits obtained in the first year relative to the costs incurred. This measure indicates how well an investment will fare in the very short term – generally an advantage of ITS projects. A positive rate of return with just one year of benefits is a good result.

Cost Effectiveness Analysis

Unlike the other analyses presented here, the cost effectiveness analysis involves ratios between cost and certain key results of the investment, rather than a comparison with benefits as a whole. These measures may be required when the full range of benefit information cannot be obtained. But they can also provide a common sense way to compare projects. For example, the cost per hour of travel time saved is a straightforward calculation and may be relevant for projects with a focus on mobility. For a safety-oriented project, one could calculate the cost per accident avoided.

2.4 Step 4: Recommendations and Final Report

4(a) Develop Recommendations

Evaluation serves multiple purposes. One, of course, is to review past projects to see how well funds have been spent. More importantly, however, is to use evaluation as a guide to designing and selecting more effective projects in the future. More than simply looking at the bottom line numbers, this requires an examination of:

- Successes, challenges and barriers met during the project
- Which types of benefits are most important
- Interactions between a single ITS project and other ITS investments in the same geographic area
- Interactions with non-ITS projects

Each of these efforts requires some judgment. For example, while evaluation efforts work to put all costs and benefits into a single metric, not all benefits may be considered equal. Safety is a good example, since the ability to save lives often receives greater attention than implied by the dollar value that economists assign to a human life. In particular, the interaction among projects can help stimulate higher levels of return. This systems view is not common within ITS (nor other parts of transportation), but would seem to offer significant value now that ITS has moved beyond the early stages of its deployment.

4(b) Create Final Report

A clear and comprehensive final report is important. While ITS evaluations have an immediate value – informing practitioners and decision makers about a particular project – they also add value by helping in the design and selection of ITS projects in the future. The final report serves to preserve the methods, results, and insights gained through the evaluation process.

Because of the wide variety of ITS projects, the content of the final ITS Evaluation Report will vary. To ensure consistency of reports and facilitate comparisons of evaluations across projects, however, a recommended outline has been developed and is included here. Depending on the individual project, it may be necessary to add sections or make modifications to the recommended outline, but ideally the general content will remain the same.

2.5 Recommended Outline for ITS Evaluation Final Reports

EXECUTIVE SUMMARY

a. Project overview
b. Evaluation methodology
c. Summary of analysis results
d. Summary of conclusions & recommendations

MAIN REPORT BODY

I. EVALUATION PLAN
    a. Project description & motivation

    i. Include information about ITS program that this project is a part of, if applicable
  b. Project classification and objectives
  c. Discussion of expected project benefits (all-inclusive, including those which cannot or will not be measured)
  d. Selection of benefits (impacts) to be measured
    i. If necessary, include discussion of proxies used to estimate a benefit.

II. DATA COLLECTION
  a. Method(s) of data collection
  b. Data collection location(s) and timeline
  c. Accuracies of data collection method(s)
  d. Summary of data collected
  e. Missing / unavailable data
    i. Data source (benefits / costs database, IDAS, etc.)
    ii. Modifications made to data prior to use
    iii. Estimate of error (quantitative if possible, otherwise qualitative) introduced by substituted error

III. ANALYSIS
  a. Description of analysis approach
  b. Conversion of data into appropriate units for calculation
  c. Analysis calculations
  d. Summary table of analysis results

IV. CONCLUSIONS AND RECOMMENDATIONS
  a. Discussion of results of analysis (non-technical)
    i. Reiterate assumptions made / inherent limitations
  b. Project recommendations and considerations
  c. Recommendations about the evaluation process (for future evaluations)

APPENDIX
- Bibliography (sources of secondary research)
- Selected data output (only include summaries of critical data; not intended to be a download of the data collection process)
- Survey forms used (if applicable)
- Technical memoranda

3. Application of Framework to Sample Projects

3.1 Sample Project 1: Motor Carrier Profile for the Province of New Brunswick

In this example, the Evaluation Framework is applied to an ITS investment in the Commercial Vehicle Operations (CVO) area.

I. EVALUATION PLAN

a. Project Description and Motivation

The Province of New Brunswick is in the process of upgrading its commercial vehicle enforcement operations. As part of that process, new Weigh-in-Motion (WIM) systems have recently been installed at commercial vehicle inspection facilities on the province's main transportation corridors, and a strategic plan for the implementation and deployment of ITS applicable to CVO in New Brunswick is now being completed.

The ITS/CVO Deployment Plan for New Brunswick identifies a number of potential ITS/CVO investments and initiatives to be implemented in the near future. One of the initiatives being recommended is the **Motor Carrier Profile (MCP)**, which has been selected as one of the sample projects for the application of the evaluation framework.

b. Project Classification and Objectives

Commercial vehicle enforcement (CVE) in New Brunswick is the responsibility of the Commercial Vehicle Enforcement Branch, New Brunswick Department of Public Safety.

Commercial vehicles are subject to enforcement of the province's weights and dimensions legislation and the National Safety Code (NSC) requirements through inspections on-road and at commercial vehicle inspection facilities. Currently the Province of New Brunswick operates 9 fixed inspection facilities and 23 mobile units. All commercial vehicles (vehicles with a gross vehicle weight exceeding 4500 kg) passing an inspection facility are required to enter when the facility is open, or in the case of weigh-in-motion (WIM), when directed to do so.

Each commercial vehicle inspection facility is manned by one or more CVE officers who are authorized to inspect each vehicle and driver for compliance with current regulations. The Province of New Brunswick currently has 63 CVE officers, including supervisory staff and facility auditors.

All of the inspection facilities are capable of operating on a 24-hour-a-day, 7-day-a-week basis, but due to staffing restrictions are not open 24 hours a day. Typically, an inspection facility in New Brunswick is open approximately 50 percent of the time, based on a 24-hour-a-day, 7-day-a-week basis.

As a truck passes over the scales, the CVE officer can decide to conduct a more thorough inspection. If so, the signs on the highway may be temporarily turned off for the duration of the inspection (depending on staffing and the level of inspection required) to avoid any unnecessary delay to passing commercial vehicles.

Results of all inspections and violations are entered into the carrier profile system when the inspection sheets are sent in and the finding of guilt is completed, should a court appearance be required. Typically data can take a number of months before it is entered into the carrier profile due to delays in data entry, court proceedings, etc. This results in CVE officers using out-of-date information in the field. There are also problems in receiving data from other jurisdictions and delays in getting this information entered into the carrier profile system.

The coverage provided by the fixed inspection facilities is potentially problematic, considering the use of fixed operational schedules, operational rates of 50 percent, and the potential closure of the inspection facility when CVE officers are fully occupied conducting inspections. The combination of these factors has the potential of allowing problem carriers the opportunity to operate in violation of provincial regulations.

The Province of New Brunswick has targets for the operation of its inspection facilities. A review of the data made available indicates that, on average, the number of vehicles stopped is currently slightly below the established target of one vehicle stopped per shift-hour. With increasing traffic, the percentage of commercial vehicle traffic stopped at the inspection facilities will naturally decrease.

If commercial vehicle inspection facilities continue to operate as previously described (i.e., with signs turned off while one vehicle is being inspected), no delays or additional wait times will be incurred by commercial vehicles. However, increased truck volumes under current operations will result in a reduction of enforcement levels.

c. Discussion of Expected Benefits

Commercial vehicle safety inspections take place to prevent crashes and, consequently, fatalities, injuries and property damage. Studies conducted by the U.S. Federal Motor Carrier Safety Administration (FMCSA)[4] show a clear relationship between number of inspections and prevented crashes. It is reasonable, then, to assume that, in order to prevent a deterioration of provincial safety levels, current commercial vehicle inspection and enforcement targets in New Brunswick should be maintained in the future.

Under current enforcement operations, future truck traffic volumes will result in a reduction of enforcement levels. Clearly, in order to continue with current enforcement targets, operations will have to be adjusted.

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[4] *FMCSA Safety Program Performance Measures – Intervention Model: Roadside Inspection and Traffic Enforcement Effectiveness Assessment*, John A. Volpe National Transportation Systems Center, Motor Carrier Safety Assessment Division, Cambridge, MA, September 2002.

Two possibilities exist:

1. Adjust operations by changing schedules, extending staff hours, adding staff and eventually adding more inspection facilities; or
2. Perform a more focused safety enforcement by making use of technology for screening purposes (similarly to WIM systems used for the detection of non-compliant vehicles).

Increasing staffing levels is only possible to some extent. However, it might be difficult and not cost-effective, particularly to the required maximum levels. As presented in the FMCSA study, the use of technology appears to be a more feasible alternative.

For New Brunswick, a Motor Carrier Profile (MCP) system is proposed. The MCP will allow the CVE officer access to safety-related data for all carriers that are both complete and current. This will require:

- availability of recent information (preferably less than 24 hours old), requiring a move away from the current paper-based systems;
- sharing the MCP and related safety information with other provinces and states;
- providing access to the MCP and safety data to the CVE officer in a format that can be easily and quickly understood; and
- use of the MCP and safety-related data as a criterion in the screening of passing commercial vehicles to decide whether they should report to the CVE officer.

Findings of the FMCSA study show that roadside inspection resources in the U.S. are working at capacity. The increase in commercial vehicle traffic, combined with the decrease in enforcement resources and the addition of security related responsibilities, is creating a significant safety risk.

Alternative inspection strategies offer the opportunity to maximize the use of enforcement resources and improve the effectiveness of commercial vehicle safety inspection programs.

Key findings from the study include:

- All stakeholders agree that alternative inspection strategies should be employed.
- Alternative inspection strategies offer benefits to stakeholders (e.g., increased effectiveness, maximized resources) as well as to the industry (e.g., level playing field, improved productivity).
- A variety of strategies and automated tools are being used by the enforcement community today. These strategies and/or tools include selection algorithms, software to automatically capture inspection data, and electronic screening systems.
- The need for timely and accurate information at roadside is critical. Programs like the Commercial Vehicle Information Systems and Networks (CVISN) are

supporting the deployment of centralized data repositories that contain driver, vehicle, and carrier safety data. The enforcement community should be actively involved in the design and deployment of these systems to ensure that their needs are met.

- Although the industry representatives that were interviewed during this project are very receptive to increasing safety, agencies charged with conducting commercial vehicle inspections should demonstrate to industry that by working together there will be tangible, monetary benefits that will accrue to the trucking industry at large. For instance, enforcement agencies could demonstrate that qualification for participation in an electronic screening program will result in a decrease in the number of inspections for a carrier with a good safety compliance record.

There is, therefore, clear evidence in support of the use of technology as a feasible alternative to staff and/or institutional changes in order to maintain current enforcement targets and highway safety.

d. Selection of Benefits To Be Measured

As described above, the MCP element of the CVO Program is primarily oriented to the CVO enforcement staff providing significant improvements in their ability to monitor the safety performance of the commercial vehicle fleet and in the operational efficiency of the roadside commercial vehicle inspection facilities. This will be accomplished through the access and use of up-to-date MCP, safety, and recent contact data by the CVE officers in their inspection processes. Since it is reasonable to assume that enforcement levels in New Brunswick must be maintained in the future, *the relevant comparison for the purpose of the project evaluation is between an increase in resources and staff, and the use of technology for alternative inspection strategies.*

Thus, while benefits of this element are ultimately related to safety, they also make a direct contribution in the area of agency efficiency.

As pointed out previously, the MCP system should also result in a decrease in the number of inspections for a carrier, saving time and increasing customer satisfaction. These benefits, however, were not considered for this sample case.

II. DATA COLLECTION

The evaluation of the MCP system for New Brunswick required a variety of information and data obtained from different sources as described below.

The CVE Branch of the New Brunswick Department of Public Safety provided a description of enforcement operations, current enforcement levels and targets, hours of operation for all inspection facilities, annual number of inspections, and annual operating budgets.

Cost estimates of the proposed MCP system and estimated truck traffic volume growth rates were obtained from the ITS/CVO Deployment Plan for New Brunswick.[5]

III. ANALYSIS

a. Description of Analysis Approach

Based on the discussion presented above, a quantification of benefits and a benefit-cost analysis has been conducted for the MCP element of the CVO Program for New Brunswick.

The base case is defined as a continuation of the current enforcement practices, increasing resources over the years as required by increasing truck traffic volumes in order to meet current enforcement levels and targets.

The alternative case is defined as the implementation of the proposed MCP system in New Brunswick in the year 2007.

b. Data Assumptions

Data and assumptions used were as follows:

- Cost of capital (discount rate) was assumed to be 5%.
- Period of analysis was assumed to be 10 years.
- All costs are expressed in 2006 dollars and were assumed constant in real terms during the period of analysis.
- Enforcement costs were broken down into a fixed component (assumed to be 40%) and a variable component (60%).
- Number of inspections was assumed to grow at an annual rate of 4%, the average rate of growth for truck traffic in the province.
- Fixed costs of enforcement were assumed to be constant throughout the analysis period.
- Variable costs were assumed to increase at a rate of 3% per year (i.e. a growth slightly slower than the growth in the number of inspections).
- No enforcement cost increases were assumed under the MCP alternative.
- Useful life of the hardware components of the system was assumed to be 5 years, with an annual cost of maintenance of 10% of the capital investment.
- Software maintenance costs were assumed to be 15% per year of the initial software investment.
- Software upgrade cost of 20% of the initial software investment was assumed to take place in year 5.
- Taxes were not included in the analysis.

[5] *ITS / CVO Deployment Plan for New Brunswick – Final Report*, Delcan Corporation, July 2006.

c. Analysis Calculations

The economic analysis included a quantification of the NPV and the Benefit/Cost (B/C) Ratio.

The NPV is the present-day value of benefits (savings in annual enforcement costs) minus the present-day value of costs (capital costs). An NPV greater than zero means that the net benefits of the project exceed the project's investment costs and is therefore economically efficient.

The B/C ratio is calculated by dividing the present-day value of benefits (annual savings) by the present-day value of investment costs. A ratio greater than one means that the project is worthwhile.

d. Summary Table

Table 5 presents the results of the benefit-cost analysis, including the estimated NPV and B/C ratio.

Table 5 – Motor Carrier Profile B/C Analysis

BASE CASE: CONTINUATION OF CURRENT ENFORCEMENT OPERATIONS					ALTERNATIVE: ITS-CVO SOLUTION - MOTOR CARRIER PROFILE								
Year	Inspections	Annual Cost of Enforcement			Capital Investment		Maintenance Cost		Inspections	Annual Cost of Enforcement			
		Fixed	Variable	Total	Hardware	Software	Hardware	Software		Fixed	Variable	Total	Grand Total
	#/year	$/year	$/year	$/year	$	$	$/year	$/year	#/year	$/year	$/year	$/year	$/year
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
2005	26,461	1,463,600	2,195,400	3,659,000					26,461	1,463,600	2,195,400	3,659,000	
2006	27,519	1,463,600	2,261,262	3,724,862					27,519	1,463,600	2,195,400	3,659,000	
2007	28,620	1,463,600	2,329,100	3,792,700	480,000	625,000	48,000	93,750	28,620	1,463,600	2,195,400	3,659,000	3,800,750
2008	29,765	1,463,600	2,398,973	3,862,573			48,000	93,750	29,765	1,463,600	2,195,400	3,659,000	3,800,750
2009	30,956	1,463,600	2,470,942	3,934,542			48,000	93,750	30,956	1,463,600	2,195,400	3,659,000	3,800,750
2010	32,194	1,463,600	2,545,070	4,008,670			48,000	93,750	32,194	1,463,600	2,195,400	3,659,000	3,800,750
2011	33,482	1,463,600	2,621,422	4,085,022			48,000	93,750	33,482	1,463,600	2,195,400	3,659,000	3,800,750
2012	34,821	1,463,600	2,700,065	4,163,665	480,000	125,000	48,000	93,750	34,821	1,463,600	2,195,400	3,659,000	3,800,750
2013	36,214	1,463,600	2,781,067	4,244,667			48,000	93,750	36,214	1,463,600	2,195,400	3,659,000	3,800,750
2014	37,662	1,463,600	2,864,499	4,328,099			48,000	93,750	37,662	1,463,600	2,195,400	3,659,000	3,800,750
2015	39,169	1,463,600	2,950,434	4,414,034			48,000	93,750	39,169	1,463,600	2,195,400	3,659,000	3,800,750
2016	40,735	1,463,600	3,038,947	4,502,547			48,000	93,750	40,735	1,463,600	2,195,400	3,659,000	3,800,750
PRESENT VALUE (PV) [2006, 5%]				**31,675,556**	**892,517**	**708,617**							**29,348,384**

NET PRESENT VALUE (NPV) [2006, 5%] = PRESENT VALUE OF BASE CASE COSTS - PRESENT VALUE OF ALTERNATIVE COSTS
NPV [2006, 5%] = PV (4) - {PV(5) + PV(6) + PV(13)
NPV [2006, 5%] = $726,038

BENEFIT/COST (B/C) [2006, 5%] = {PV OF ANNUAL BASE CASE COSTS - PV OF ANNUAL ALTERNATIVE COSTS} / PV OF CAPITAL COST OF ALTERNATIVE
B/C = {PV(4) - PV(13)} / {PV(5) + PV(6)}
B/C = 1.5

Table 5 – Notes

(1): 2005 data from Commercial Vehicle Enforcement Branch. Subsequent years increased at 4%/year (average provincial truck traffic volume growth rate).
(2): 40% of total enforcement costs. Assumed to remain constant throughout the analysis period.
(3): 60% of total enforcement costs. Assumed to increase 3% per year.
(4): Made available by Commercial Vehicle Enforcement Branch, New Brunswick Department of Public Safety.
(5): Useful life of hardware components = 5 years.
(6): Software upgrades in year 5 assumed to cost 20% of initial software costs.
(7): 10% per year of initial hardware cost.
(8): 15% per year of initial software cost.
(9): Same as (1).
(10): Same as (2).
(11): Same as (3). No cost increase during period of analysis.
(12): (10)+(11).
(13): (12)+(7)+(8).

IV. CONCLUSIONS AND RECOMMENDATIONS

As seen in Table 5, the MCP element of the CVO Program, both the NPV and the B/C indicate that the project is economically viable and a good investment for the province.

As stated before, a number of assumptions have been made, including truck traffic growth rates and cost estimates. The most important underlying assumption is perhaps related to the fact that fewer, but more focused, inspections should result in provincial safety levels that are similar, or better, than existing ones under current enforcement practices. No quantified evidence exists to prove that, as focused enforcement programs based on the use of timely and accurate safety-related information at roadside are relatively new. However, preliminary indications and stakeholder surveys appear to suggest so.[6]

Also, while cost estimates for the MCP system include only investments required in the Province of New Brunswick, truck traffic volumes (and therefore benefits) include carriers based both in and outside New Brunswick. Since carriers based outside New Brunswick may not necessarily be exempt from inspections, the total value of benefits may be overestimated.

Should New Brunswick decide to proceed with the proposed MCP system, future performance monitoring should be put in place to confirm the validity of the assumptions made and provide lessons for future similar undertakings.

Quantified benefits for this project relate to increases in public agency efficiency. Because of the nature of current (and future) CVE operations in New Brunswick, no delays are, or will be, experienced at commercial vehicle inspection facilities. However, the implementation of the MCP should eventually result in a decrease in the number of inspections for a carrier, saving time and increasing customer satisfaction. As pointed out before, these benefits were not considered for this sample case.

3.2 Sample Project 2: Richmond-Vancouver Bus Rapid Transit

In this sample project, the Evaluation Framework is applied to a Bus Rapid Transit investment incorporating ITS technologies such as Automatic Vehicle Location (AVL), Transit Signal Priority (TSP) and Real-Time Passenger Information.

I. EVALUATION PLAN

a. Project Description and Motivation

In 1995 the Greater Vancouver Transportation Authority (TransLink) started a transit service improvement program that included, among other initiatives, the implementation of Bus Rapid Transit (BRT) services between the cities of Richmond and Vancouver in

[6] Key findings of the FMCSA study, a summary of which is presented on page 18 of this report.

the province of British Columbia. The second BRT route implemented by TransLink, known as the 98 B-Line, provides frequent and reliable transit services along dedicated bus lanes using high-capacity, articulated buses and ITS technologies, including transit management using AVL, TSP, and real-time passenger information. The 98 B-Line project was the subject of a comprehensive evaluation, the purpose of which was to compile lessons and experience gained for the benefit of future BRT implementations. The application of the Evaluation Framework to this project is largely based on the evaluation work previously conducted and documented in a report published in 2003.[7]

b. Project Classification and Objectives

The 98 B-Line is a 16 km BRT service connecting Richmond City Hall in the south, the Airport Station at the Vancouver International Airport, and downtown Vancouver. The 98 B-Line operates on dedicated bus lanes on arterial roads and incorporates a number of improvements to the roadway and traffic signals that allow it to provide travel speeds competitive with those of car travel.

Roadway improvements include geometry and operational treatments, such as exclusive median and curbside bus lanes, enhanced landscape, street furniture improvements, and queue jump lanes on sections approaching the bridges over the Fraser River. The 98 B-Line route includes 68 signalized intersections for the round trip, all incorporating TSP measures.

Stations are conveniently located at cross street bus routes, maximizing passenger access and minimizing passenger travel time. Distinctive, architecturally designed shelters provide a high quality, rapid transit-like image for rapid bus.

The 98 B-Line BRT service is provided by a fleet of 28 new, low-floor, high-capacity, articulated buses that can accommodate up to 75 passengers per bus seated and standing. Buses are also wheelchair accessible.

The ITS elements that contribute to efficient operations and enhanced customer service are:

- **Transit Management**: this system includes AVL and schedule adherence monitoring supported by voice and data communications to the transit centre (located in Surrey).
- **Transit Signal Priority**: this system allows buses to receive priority at traffic signals when running behind schedule, reducing both the number of stops at intersections and the amount of delay experienced at traffic signals. In turn, trip time reliability is improved and operating costs reduced.
- **Real-Time Passenger Information**: this system provides "next bus" arrival time information at stations, updated in real time based on vehicle locations and schedule adherence, all of which increases passenger convenience and accessibility to the service.

[7] *98 B-Line Bus Rapid Transit Evaluation Study,* IBI Group – TransLink, September 2003.

- **Automated Voice and Digital Next Stop**: automated voice and digital displays provide “next stop” announcements to passengers on board.

The 98 B-Line service was implemented in stages, commencing in November 2000. Full implementation involved an expenditure of approximately $52 million for vehicles, on-board transit management equipment, stations, busways, land, traveller information systems, and a share of a new bus maintenance facility in Richmond. Full service started in the summer of 2001.

Together, the infrastructure, equipment and technology used for the 98 B-Line assist in branding it as a new form of rapid transit associated by both users and the general public with high-quality transit services. Therefore, although this project has a significant ITS component in the areas of Transit Management, Traveller Information, and Arterial Management, its benefits, as discussed below, are in fact the result of a combination of investments in infrastructure improvements, vehicles, and technology that are difficult to separate and must be evaluated together.

c. Discussion of Expected Benefits

The goals and objectives established for the 98 B-Line provide an indication of the expected benefits of the service. The 98 B-Line service had the following fundamental goals:

- provide fast and frequent service
- provide improved customer service through reliability and convenience
- induce increased ridership
- operate an efficient transit service relative to traditional bus routes

These goals provide the basis for the selection of benefits and performance or effectiveness measures as described below.

d. Selection of Benefits To Be Measured

In accordance with the established goals, a number of Measures of Effectiveness (MOE’s) were selected to assess their attainment. The MOE’s were grouped into three categories that reflect the stakeholder group affected by the service:

1. 98 B-Line Users
2. Owner/Operator (TransLink)
3. General Purpose Traffic

98 B-Line Users

Three MOE’s were used to assess the impact of the 98 B-Line service on its users:

1. **Travel Times**: Travel times before and after project implementation were measured and compared. (Some limitations must be taken into account, as travel times for the before and after conditions were not directly comparable.)

2. **Reliability of Service**: Variability in schedule adherence was the MOE selected to measure reliability of service. This benefit is brought about by the implementation of TSP and AVL systems.
3. **Customer Satisfaction**: This included users' responses to customer satisfaction surveys conducted after the initial stage of implementation of the 98 B-Line and then later when most of the TSP system was operational.

The above MOE's were used to evaluate service between Richmond Centre and downtown Vancouver, and between the Airport Station and downtown Vancouver. The analysis recognizes that benefits may vary somewhat for other types of trips, such as within Richmond only or within Vancouver only.

Owner/Operator (TransLink)

Benefits to the owner/operator (TransLink) resulting from the operation of the 98 B-Line are as follows:

- **Vehicle Travel Time**: Increased speeds and reduced travel times translate into fewer buses and fewer bus-hours to provide the same level of service. The MOE used in the analysis was round-trip time. Again, some limitations should be taken into account as there was no directly comparable "before" bus service.
- **Ridership**: Increased ridership is a direct benefit to the operator as it represents additional riders and additional revenue. Other benefits to the community and society as whole associated with increased use of transit were also identified.
- **Costs**: Changes in both vehicle capital costs and vehicle operating costs were considered. These benefits were measured in terms of potential reductions in the vehicle fleet and in the annual vehicle operating hours resulting from faster speeds and reduced travel times to provide the service (again, relative to providing the same amount of service operating at the estimated "before" travel speeds and travel times).

General Purpose Traffic

General purpose traffic was affected by the implementation of the 98 B-Line in the following ways:

- Vehicles travelling in the same direction as the 98 B-Line bus benefit from the TSP advantage, particularly those vehicles adjacent to the bus receiving the priority.
- Cross-street traffic along the 98 B-Line route experience delays due to the reallocation of green time from the cross streets to the BRT mainline.
- Traffic forced to access properties on the other side of the median busway (by making U-turns at the downstream intersection) will affect left-turning traffic by utilizing available capacity within the protected left-turn lanes.

The impact on General Purpose Traffic was assessed by using the TSP log data to measure both the frequency and the magnitude of disruptions at intersections caused by TSP, as follows:

- **Frequency of TSP Grants**: This MOE captures the frequency at which TSP is granted relative to the number of cycles an intersection goes through. For example, an intersection with a cycle length of 120 seconds will cycle 30 times per hour; if this intersection is observed to grant 10 TSP requests within the same hour, it can be concluded that the intersection experiences disruptions 10 out of 30 cycles per hour due to TSP.
- **General Purpose Traffic Delay Penalty due to TSP**: This MOE builds on the previous one by assessing the magnitude of the disruption experienced by cross-street traffic. The delay penalty is measured in terms of reallocated green time from cross street to main street (mainline) when TSP is activated.

II. DATA COLLECTION

The evaluation study included a comprehensive data collection program, including both "before" and "after" implementation data, as described below.

The "before" data collection covered the period before the start-up of the 98 B-Line as well as the period during which limited service was provided between some stations (Airport Station and Waterfront Station). Likewise, the "after" implementation data was obtained from a number of sources of information and data collection methods.

Data collected and sources of information are listed below:

- **Previous Studies**: review of all relevant reports and studies providing baseline performance statistics
- **Traffic Volumes**: all available traffic volume information (before and after implementation) from the BC Ministry of Transportation and the cities of Richmond and Vancouver.
- **Signal Timing Information**: all available before and after signal timing information from the BC Ministry of Transportation and the cities of Richmond and Vancouver
- **Ride-Check Data**: All available ride-check data associated with four related routes was collected from TransLink. The ride-check data was used to determine travel times, schedule adherence, on-time performance, and loading on the associated bus routes.
- **Bus Travel Times**: Baseline bus travel time data was specifically collected in March 2001 to obtain samples of operating conditions prior to TSP being in place. Travel time data was collected on the interim operation of the 98 B-Line (i.e., between Airport Station and downtown Vancouver) prior to activation of the TSP system.
- **Customer Satisfaction Surveys**: over 600 on-board interviews to obtain customer satisfaction statistics

- **BRT Performance**: statistics collected using the GPS/AVL capabilities of the transit management system
- **Traffic Signal Controller TSP logs**: data logs of TSP requests and durations from their traffic signal controllers of Vancouver and Richmond
- **Ridership Data**: provided by TransLink
- **Capital and Operating Cost Information**: provided by TransLink

III. ANALYSIS

a. Description of Analysis Approach

The evaluation study includes the quantification and comparison of the MOE's described above as well as a benefit-cost analysis of the 98 B-Line BRT service.

A summary of the analysis conducted and results obtained is presented below. Full details are contained in the study report.

b. Data Assumptions

Data and assumptions used are as follows:

- Cost of capital (discount rate) was assumed to be 5%
- The value of time was considered to be $10/hour
- Taxes were not included in the analysis

c. Analysis and Results

Impact on Users

Travel Time Variability

The analysis of sampled travel times indicates that the difference between "before" and "after" implementation is very small (approximately 1 minute), but the reduction in travel time variability is significant in almost all cases (from 2 to 5 minutes). The results suggest that the TSP and AVL systems helped to make travel times less variable throughout the day, reducing variability by 40 to 50 percent.

Transit travel times were also compared with travel times for general purpose traffic in the same corridor. The analysis shows that travel times by car are faster but have greater variability.

Schedule Adherence

The variability of schedule adherence has improved throughout the day in the southbound direction and during the midday in the northbound direction. The analysis also shows that the 98 B-Line tends to run behind schedule northbound, without significant variability, due to both existing congestion and the high number of boardings in some sections.

Customer Satisfaction

Results of a comprehensive customer survey are summarized as follows:

- 25 percent of users changed their mode of travel to the 98 B-Line service
- 31 percent of the trips are new trips; 44 percent are previous transit users
- 12 percent of previous car users changed to the 98 B-Line because of faster service, 22 percent because of convenience, and 34% because of cost
- 69 percent of previous transit users perceive the 98 B-Line as faster

Most users indicate a strong degree of satisfaction with the 98 B-Line service for most service attributes. The only area of improvement necessary appears to be the need to provide more capacity during peak periods to meet the consistently growing travel demand.

Impact on General Purpose Traffic

Frequency of TSP

TSP in the 98 B-Line is granted conditionally when vehicles are 2 minutes behind schedule. The analysis of the TSP log data indicates:

- In Vancouver, TSP is granted during 5 percent of the number of cycles throughout the day.
- In Richmond, TSP is granted during 15 to 25 percent of the cycles throughout the day. These higher percentages are the result of longer cycle lengths and multi-phase intersections in Richmond.

Delays and disruptions to General Purpose Traffic in Vancouver occur from 5 percent of the time to cross-street traffic only. In Richmond, General Purpose Traffic delays occur up to 25 percent of the time and affect both cross-street and north/south left-turn traffic.

Delay Penalty due to TSP

The average sum of green extension and red truncation at each intersection is approximately 20 seconds in Vancouver and approximately 60 seconds in Richmond during one hour. Based on typical cross-street green-time allocation in the two cities, the potential delay penalty to cross-street traffic in one hour is approximately a 1 percent reduction in green time in Vancouver and a 6 percent reduction in green time in Richmond. These impacts are considered minor.

Impact on Owner/Operator (TransLink)

Reductions in Travel Times

Less frequent stops, bus lanes, and queue jump lanes contribute to reduced travel times. On average, it is estimated that the 98 B-Line travel time is 20 percent lower than the "before" travel time, which would result in five fewer vehicles and 20 percent fewer annual vehicle hours of service.

In addition, TSP keeps vehicles on schedule, which in turn results in additional savings. It is estimated that the much more reliable schedule adherence permits lower layover time to be incorporated in the schedule and is estimated to result in potential travel time savings of 4 minutes, which represents 5 percent of the route travel time, or one vehicle of the fleet used for the 98 B-Line. This vehicle and vehicle-hours reduction associated with improved on-time performance is directly attributed to the AVL and TSP systems.

Increase in Ridership

Ridership on the 98 B-Line was estimated to be approximately 18,000 passengers/day in 2002, or 5.4 million rides per year. In comparison, ridership in 2001 was estimated at 14,000 passengers per day. The increase in ridership of approximately 1.2 million passengers per year is directly attributed to a high level of user satisfaction with the service and represented an increase of $1.2 million per year in revenues to TransLink.

Capital and Operating Cost Savings

The 98 B-Line results in savings to TransLink due to reductions in capital expenditures in vehicles and in annual vehicle operating costs.

Vehicle capital cost reductions are associated with reduced travel times and represent 20 percent of the fleet, or five vehicles. An additional vehicle is saved as a result of AVL and TSP.

Operating cost savings as a result of reduced travel times amount to $1.8 million per year plus an additional $360,000 per year due to AVL and TSP.

Benefit-Cost Analysis

The economic analysis included a quantification of the Benefit/Cost (B/C) ratio. Capital costs of the various components were annualized using the cost of capital and the assumed useful life of each component. The B/C ratio was calculated by dividing the annual value of benefits (annual savings) by the annualized value of capital, operating and maintenance costs. Thus, a Netted B/C ratio was calculated whose numerator includes as benefits all user cost savings as well as decreases (or increases) in maintenance and operating costs plus any salvage value, while the denominator includes only construction costs of the investment.[8]

Table 6 presents a summary of the results of the analysis. The impact to General Purpose Traffic was not quantified in monetary terms and is not included in the B/C calculation.

Table 6 – 98 B-Line BRT Project Costs and Benefits			
Item	**Capital Cost ($)**	**Life (Years)**	**Annualized Cost at 5% ($)**
Costs			
Vehicles (23%)	4,186,000	17	371,300
Design/Administration	3,600,000	20	288,900
AVL/TSP Systems	6,200,000	20	497,500
Stations	2,600,000	20	208,600
Infrastructure	9,700,000	40	565,300
Land	5,000,000	100	251,900
Maintenance Facility	6,000,000	40	349,700
Operating Costs			8,960,000
Total	37,286,000		11,493,200
Benefits			
Annual Operating Savings			9,198,900
Travel Time Savings			3,982,500
Total			13,172,400
Net Benefit/Year			1,679,200
Netted Benefit/Cost Ratio			**1.15**

IV. CONCLUSIONS AND RECOMMENDATIONS

The 98 B-Line BRT was a project involving a significant investment in infrastructure, vehicles, and technology. The size of the investment and the visibility of the project provided TransLink with an important reason to perform an evaluation of the project. Amongst other things, the evaluation identified a number of opportunities to enhance the 98 B-Line service as well as guidelines for the application of BRT.

A number of assumptions and simplifications were required to assess and quantify selected MOE's for the "before" part of the project. This, as mentioned earlier in this report, is a common issue in evaluation studies.

The example also illustrates a complex evaluation case involving a combination of investments in different areas with impacts on different stakeholders (BRT users, TransLink, general purpose traffic, and the community at large).

[8] In the Gross B/C Ratio, benefits in the numerator represent savings in user costs, and costs in the denominator represent construction costs minus salvage values plus (or minus) any increase (decrease) in maintenance or operating costs.

4. Next Steps

The first step is to begin to use the framework to complete some evaluations. The example in Section 3 is a start, of course. This process does require some judgment, since not every project needs a full-scale evaluation – indeed, cost-effectiveness measures can be a useful low-cost option. Rather, the full evaluation effort should focus on those projects that are likely to provide the most useful lessons. Integrating evaluation into the early planning is important, however, since it can ease data collection problems.

Once the evaluation process is under way, some feedback should be collected regarding the evaluation framework presented in this report and how it performs in practice. A revised framework may be useful, particularly one with more examples of practical problems encountered and the solutions that were developed.

Based on this early experience, it should be decided when and how evaluation should be integrated into the project cycle for ITS investments.

Results from the evaluations need to be summarized in order to help provide access to others. One option is to create a Canadian-specific database that summarizes information on costs and benefits by type of project. A more cost-effective approach, however, would be to integrate the Canadian evaluation material into one of the existing databases in the UK or the U.S. This also makes practical sense in the near term, since it will take time for Canada to develop a large body of evaluation examples of its own.

While evaluations provide useful information for staff who design and select individual projects, the data generated by evaluations should be of direct value to decision makers. A "lessons learned" report would be useful in providing guidance regarding which projects perform well and in identifying the implications for future programs. This report needs to be as current as possible – possibly quarterly.

One drawback with individual evaluations is that they miss the interactions among groups of ITS investments and between ITS and the underlying transportation infrastructure. Limited work has been done on this in other countries, even though these synergistic impacts may outweigh the value of individual ITS projects. While less elegant than developing a new model or framework, one simple approach here would be to mandate that individual evaluations and the "lessons learned" report both address these types of impacts. An effort to identify and implement these "value added" projects offers an opportunity to leverage the limited resources available for ITS investment.

Appendix A Recommended Performance Measures for ITS Projects

UNITED STATES	FINLAND (VIKING)	SWEDEN (PLUTO)
Safety		
• Reduction in overall rate of crashes • Reduction in rate of fatal accidents • Reduction in rate of injury crashes	• Number of traffic accident fatalities • Number of injuries incurred in traffic accidents • Number of accidents • Number of conflicts (near accidents) • Traffic volume • Vehicle-kilometers driven • Person-kilometers traveled • Mean and standard deviation of spot speeds • Mean and standard deviation of traveling speeds • Number of traffic violations • Number of drunken-driving offences • Alertness • Focus of attention • Share of short accepted time • Short (under 0.5 seconds) following time headways' share of all platooning headways • Share of short (under 1 second) time to collision values • Number of crimes committed in vehicles and terminals	• Speed • Drunken driving • Accidents • Road conditions, weather (darkness, fog, etc.) • Braking and acceleration at intersections • Uneven driving patterns in urban areas • Searching traffic and irrational traffic • Accidents involving hazardous goods • Obstacles/sections of road dangerous to vulnerable road users

UNITED STATES	FINLAND (VIKING)	SWEDEN (PLUTO)
Mobility		
• Reduction in travel time delay • Reduction in travel time variability	• Travel time (mean and std. deviation) • Total door-to-door travel time • Waiting time (terminal, stop, junction etc.) • Additional travel time caused by incidents • Public transport's deviations from timetables • Spot speed (mean and std. deviation) • Vehicle-kilometers traveled in congestion • Stability of traffic flow (number of changes in speed) • Incident proneness of traffic flow (share of short headways or time to collision values) • Capacity of link/junction • Need for overtaking • Number of delays • Perceived fluency • Transfer possibilities and information about them • Maximum transfer time • Availability of public transport timetables • Public transport service frequency • Barrier effect of traffic	• Congestion owing to bottlenecks • Traffic jams during the rush-hour (long travel times) • Temporary disruptions (road works, accidents, etc.) • Built-in obstacles (bridges, etc.) • Poor road standard (width, frost heave problems, etc.) • Space requirements

UNITED STATES	FINLAND (VIKING)	SWEDEN (PLUTO)
Efficiency		
• Increase in freeway and arterial throughput	• Network utilization (change in vehicle kilometres traveled or the use of a particular area) • Change in the time in which traffic demand exceeds network's capacity • Change in average speed during peak hours • Number of incident situations caused by insufficiency of network capacity • Time loss caused by insufficiency of network capacity • Changes in contents and timing of network maintenance measures • Necessity for and urgency of constructing additional network capacity	• Intermodality – transport interchanges and combinations of transport modes • Efficiency of public transport • Efficiency of goods transport • Movement of vulnerable road users • Efficiency of the traffic system

Productivity		
• Cost savings	• Change in network's investment or maintenance costs	

UNITED STATES	FINLAND (VIKING)	SWEDEN (PLUTO)
Energy and Environment		
• Decrease in vehicle emissions • Decrease in vehicle energy consumption	• Number of inhabitants affected by traffic noise • Number of people exposed to exhaust emissions • Air quality indices of urban districts • Number of people suffering from illnesses directly or indirectly caused by emissions • CO_2 emissions • Use of salt • Transport energy consumption • Range of area affected by traffic noise • Number of animals exposed to traffic noise • Number of people disturbed by traffic noise • Vehicle-kilometers driven • Person-kilometers traveled • Goods tons transported • Mean and standard deviation of spot speeds • Amount of traffic exhaust emissions • Damage caused to valuable natural sites • Safety of hazardous goods transportation • Hazardous goods-tons transported • Impact of transport infrastructure on the landscape	• Improve air quality • Reduce noise disturbance and vibrations • Increase safety and security on the streets • Reduce traffic in sensitive areas or during certain periods • Emissions from cold starts

UNITED STATES	FINLAND (VIKING)	SWEDEN (PLUTO)
Customer Satisfaction		
• Increase customer satisfaction	• Number of uses • Opinion of system and its characteristics • Willingness to pay for service • Willingness to pay for mobility • Users' attitudes towards transport system • Users' attitudes towards different transport modes • Travel comfort experienced by users • Feeling of personal security • Number of users of a service • Number of users of a transport service • Organization/Unit image	

Appendix B ITS Evaluation Literature Review

As ITS investments have become a critical part of the transportation network, the importance of ITS evaluation has become recognized by a wide variety of transportation agencies and organizations. The creation of the International Benefits Evaluation and Costs Working Group (IBEC) in 2002 is evidence of the worldwide interest in ITS evaluation. IBEC has been present at every ITS World Congress meeting since 2002, in addition to numerous regional or national ITS conferences, such as the ITS European Congress, the EuroRegional Conference and TRB. IBEC's objective is to improve access for all public and private organizations to information about the costs and benefits of ITS, and appropriate analysis procedures and tools that can be applied to local circumstances.

Publications, workshop presentations, websites and other resources were reviewed to understand relevant evaluation approaches and extract key components useful for the development of an evaluation framework for Transport Canada.

Federal Highway Administration's (FHWA) Joint Program Office (JPO)[1]

The Federal Highway Administration's Joint Program Office (FHWA-JPO) is the coordination and standardization agency for ITS in the United States. In this role, the JPO performs critical functions of program assessment, including tracking ITS deployments, determining the benefits and costs of ITS and sharing these results with others. Widely considered the standard in ITS evaluation, FHWA's Joint Program Office has had a formal evaluation process in place for more than a decade. This framework has become the foundation for many ITS evaluation procedures around the world, which can be modified for local or national objectives. By synthesizing the results of ITS evaluations over the years, the JPO has developed an extensive database of benefits and costs[2], which will be discussed further in technical memorandum 2.

The JPO provides the following steps for a general framework for evaluation of ITS investments from the local to national level.[3] The emphasis of the framework is on the overall process, rather than specific analysis techniques. The primary goal of these guidelines is to establish a standardized approach that ensures consistency across evaluations.

1. **Form the Evaluation Team.** Each project stakeholder should designate one member for the evaluation team. In additional, the program manager should designate an evaluation team leader. An independent party should be consulted throughout the process to ensure an effective, unbiased evaluation. The evaluation team should be formed as early as possible.

[1] Federal Highway Administration Joint Program Office website: http://www.its.dot.gov/index.htm
[2] FHWA-JPO Benefits and Costs databases are located at http://www.itsbenefits.its.dot.gov and http://www.itscosts.its.dot.gov, respectively.
[3] The FHWA-JPO evaluation homepage can be found at http://www.its.dot.gov/evaluation. The *evaluation guidelines* link leads to documentation of the ITS evaluation framework.

2. **Develop the Evaluation Strategy.** This document describes the project and relates the purpose of the project to general ITS goal areas. Goal areas can then be associated with measurable outcomes of deployment (measures). The goals areas and most common measures include:

Goal Area	Measure
Safety	• Reduction in the overall Rate of Crashes • Reduction in the Rate of Crashes Resulting in Fatalities
Mobility	• Reduction in the Rate of Crashes Resulting in Injuries • Reduction in Delay • Reduction in Travel Time Variability • Improvement in Customer Satisfaction
Efficiency	• Increases in Freeway and Arterial Throughput or Effective Capacity
Productivity	• Costs Savings
Energy and Environment	• Decrease in Emissions Levels • Decreases in Energy Consumption

3. **Develop the Evaluation Plan.** This step refines the evaluation approach by developing "if-then" statements about expected outcomes following project deployment. The evaluation plan also identifies qualitative studies that will be performed regarding the key components of the project. Evaluations should make an effort to address "institutional issues", which are the non-technical factors influencing project performance such as: procurement practices, contracting policy, organizational structure, and relationships among major participants. (The FHWA's *ITS Resources Guide* provides a sample Evaluation Plan.)

4. **Test Plans.** Each "test" developed in the evaluation plan requires a test plan identifying personnel requirements, equipment, supplies, procedures, schedules and other resources required to complete the test.

5. **Collect and Analyze Data.** This step is the implementation of the test plans. Early planning may provide the opportunity for building automatic data collection into the ITS project capabilities.

6. **Final Report.** This documents strategy, plans, results, conclusions and recommendations. (Examples of several Final Reports are given in appendix B of FHWA's *ITS Evaluation Resources Guide*.[4])

Considerations for Data Analysis

Standard economic analysis tools are available for the evaluation of ITS investments, including: benefit/cost ratio, internal rate of return / return on investment, time until breakeven, and first year benefit. The JPO framework does not dictate which techniques should be used for analysis, rather it is up to evaluators to decide what tools fit a specific project or objective.

While the benefit cost analysis is most commonly at the core of ITS evaluations, it should not be seen in isolation. During the *ITS Performance Measures and Evaluation Techniques Workshop* given at the ITS World Congress meeting in October 2002, it was noted that these analyses should appropriately link the evaluation to program goals and objectives. Therefore, performance measures must be carefully selected ensuring that they are appropriate for each project's goals and objectives.

Transport Canada developed *Intelligent Transportation Systems – An Approach to Benefit-Cost Studies* in May 1996 that recognizes the shortcomings of traditional benefit-cost studies when applied to ITS projects. It is relatively easy to measure or estimate benefits to safety and congestion, as these can be readily observed and tracked. However, improved mobility can improve economic performance (defined in this report as a third-order benefit), which can undoubtedly be a significant benefit, yet is very difficult to measure. Ignoring this benefit can result in a minor or tremendous underestimation of ITS benefits, depending on the type and size of the project.

This work underscores one of several problems that pose challenges for evaluating ITS investments. Unavailable or immeasurable data can be problematic for performing desired analyses. At best, the use of estimates or comparable data from the JPO database will introduce a level of uncertainty into the results. At worst, it could prevent the calculation of meaningful results.

The timing of the evaluation also presents challenges to be considered. Ideally, the evaluation plan is developed at the beginning of the project, such that evaluation needs are taken into consideration through the entire life of the ITS project. However, this is not often the case, and proxy variables and/or estimates of conditions prior to implementation of the project will be necessary.

Another challenge for developing a useful evaluation is the need for projections of data into the future. At the heart of this problem is the fact that it may take years for the full effects of an ITS project to be realized in the transportation network, and furthermore in the economic development of a community. A tradeoff must occur between the

[4] Examples of ITS Evaluation Final Reports: http://www.its.dot.gov/evaluation/eguide_resource.htm#appb

availability of the ITS evaluation so that the results may be put into practical use, and the length of time that data is collected after the completion of an ITS project, but prior to completing the evaluation.

ITS Deployment Analysis System (IDAS)

The FHWA developed the IDAS[5] to help state, regional and local agencies easily and consistently assess ITS deployments. IDAS is a computer program designed to facilitate the systematic evaluations of more than sixty types of ITS investments deployed in isolation or combination. Among the inputs to IDAS are the outputs of transportation planning models, specifically network data files about the transportation network (nodes and links) and corresponding existing volumes. The user must enter information about the ITS project alternatives being considered. The IDAS program uses this user data in conjunction with the existing FHWA benefits and costs databases to run several databases (ITS component costs, construction and program costs, and benefits) to run the five modules of the program:

1. An Input/Output Interface Module (IOM)
2. An Alternatives Generator Module (AGM)
3. A Benefits Module
4. A Cost Module
5. An Alternatives Comparison Module (ACM)

As each of the modules is run, the user is given the opportunity to modify default data imported from the databases if a more accurate value is known. The ability of IDAS to fill in missing data using a standard database makes the program unique, although the user needs to exercise caution to ensure that default data is appropriate to the project being evaluated.

IDAS can perform the following analyses:

- Comparison and screening of ITS alternatives
- Estimation of impacts and traveler responses to ITS
- Estimation of life-cycle costs
- Inventory of ITS equipment, and identification of cost-sharing opportunities
- Sensitivity and risk analysis
- ITS deployment and operations/maintenance scheduling
- Documentation for transition into design and implementation

United States versus European ITS Evaluation Frameworks

The most mature ITS evaluation frameworks have been developed in the United States and Europe. IBEC provides training materials covering the general differences between the frameworks from these two regions.[6] The primary difference is that the European approach includes the development of the project aims and objectives and a pre-

[5] Information of IDAS is available at http://ops.fhwa.dot.gov/trafficanalysistools/idas.htm
[6] Library of ITS Evaluation Materials from IBEC can be found at http://www.ibec-its.org/library.htm

implementation objective, which lead up to a decision to proceed with the project. In the U.S. approach, prior to commencing the evaluation, it is assumed that the project goals have already been established and the project will be deployed. The European situation is also unique due to the number and proximity of different nations, many with differing transportation objectives. While in the U.S. ITS projects may require coordination across state boundaries, European ITS projects require coordination across national boundaries. Beyond these differences, the evaluation techniques are similar between the two regions.

As a part of the European Union TEMPO program, a set of guidelines was developed for Euro-Regional ITS Project Evaluations. Underneath these guidelines, European countries such as Finland and Sweden have developed ITS evaluation frameworks. These three documents will be discussed in further detail in this section.

Euro-Regional Project Evaluation

Under the Tempo Program and co-funded by the European Commissions, guidelines were developed to provide a high-level approach to ITS project evaluation. These guidelines are generic in nature, and describe very loosely the process and methods to be used. In the context of the European Region, the purposes of ITS evaluation are:

- Justify EU and National Government expenditure on the projects;
- Demonstrate the benefits (financial and socio-economic) of individual applications;
- Demonstrate the benefits of the Euro-regional projects as a whole; and
- Increase understanding of the impacts of ITS services.

Very general principles are given that should govern the development of individual ITS evaluation plans or an entire ITS evaluation framework:

- Be clear about reasons for undertaking the evaluation.
- Use and build on national approaches in order to ensure consistency across evaluations.
- Adopt national objectives with the framework.
- State the objectives of the application.
- Clearly describe the environment of the ITS application.
- Clearly describe the measurement approach.
- Use well-established indicators in measuring the impacts, thus improving the comparability of the results from different evaluations.
- Express the results in real, not just relative numbers.
- Clearly indicate the level of significance in the results.

The magnitude of the evaluation effort should be consistent with the expected benefits of the ITS application, scale of the project, certainty of outcomes being measures and other such considerations. A small, unique ITS project does not require a hefty evaluation. However, a small ITS project that is essentially a pilot study for much larger, but similar, projects, would justify a serious evaluation effort. For these situations, the framework gives a generic approach for pilot studies:

1. Produce an initial specification for the pilot including a description of the problem.
2. Identify the objectives and anticipated impacts of the pilot project.
3. Refine the specification based on these considerations.
4. Specify the evaluation data collection requirements.
5. Consider how the evaluation data collection specification might be met.
6. Confirm the overall pilot and evaluation data collection specification.
7. Implement the evaluation data collection program.
8. Analyze the data, considering:
   a) Technical performance;
   b) Impact assessment (including socio-economic);
   c) Financial performance; and
   d) User acceptance.

For more routine implementation projects, the generic approach is given as:

1. Document the problem.
2. Define the aims and objectives of the project.
3. Identify the expected impacts of the project, both positive and negative (technical, socio-economic, environmental, user acceptance, financial).
4. Identify appropriate performance indicators to assess these impacts.
5. Determine data collection requirements and approaches.
6. Collect "before" data.
7. Implement the application.
8. Collect "after" data.

To ensure consistency among the reports across the European region, TEMPO developed a framework for the reporting of results.

1. Key evaluation results
2. Description of the problem
   a) Site
   b) Issues Addressed
3. Description of the ITS project
   a) Objectives
   b) Systems and Technologies Applied
   c) Status of the project
4. Evaluation
   a) Timing and type of evaluation
   b) Objectives for the evaluation
   c) Impacts to be measured
   d) Methods to be employed
5. The impact of the project
   a) Technical performance
   b) Results
   c) Statistical Analysis
   d) Overall assessment

The JPO's ITS evaluation guidelines specify the basic content for a final report, but do not lay out the chapters and subsections in detail. Consequently, the sample reports given by the JPO contain similar content, but without a consistent arrangement of topics. Naturally, significant variations in content between reports are to be expected, given the wide range of ITS projects. However, the Euro-Regional guidelines underscore the importance of utilizing a consistent report to enable easy comparisons of results across evaluations. Ultimately, this will aid not only ITS evaluators within a particular country or region, but globally.

Finnish Framework

The Finnish *Guidelines for the Evaluation of ITS Projects*[7] are very thorough and cover the nuances of ITS evaluation in great detail. These guidelines were developed specifically for ITS projects by modifying existing Finnish transportation investment evaluation tools.[8] Like the U.S. JPO guidelines, these guidelines are more process oriented. The use of specific methods, such as benefit cost analyses, should follow standard Ministry of Transport and Communications documentation, such as the YHTALI framework. The overarching goal of this evaluation framework is to determine, primarily through the use of checklists, the potential impacts of ITS projects on the transport system, as well as users of all modes of logistics systems, and tie these goals to transport and information society objectives. Information society objectives are included because Finland is aiming to be a forerunner in information technology, by stating that knowledge and know-how are a part of the culture, and the main productive resource. Consequently, transport users, service systems, vehicles and infrastructure should utilize the full potential of ITS. Finland's transport policy objectives are:

- Transport system level of service and costs
- Safety and health
- Social sustainability
- Regional and community development
- Detriments to the environment

The guidelines, shown in Figure 1, follow the same general procedures as the YHTALI framework, with appropriate modifications for ITS investments. ITS projects typically have much smaller budgets relative to other transportation projects, and this should be taken into account in the calculations and method of presentation. The depth and scope of each evaluation should be determined on a project basis. This framework is primarily for new or supplemental ITS projects, as it neither provides a complete framework for

[7] The Finnish Framework can be downloaded in PDF format at http://www.ibec-its.org/evaluationhandbooks.asp or in Excel format at http://www.aino.info/hankkeet/5_palvelup/AINO_evaluation_framework_advice.xls

[8] Specifically, the existing Finnish transportation investment evaluation tool is the "YHTALI" report "Harmonisation of Assessment of Transport Infrastructure Projects" (Ministry of Transport and Communications 1994) and its two amending documents "Development Needs of Project Assessment in the Transport Sector" (Niskanen et al. 1998) and "General Guidelines for Project Evaluations" (Pesonen et al. 2000).

retrospective evaluation of individual ITS projects, nor for the assessment of the project implementation process.

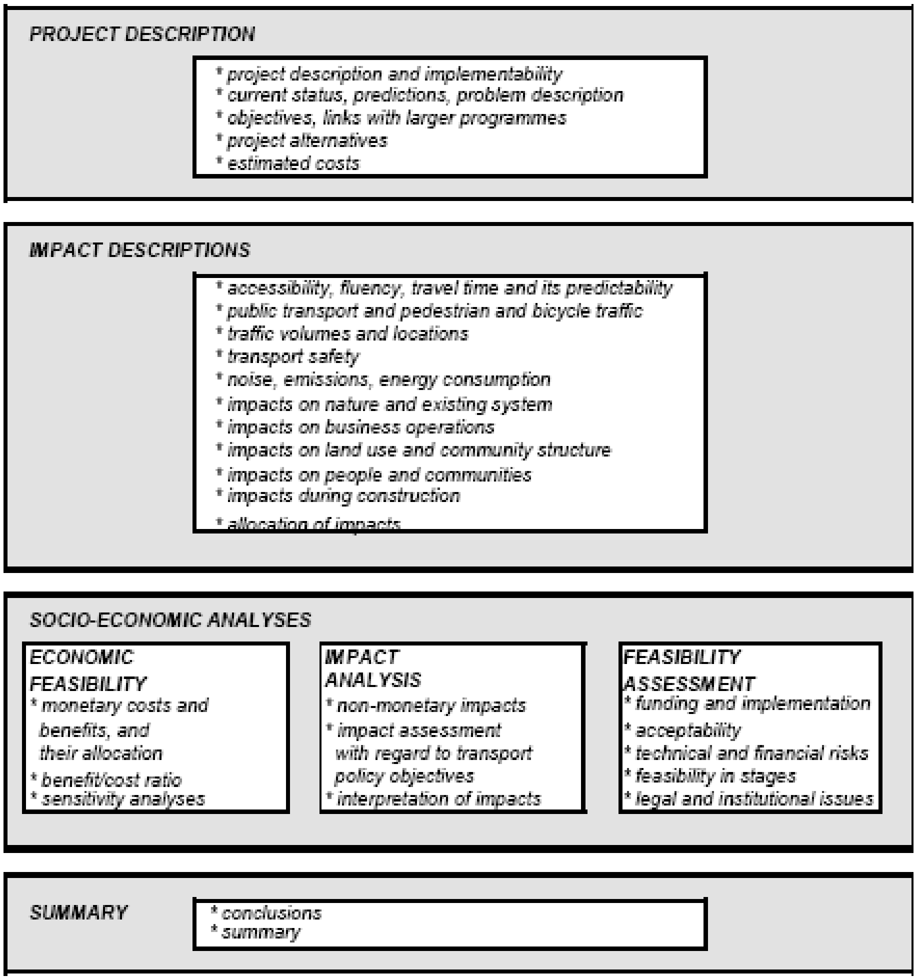

Figure 1. General Finnish ITS evaluation framework

The Finnish framework is unique in its approach to identifying the impacts of ITS projects. As mentioned before, numerous checklists are given (either in the report or in Excel format) which aid in identifying the primary and secondary impact mechanisms of an ITS function. Once this is determined, the impacts can be mapped to specific transport or information society objectives.

Once the impacts are determined, evaluation methods can be selected which will form the basis for the data collection effort. It is noted that sometimes the most ideal indicator cannot be measured easily or immediately, and in such cases another indicator should be selected. Appendix 2 of the Finnish framework provides tables with the desired evaluation methods for a variety of indicators, sorted by impact. The study should be designed to examine the impacts of an ITS project free of any intervening factors. Typically a before case is used, with two after cases: the immediate impacts and permanent (stabilized) impacts.

Some ITS functions do not have direct primary impacts, such as traffic management and information centers. In these cases, the evaluation should examine the impacts of a greater group of systems. From this perspective the subsystem can be evaluated to determine how well it is performing its own role in the system as a whole. The Finnish guidance notes that this requires care, as it is often difficult to map impacts of the system to individual subsystems. It is not recommended to allocate numerical values to the impacts of specific subsystems. Instead, evaluators should define objectives and end products for the subsystem, and assess the subsystem relative to these objectives.

Because ITS projects can differ so greatly from one another, the framework for analysis must be flexible. The point of comparison for evaluations is "Alternative 0", or what is the default scenario, and should be described in the project description. Usually this will be the "do nothing" option, where the ITS project is not implemented. But, it could also be that the ITS project is implemented, with the intention of avoiding or postponing other investments in transportation infrastructure.

The project should be evaluated quantitatively wherever possible using a standard socio-economic profitability analysis. Costs of transport, where benefits can be thought of in terms of reduced costs, are given in Figure 2. Project costs are relatively easy to determine, and can be broken down by component and subcomponent, as well as subsequent annual operating and maintenance costs. If benefits can be evaluated in monetary terms, cost-benefit, first year return rate or return on investment analyses become logical choices. If economic impacts are highly uncertain a sensitivity analysis should be provided, and multi-criteria analyses or verbal descriptions may be preferred. The Finnish framework also notes the evaluations can be performed on the market assessment, technical feasibility, human machine interface/interaction, financial issues, and the legal and institutional situation.

Project's implementation and maintenance costs*
Impacts on driving costs. Transport economy-related impacts with specified shadow prices
accident costs*
time costs*
vehicle operating costs*
environmental costs* (e.g. exhaust emission and noise costs)
Market-price impacts. Impacts in monetary terms that can be estimated / calculated
on the economic status of private persons (e.g. changes in service prices)
on corporate economy
on costs – not project-related – of transport infrastructure operators (e.g. savings in infrastructure maintenance costs due to transport telematics)*

* costs should primarily be included in the basic estimate

Figure 2. Transport costs[9]

[9] Ibid.

Significant guidance is also given to apply this framework to logistics ITS projects, where impacts transcend corporate and organizational limits. This is a similar format, but provides additional logistics-specific impact areas.

Finally, guidelines are provided for consistent preparation of summary and final reports, and examples are provided.

PLUTO Evaluation Framework (Sweden)

The Swedish National Road Administration's ITS Division has developed the PLUTO Evaluation Planning document as its ITS evaluation framework. This document is less detailed than the Finnish guidance, and focuses heavily on the evaluation process and the methods and statistics of data collection. The foreword provides a general rule of thumb that 10% of project investment costs should be allocated for evaluation, with this percentage higher for smaller projects, and lower for larger projects.

The Swedish evaluation process is visualized in Figure 3 as operating in parallel with the overall ITS implementation program. This process, shown in Figure 4 and in more detail in Table 1, is not intended as advanced assessment, or a predictor of the future, but rather to simply look back, assess what has been done, and provide guidance for the future.

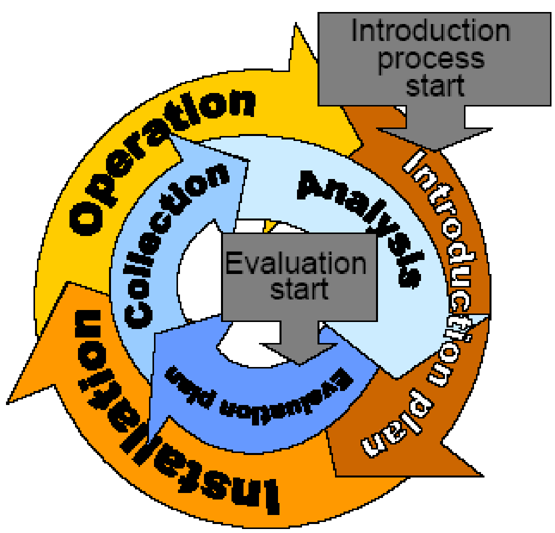

Figure 3. PLUTO vision of the evaluation process (inner loop) operating in tandem with the ITS implementation process (outer loop)[10]

[10] Taken from *PLUTO Evaluation Planning*, 2002.

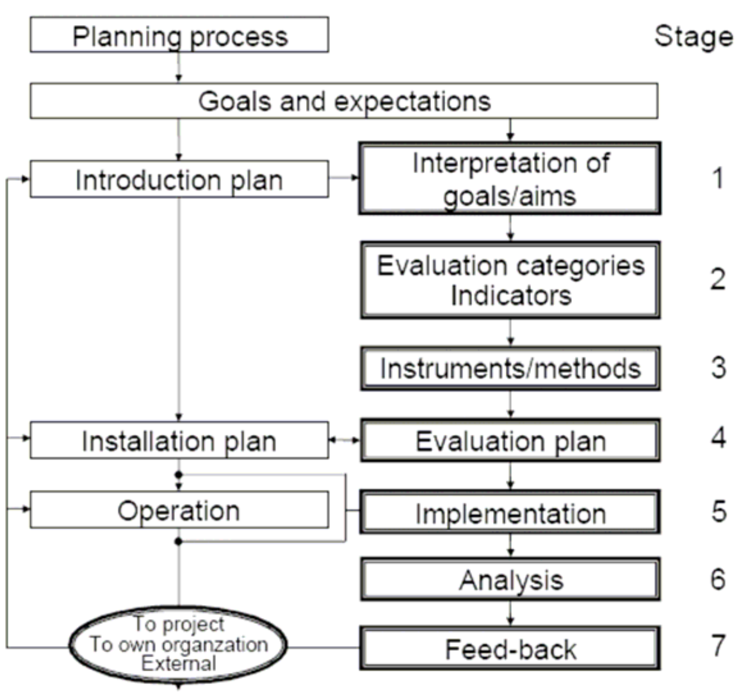

Figure 4. PLUTO ITS evaluation framework[11]

Table 1. Stages of the PLUTO Evaluation Planning Process

Stage 1: Define and break down vision and goals of the Project. **Phase 1.1:** Specify type of problem, need or ambition identified in the planning stage. **Phase 1.2:** Refine goals. When will they be achieved. Choose goals to serve as critical success factors. **Phase 1.3:** Trace other possible effects that are not apparent from goal description. (Effects on businesses, acceptance, other economic impacts) **Phase 1.4:** Formulate the aim of the evaluation **Phase 1.5:** Explain what evaluation results will be used for. (General public, decision makers, simply adding to knowledge-base…)
Stage 2: Choose evaluation categories and decide on indicators.
Stage 3: Select analysis method and data requirements.
Stage 4: Prepare evaluation plan. **Phase 4.1:** Describe all constituent activities and connection between activities. **Phase 4.2:** Alternative action plans if evaluation activities cannot be carried out. **Phase 4.3:** Preparation of activities needed to log all events that could influence evaluation results. This includes project organization and follow-up plan.
Stage 5: Data collection
Stage 6: Analysis **Phase 6.1:** Prepare data for analysis. **Phase 6.2:** Carry out analysis using methods selected in Stage 3.
Stage 7: Feedback and presentation.

[11] Ibid.

Like the Finnish guidance, the Swedish PLUTO framework begins by defining and breaking down the vision and goals of the ITS project. The following goal areas are given, with sub impacts provided for each area:

1. Vitality of the region
2. Quality of life
3. Impact of Traffic
   a) Road safety
   b) Accessibility
4. Mobility and accessibility for people and goods
5. Duties of road authorities and other public players

As noted in other evaluation framework guidance, it takes time for effect to filter down from immediate users to society, as depicted in Figure 5. This is an important consideration when determining goal areas of the project, and ultimately the data to be collected. The method of data collection is governed largely by the circumstances of the project such as quality requirements, time aspects and available resources. The PLUTO guidance provides guidance on numerous methods of data collection, listed in Table 2.

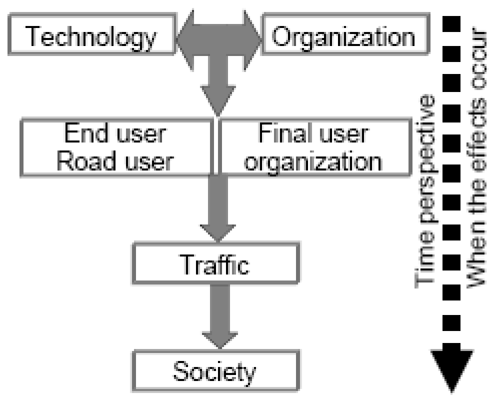

Figure 5. Effects of an ITS implementation moving from ends users to society over time[12]

Table 2. Methods of data collection described in PLUTO guidance

Questionnaire	Internet-based questionnaire	Interview
Roadside-based interview	In-depth interview	Stated preference
Driver observation	Interaction study	Conflict study
Traffic measurement with detectors	Number plate registration	Logging/Floating car measurement
Car shadowing	Video registration	Laboratory testing
Journal	Surveying	

[12] Ibid.

The PLUTO guidance is very general in describing how the evaluation should be documented, but examples are provided. Broadly, a communications plan should be developed early in the project, and followed throughout. The results should be documented in a way suitable to the evaluator's own organization and externally, keeping in mind the purposes and needs of the stakeholders that ordered the evaluation. If the report shows negative results for the performance of the ITS system, caution should be exercised when distributing the document to a larger circle. Such results will typically result in a modification of the ITS system, therefore making the evaluation report an academic exercise, rather than something that a larger audience should use to judge that particular ITS project.

Appendix C Lookup Table of Commonly Used Measures by Project Type

This section is intended to be used as a reference of common measures that are used for various types of ITS systems. While this is far from an all-inclusive list of the measures that can or should be used for a given system, it may provide the evaluator a starting point.

Purpose of ITS System	Commonly Cited Benefits / Measures
Arterial Management	• Reduction of emissions • Delay (Congestion / Incident / Transit) • Improvement in intersection LOS • Reduction in traffic violations (red light running, speed) • Accident reduction
Freeway Management	• Accident reduction • Congestion delay • Emissions
Incident Management	• Decrease of secondary incidents • Decrease in duration of stall incidents • Reduction of incident delay • Reduction of emissions • Incident response time
Traveler Information	• Reduction of emissions • Improved parking operations • Reduction of delay
Roadway Operations & Maintenance	• Accident reduction (rear-end, injury and fatal) • Reduction in average observed travel speed (if speeding is an issue) • Reduction in overweight trucks
Emergency Management	• Reduction in incident response time • Reductions in delay • Reduction of emissions
Road Weather Management	• Average speed reduction (during inclement weather) • Accident reduction • Accuracy of road treatment (e.g. salting operations)

Purpose of ITS System	Commonly Cited Benefits / Measures
Intermodal Freight	• Time savings per truck / shipment • Reduction in error rate (for shipment tracking, ID of contents, etc.) • Improved access to shipment status • Reduction in vehicle emissions • Expense reduction • Transit request acceptance / turn-down • Crime reduction
Transit Management	• Transit delay reduction • On-time transit performance • Customer complaint reduction • Improvement in transit LOS
Electronic Payment Systems	• Reduction in delay (vehicle, transit) • Accident reduction • Emissions reduction • On-time transit performance • Reduction in costs (operational and fare evasion)
Crash Prevention & Safety	• Accident reduction
Commercial Vehicle Operations	• Reduction in border delay • Reduction in emissions
Collision Notification Systems	• Collision notification time • Reduction in false notifications
Driver Assistance System	• Travel time savings • Reduction in accidents • Reduction in emissions • Improvements in fleet efficiency (for fleet tracking systems)