A FRAMEWORK FOR EVALUATING THE BENEFITS OF INTELLIGENT TRANSPORTATION SYSTEMS FOR COMMERCIAL VEHICLE OPERATIONS

by

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ABSTRACT

The incorporation of intelligent transportation systems into commercial vehicle operations (ITS/CVO) comprise many technologies that are designed to improve operational aspects of commercial vehicles and goods movement by streamlining the collection and exchange of vehicle/driver/carrier information (*e.g.*, safety, registration, licensing, tax payment) via emerging technologies and information systems. Various time and cost savings in addition to enhanced safety and security of freight transportation system are just examples of the benefits from deploying these technologies; however, there is always considerable uncertainty about what the impacts of deployment will be and what can be achieved with new applications.

The benefits and impacts of the ITS/CVO deployment can be demonstrated by evaluation. However, a review of the literature on ITS/CVO evaluation studies suggests that there have been inconsistencies among evaluators in all stages of evaluation processes from initial stages to reporting the benefits. For instance, lack of a consistent terminology among transportation professionals was found to be one of the issues in evaluation processes making the interpretation of the results difficult and sometimes misleading. Some of the other issues in evaluation studies include problems with availability and transferability of data, and uncertainties about new technologies and associated benefits for both public and private sectors.

This thesis explores these issues, while attempting to address them by developing a framework for evaluating the benefits of ITS/CVO projects. The methodology for developing the framework involves the following major steps:

1. Review of available literature to document current evaluation practices and reported benefits to date;

2. Analyses of all ITS/CVO market packages under Canadian ITS Architecture to identify their potential benefits;

3. Identification of issues relating to deficiencies in existing ITS/CVO evaluation practices;

4. Development of an ITS/CVO evaluation framework that addresses the key issues identified; and
5. Undertaking of a case study to demonstrate the practicality of the developed framework.

It is expected that the evaluation framework will assist evaluators to investigate the impacts of the proposed ITS/CVO deployment and to better quantify the benefits. The results of the evaluation should help decision makers to make future investment decisions on whether the deployment should be extended or dismantled.

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TO

MY LOVE, PARISA

GLOSSARY OF TERMS

ABBCS	Ambassador Bridge Border Crossing System
ACI	Advance Commercial Information
APTS	Advanced Public Transportation Systems
ATIS	Advanced Traveller Information Systems
ATMS	Advanced Traveller Management Systems
AVCS	Advanced Vehicle Control Systems
AVL	Automatic Vehicle Location
AVI	Automated Vehicle Identification
B.C.	British Columbia
BCA	Benefit-Cost Analysis
CBP	Customs and Border Protection
CBSA	Canadian Border Services Agency
CFIA	Canadian Food Inspection Agency
CIC	Citizenship and Immigration Canada
CMV	Commercial Motor Vehicle
CSA	Customs Self Assessment Program
C-TPAT	Customs Trade Partnership against Terrorism
CVIEW	Commercial Vehicle Information Exchange Window
CVISN	Commercial Vehicle Information Systems and Networks
CVO	Commercial Vehicle Operations
DCBF	Data Clearinghouse/Brokerage Facility
DSRC	Dedicated Short-Range Communications
ECRI	Electronic Clearance and Roadside Inspection

EDI	Electronic Data Interchange
FAST	Free and Secure Trade
FIRST	Frequent Importer Release System
FHWA	Federal Highways Administration
FOT	Field Operational Test
GTAP	General Trade Analysis Project
ICBC	Insurance Corporation of British Columbia
IFTA	International Fuel Tax Agreement
IMTC	International Mobility and Trade Corridor Project
IRP	International Registration Plan
ITBCS	Intelligent Transportation Border Crossing System
ITS	Intelligent Transportation System
ITS/CVO	Intelligent Transportation Systems for Commercial Vehicle Operations
IVHS	Advanced Vehicle-Highway Systems
JIT	Just in Time
MDA	MacDonald, Dettwiler and Associates
MDI	Model Deployment Initiative
MoT	Ministry of Transportation
MOU	Memorandum of Understanding
NATAP	North American Trade Operation Prototype
NPV	Net Present Value
OBU	On-Board Unit
OOS	Out-Of-Service
PIP	Partners in Protection Program
POE	Ports of Entry

RFD	Release on Full Documentation
SAFER	Safety and Fitness Electronic Records System
TDC	Transportation Development Centre
UBC	University of British Columbia
WIM	Weigh-In-Motion
WSDOT	Washington State Department of Transportation
XML	Extensible Markup Language

1. INTRODUCTION

1.1. BACKGROUND

Intelligent transportation systems (ITS) have received a great deal of attention in the transportation community as well as in governments over the last 15 years. The initial efforts were referred to as *intelligent vehicle-highway systems* (IVHS); however, with the increasingly intermodal focus on transportation problems, the scope was expanded to include modes beyond highways. The term ITS means different things to different people; however, ITS can be defined as the application of advanced technologies to the transportation system. ITS include a wide range of advanced tools for managing transportation networks, as well as services for travellers. These tools are based on three core features (*i.e.*, information, communications, and integration) that enable authorities, operators and individual travellers to make better informed, more coordinated and more intelligent decisions (Chen and Miles 1999). This means that rather than increase supply, ITS enhance system efficiency using advanced computing, real-time data, sensors, and communication technologies. The main objective is making transportation systems more efficient, safer, more secure, and environmentally friendly.

Commercial vehicle operations (CVO) can be defined as those operations associated with the movement of goods and passengers via commercial vehicles over the highway system, and the activities necessary to regulate such operations. The incorporation of intelligent transportation systems into commercial vehicle operations, ITS/CVO, comprise many technologies that are designed to improve operational aspects of commercial vehicles and goods movement by streamlining the collection and exchange of vehicle/driver/carrier information (*e.g.*, safety, registration, licensing, tax payment, *etc.*) via emerging technologies and information systems.

Electronic screening of vehicles is an example of ITS/CVO capabilities that requires installation of *weigh-in-motions* (WIM) scales in the main highways, and transponders in trucks (Figure 1.1). WIM scales enable inspection staff to measure the weight of trucks while they are moving at mainline speeds. A roadside reader communicates with truck transponder to obtain identifying information. The information is then processed by a computer to check the driver/vehicle/carrier history, the vehicle registration, tax obligation, and any other potential problems. If weight and all checks are good, the truck will receive a message by its transponder showing that the truck can be cleared without any need for pulling into the inspection site. The reliability of the system can be increased by selecting a certain number of trucks for inspection.

The *Commercial Vehicle Information Systems and Networks* (CVISN) Model Deployment Initiative (MDI) is one of the major programs that has been sponsored by the U.S. Department of Transportation (U.S. DOT) to demonstrate the practicality and benefits of new ITS/CVO technologies. The goal of the CVISN program is to improve safety and efficiency of commercial vehicle operations through three technology areas, including safety information exchange, electronic credentialing, and electronic screening. The U.S. *Federal Motor Carrier Safety Administration* (FMCSA) has defined three "levels" of CVISN program to allow incremental deployment of a specific set of capabilities by a state and its motor carriers (Richeson 2000). The CVISN Level 1 is a baseline for CVISN Level 2 and 3, which are still under development based on deployment capabilities of states, motor carriers, and core infrastructure systems. Table 1.1 represents a summary of CVISN Level 1 deployment whose requirements for the states include (Richeson 2000):

- Establishing an organizational framework among state agencies and motor carriers for cooperative system development;
- Establishing a State CVISN System Design that conforms to the CVISN Architecture and can evolve to include new technology and capabilities; and
- Implementing all the elements of three capability areas (as shown in Table 1.1) utilizing applicable architectural guidelines, operational concepts, and standards.

Programs such as CVISN and other ITS/CVO technologies are still in developing stages. Various time and cost savings in addition to enhanced safety and security of freight transportation system are just examples of the benefits from deploying these technologies; however, there is always considerable uncertainty about what the impacts of deployment will be and what can be achieved with new applications.

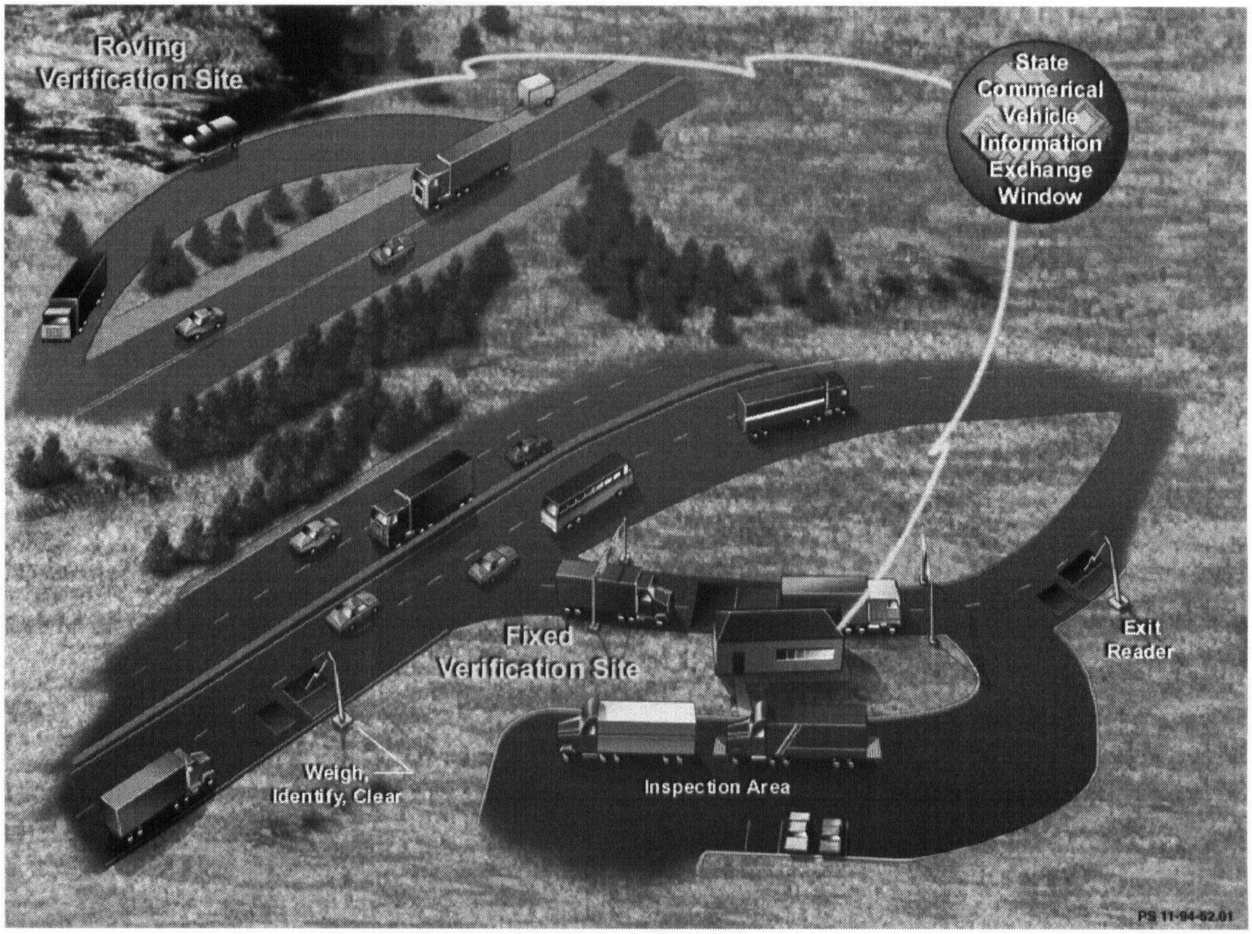


Figure 1.1 – Electronic screening operational concept (Richeson 2000)

The benefits and impacts of the project can be demonstrated by evaluation. Evaluation is an integral part of the project development process by which the desirability of various courses of actions are determined and presented to decision makers in a comprehensive and useful form (Meyer and Miller 2001). However, review of the literature on ITS/CVO evaluation studies suggests that there have been inconsistencies among evaluators in all stages of evaluation processes from initial stages to reporting the benefits. For instance, lack of a consistent terminology among transportation professionals was found to be one of the challenges in evaluation processes that make the interpretation of the results difficult and sometimes misleading. Some of the other challenges in evaluation studies include problems with availability and transferability of data, uncertainties about new technologies and associated benefits for both public and private sectors, and uncertainties about user's willingness to pay for the product.

Table 1.1 – CVISN Level 1 deployment (Richeson 2000)

Capability Area	CVISN Level 1 Capabilities
Safety Information Exchange	• Use of ASPEN (or equivalent software) at all major inspection sites • Connection to the *Safety and Fitness Electronic Records* (SAFER) system to allow states to exchange interstate carrier and vehicle snapshots • Implementation of the *Commercial Vehicle Information Exchange Window* (CVIEW) (or equivalent) system for exchange of intrastate and interstate snapshots and for integration of SAFER and other national and interstate data
Electronic Credentialing	• Automated processing (*i.e.*, application, state processing, credential issuance, and tax filing) of at least *International Registration Plan* (IRP) and *International Fuel Tax Agreement* (IFTA) credentials with readiness to extend to other credentials (*e.g.*, intrastate, titling, oversize/overweight, carrier registration, and hazardous material) • Connection to IRP and IFTA Clearinghouses • Minimum 10 percent of the transaction volume handled electronically, with readiness to bring on more carriers and readiness to extend to branch offices where applicable
Electronic Screening	• Electronic screening implementation at a minimum of one fixed or mobile inspection sites • Readiness to replicate electronic screening capability at other sites

It is believed that lack of a framework for evaluating the benefits of ITS/CVO projects is the major cause of aforementioned problems. A well-defined evaluation framework will assist evaluators to investigate the impacts of the proposed deployment and to better quantify the benefits. The results of the evaluation help decision makers to make future investment decisions on whether the deployment should be extended or dismantled. The results of the evaluation can also be employed to optimize the design and operation of the ITS/CVO deployment programs. This outcome is very important as due to innovative nature of ITS/CVO deployment programs, these programs are still facing challenges that retard the speed of their widespread deployment. Some of these challenges include technical barriers with communications among systems, challenges and costs of connecting to legacy systems, interoperability issues, and institutional issues.

1.2. FREIGHT TRANSPORTATION SECURITY

The events of September 11, 2001 raised the consciousness of the transportation and other communities about the security and robustness of critical infrastructure. There is a certain need for better critical infrastructure protection and crisis management, disaster planning and prevention, as well as effective detection and response, particularly in the case of deliberate terrorist attack (ITS America 2002). There is an agreement among knowledgeable observers on multi-faceted vulnerability of freight transportation systems to terrorist attack, due to the diversity, ubiquity, and openness of freight transportation systems (Wolf 2002).

The security of the freight transportation system can be improved by employing various ITS/CVO technologies that provide surveillance of commercial vehicles and freight equipment and interface with intermodal facilities. These technologies enable inspection staff to monitor the identities of vehicle/driver/carrier for consistency with planned assignment as well as for a breach or tamper event, and to keep track of commercial vehicle locations to determine if an asset has deviated from its planned route. On the other hand, ITS/CVO systems are also subject to security threats like any other information technology system and they must be protected to assure that their applications are reliable and available when they are needed.

A review of the literature on ITS/CVO evaluation studies clearly shows that security is "the missing link" of evaluation processes. Security is not even one of the ITS goal areas in the *ITS Evaluation Resource Guide* (ITS/JPO 2002) of the Intelligent Transportation Systems Joint Program Office, the U.S. Department of Transportation. This deficiency must overcome with an evaluation framework that introduces security as one of the major goal areas and considers vulnerability analyses of the proposed ITS/CVO deployment program as part of routine evaluation exercises. The outcome of employing this framework is to provide new information about security benefits of the proposed technology to the decision makers. The results can be utilized to introduce freight-related mitigation countermeasures for reducing negative impacts of potential attacks to freight transportation system.

1.3. PURPOSE AND METHODOLOGY

The purpose of this thesis is to address some of the issues by developing a framework for evaluating the benefits of ITS for commercial vehicle operations (ITS/CVO). The methodology for developing the framework involves the following major steps:

1. Review of available literature to document current evaluation practices (*i.e.*, evaluation in general and evaluation studies of major ITS/CVO projects in North America) and reported benefits to date;

2. Analyses of all ITS/CVO market packages under Canadian ITS Architecture to identify their potential benefits;

3. Identification of issues relating to deficiencies in existing ITS/CVO evaluation practices;

4. Development of an ITS/CVO evaluation framework that addresses the key issues identified; and

5. Undertaking of a case study to demonstrate the practicality of the developed framework.

1.4. THESIS STRUCTURE

The thesis is divided into six chapters. The first chapter provides an introduction to the thesis by including background information, an overview of the research problems, and a description of structure. Chapter 2 provides a review of the ITS/CVO evaluation literature and reported benefits from major ITS/CVO deployments that shed some light on specific issues related to developing the evaluation framework. Chapter 3 describes the Canadian ITS Architecture and its components for commercial vehicle operations. All Canadian ITS/CVO market packages will also be analyzed to demonstrate the potential benefits of employing each market packages. Chapter 4 begins with a brief description of major challenges for ITS/CVO deployments and evaluation practices followed by introducing a systematic guide for ITS/CVO project evaluation that can be employed as an evaluation framework. Chapter 5 presents an investigation on the practicality of the proposed evaluation framework through a case study, a commercial vehicle operations *data clearinghouse/brokerage facility* (DCBF) project. Chapter 6 contains the conclusions and recommendations developed from this research.

2. LITERATURE REVIEW

2.1. INTRODUCTION

The main objective of this chapter is to provide a review of several subject areas in the ITS/CVO and its evaluation literature in order to identify major issues that should be considered in an ITS/CVO evaluation process. Therefore, this chapter represents a comprehensive review of major ITS applications with emphasis on the applications for commercial vehicle operations, evaluation processes in general and the evaluation studies of major ITS/CVO projects in North America, and benefits found from major ITS/CVO deployments.

2.2. ITS USER SERVICES

There are a wide range of potential user services (or applications) for ITS, which conventionally can be grouped into five major areas, including, advanced transportation management systems (ATMS), advanced traveller information systems (ATIS), advanced vehicle control systems (AVCS), advanced public transportation systems (APTS), and commercial vehicle operations (CVO). It is worth noting that the word "advanced" in these terms was assigned to them in the early days of ITS and is now outdated because most of the technologies used in these systems are available off the shelf (Chen and Miles 1999). The Canadian ITS Architecture has a different categorization for ITS user services, which will be described later.

2.2.1. ADVANCED TRANSPORTATION MANAGEMENT SYSTEMS (ATMS)

Advanced transportation management systems (ATMS) integrate management of various roadway functions in order to ensure that road network capacity is used to its maximum. ATMS collect, utilize and disseminate real-time traffic data, predict traffic congestion and provide alternative routing instructions to vehicles and transit operators in order to improve the efficiency of the highway and transit networks and maintain priority for high-occupancy vehicles (Sussman 2000). Many cities in the world have adopted some kind of ATMS ranging from small microprocessor controllers for at-grade intersections with large variations in flow patterns (*i.e.*, complicated turning movements) to complex integrated systems controlling complete urban networks. ATMS combine various services, including traffic signals coordination in order to minimize delays and control queues; ramp metering in order to keep vehicle density below saturation on freeways; and incident detection and management (Chen and Miles 1999). Ramp metering, incident management, and demand management are some examples of various ATMS application areas.

2.2.2. Advanced Traveller Information Systems (ATIS)

ATIS provide accurate information to travellers in their vehicles, in their homes, at transit stations, or at their places of work. Information may include current traffic conditions, location of likely incidents, weather problems, optimal routings, and lane restrictions (Sussman 2000). The concept behind ATIS is that more information on system conditions will help the travellers make better-informed decisions about their journeys. Therefore, they can adjust their time, route, or mode of travel to their own advantage, which will also enhance the efficiency of intermodal transportation system. For instance, it may encourage drivers to change their routes to avoid a congested area, or to drive to a park-and-ride station and continue the trip by public transport. Simple examples of ATIS are radio traffic reports that inform drivers about traffic conditions, backups and collisions in different roadways. More advanced applications include traffic congestion maps and information about transit operations accessible over the Internet from home or work. Other ways of information dissemination are electronic *variable message signs* (VMS), traffic information systems using cellular phones, electronic kiosks with travel information, and cable television broadcasts of traffic conditions. Automatic warning systems using VMS or in-vehicle warnings to traffic approaching an incident are other forms of ATIS, which can greatly improve the safety of road network and reduce unnecessary delays. It is worth noting that ATMS normally precede ATIS in deployment. This is because of basic requirements of ATIS applications, which include detailed operational information of the transportation system that may be generated from ATMS, and a means to communicate that information in different forms to the traveller (Chen and Miles 1999).

2.2.3. ADVANCED VEHICLE CONTROL SYSTEMS (AVCS)

AVCS include any vehicle or road-based systems that improve safety and/or control to the driver, by either providing better information about the driving environment or actively helping the driver in the driving task. Technologies available include antilock braking, dynamic skid control, adaptive cruise control, and traction control. Other developing technologies include lane warning system, infrared night vision systems, driver drowsiness detectors, and automatic collision avoidance systems. A future application area of AVCS is *automated highway systems* (AHS) concept, by which vehicles will be automatically guided in the traffic while drivers do not have to operate their vehicles. While ATMS and ATIS have already been applied in many areas, AVCS, particularly AHS, is thought as a longer-term program. Sussman (2000) explains that AHS has had technical success; however, there are still political barriers that should be overcome due to high costs and difficulty in demonstrating benefits.

2.2.4. ADVANCED PUBLIC TRANSPORTATION SYSTEMS (APTS)

APTS applications are used to improve the efficiency and user-friendliness of public transit services. They include improved information systems to disseminate timetable, fare, and ridesharing information to users through the Internet and other media; automated fare collection systems; and vehicle locator systems for improved fleet management, increased security, and giving passengers information about real-time arrival time of the next bus (Chen and Miles 1999). The *Greater Vancouver Transportation Authority* (TransLink) makes trip itinerary available to its customers via telephone or the Internet. The system is linked to a GIS map display showing the roads, bus stops, and significant points of interest. Based on the origin and destination of the trip, software produces two or three optional itineraries, which can be used by the user (http://www.translink.bc.ca/). Common APTS applications include automatic vehicle location (AVL) system and public transit priority.

2.2.5. COMMERCIAL VEHICLE OPERATIONS (CVO)

In *commercial vehicle operations* (CVO), the private operators of commercial vehicles have already begun to adopt ITS technologies to improve the productivity of their fleets and efficiency of their operations. CVO utilize various concepts such as weigh-in-motion (WIM), preclearance of commercial vehicles across state, provincial and international boundaries, automatic vehicle location for fleet management, and on-board safety monitoring devices (Sussman 2000). There have been various ITS/CVO model deployment programs in North America. The *Commercial Vehicle Information Systems and Networks* (CVISN), a collection of information systems and communications networks that support CVO, is a major ITS/CVO program in the United States. The CVISN Level 1 deployment consists of three application areas, including safety information exchange, electronic screening, and electronic credentialing (Orban 2000).

2.3. WHAT IS EVALUATION?

"Evaluation is a tool to aid decision making" (Underwood and Gehring 1994). Evaluation is an integral part of the project development process by which the desirability of various courses of actions are determined and presented to decision makers in a comprehensive and useful form (Meyer and Miller 2001). The *ITS Evaluation Resource Guide* (ITS/JPO 2002) describes that evaluation makes it possible to determine how well project goals and objectives are being achieved by causing changes in the project and measuring if it meets or exceeds its goals and objectives. Brand (1994) explained that the development and evaluation of ITS plans and operational test require a methodology that be fully sensitive to the differences between ITS and conventional transportation improvements, and minimize double counting. To satisfy these requirements it is necessary to avoid underestimating the benefits from ITS while recognizing the occurrence over different periods of time of the same impacts under different names. Brand (1994) also discussed that an ITS evaluation methodology should be sensitive to the needs of different groups that benefit from the program; provide strategic direction; and rely on site-specific results as much as possible rather than "hoped-for achievement of benefits in a generic type of setting." These requirements can be realized by classifying the projects based on their location, then categorizing the projects by their relative merit within class, and finally "evaluating the absolute worth of candidate ITS projects for inclusion in a system plan or reporting the results of an operational test."

Evaluations can be qualitative or quantitative; however, employing a combination of both qualitative and qualitative analyses to compare and contrast converging and possibly conflicting evidence can result in better evaluations. The most effective evaluations can be achieved when goals and objectives are explicitly defined. Further, goals and objectives should be measurable, and agreed to by all parties involved. Meyer and Miller (2001) described three steps for determining the desirability of an alternative, including (1) define how the value can be measured; (2) estimate associate benefits and costs of the proposed action; and (3) compare these benefits and costs to determine how effective the alternative is. The *ITS Evaluation Resource Guide* (ITS/JPO 2002) recommends following six-step process for evaluating ITS projects:

1. Form the evaluation team;
2. Develop the evaluation strategy;
3. Develop the evaluation plan;
4. Develop one or more test plans;
5. Collect and analyze data and information; and
6. Prepare the final report.

McQueen and McQueen (1999) discussed that there are two major types of evaluation for ITS developments, namely, *formative* and *summative*. The former is performed during the development phase in order to keep it on track and reach the objectives. It can be viewed as a kind of "how's it going?" evaluation designed to provide short-term feedback into the development process. The latter is a retrospective look at the entire development effort in order to justify the work and discover lessons learned for the next time. The authors described a general approach to the economic evaluation of ITS as a "brain starter" for developing an evaluation approach that include:

1. Identify and confirm evaluation objectives;
2. Identify and characterize potential solutions;

3. Establish measures of effectiveness, performance parameters, and evaluation measurements;
4. Develop an evaluation plan;
5. Collect evaluation data and measure evaluation parameters;
6. Provide short-term formative evaluation feedback;
7. Provide medium-term summative feedback; and
8. Provide long-term summative feedback.

Virginia Tech Transportation Institute (VTTI) prepared an evaluation framework for Phase II of the Virginia Department of Transportation's (VDOT) I-81 ITS Model Safety Corridor Program, more commonly referred to as the I-81 ITS Program. The *I-81 ITS program evaluation framework* (VTTI 2003) proposes a step-by-step guide for designing ITS project evaluations that include: (1) determine if evaluation is appropriate; (2) choose goals, objectives and MOEs; (3) fill in project template; (4) choose evaluation methods; (5) select lessons learned questions; (6) draft an evaluation plan; and (7) report findings.

2.4. ITS/CVO EVALUATION STUDIES

As described earlier, three major areas of ITS technologies for commercial vehicle operations are safety information exchange, electronic screening, and electronic credentialing. The U.S. Department of Transportation (US DOT) has sponsored several field demonstrations of new technologies since 1991 (Orban 2000). Commercial Vehicle Information Systems and Networks (CVISN), and intelligent border crossing are examples of such tests. This section reviews evaluation studies of major ITS/CVO programs in the United States and Canada.

2.4.1. COMMERCIAL VEHICLE INFORMATION SYSTEMS AND NETWORKS

Richeson (2000) defines *Commercial Vehicle Information Systems and Networks* (CVISN) as a collection of information systems and communications networks that support commercial vehicle operations (CVO), including information systems owned and operated by governments, motor carriers, and other stakeholders (and excluding the sensor and control elements of ITS/CVO). The CVISN program can be seen as a framework or "architecture" that enables various stakeholders involved in CVO administrative, safety assurance, and regulatory activities (*i.e.*, government agencies, the motor carrier industry, *etc.*) to exchange information and conduct business transactions electronically. The goal of the CVISN program is to enhance the safety and efficiency of CVO.

Orban (2000) described that the services and technologies of CVISN Level 1 deployment consist of three functions or application areas, namely safety information exchange technologies, electronic screening systems, and electronic credentialing systems. *Safety information exchange* technologies help the enforcement officers at the roadside to collect, distribute, and retrieve more up-to-date motor carrier safety information. These data help in-transit compliance enforcement staff focus limited resources on high-risk carriers and drivers that help to reduce the number of crashes involving commercial vehicles. *Electronic screening* systems allow commercial vehicles with good safety and legal status to bypass roadside inspection and weigh stations. The result will be saving time and money for participating carriers and allowing states to assign more resources toward removing unsafe and noncompliant carriers. *Electronic credentialing* systems are used for electronic submission, processing, approval, invoicing, payment, and issuance of credentials; electronic tax filing and auditing; and participation in clearinghouses for electronic accounting and distribution of registration fee payments among states.

Bapna *et al.* (1998) conducted a study to investigate the net benefits of the CVISN deployment by the State of Maryland, based on the hypothesis that the net benefits of CVISN deployment were positive and large but varied among system components and between the state and the motor carrier industry. Their methodology consisted of both quantitative and qualitative analyses of the benefits and costs of the CVISN project. Two alternatives were the basis of their comparative analysis: CVISN deployment of an agreed-upon configuration and preservation of the status quo. The authors utilized the results of previous studies on ITS/CVO as the context for the benefit-cost evaluation as well as the basis for the qualitative portion of the study. They also used their survey data on savings in costs and time for the motor carrier industry and state agencies to calculate the benefits. The team quantified the safety benefits from CVISN enhanced weigh-in-motion (WIM) and motor carrier inspection using data modelled in other studies and applied them to the baseline data. Costs consisted of CVISN investment, maintenance and operating costs to the state. In addition, costs to the motor carrier industry for system components; for example, transponders, and computers for CVISN-derived credential processing activities and safety compliance activities, were added to the list.

Bapna *et al.* (1998) found that there are benefits to carriers and related state agencies from automated credentialing processing while there are also time saving benefits to motor carriers because of WIM and preclearance of legal and safe vehicles and drivers. The authors assumed that all transponder-equipped vehicles are identified by CVISN that result in benefits to society due to identification of potential high-risk carriers through inspection activities. There are also benefits to society due to identifying all illegally overweight carriers who otherwise may have caused accidents. Bapna *et al.* (1998) listed several additional benefits that have not been captured in their study, including:

- fiscal benefits to state safety agencies because of automated identification of high-risk vehicles/drivers, and preclearance of commercial vehicles;
- increased IRP (*i.e.*, *International Registration Plan*) and IFTA (*i.e.*, *International Fuel Tax Agreement*) revenues due to improved monitoring of carrier activities;
- benefits due to identifying high-risk vehicles/drivers based on the ASPEN system (ASPEN is a laptop-based system that allows safety inspectors to enter inspection reports at the roadside and forwards them to CVIEW; *i.e.*, *Commercial Vehicle Information Exchange Window*);
- better business environment for motor carriers that makes the state more competitive in attracting other business;

- less credential processing costs to agencies due to the integration of information systems from deployment of CVISN and consequently decreased use of resources devoted to redundant systems;

- reduction in reconstruction and maintenance to highways since all overweight motor carriers will be detected; and

- improved safety since fewer trucks will enter a weigh and inspection station, thereby lessening the number of merges of commercial vehicles into the highway.

Bapna *et al.* (1998) also conducted qualitative analyses as a verbal accounting of any "costs and benefits" for which dollar values could not be assigned. Examples are the environmental and social impacts of a project. Therefore, the authors discussed those impacts as well as safety implications that could not be readily quantified. They also made various assumptions because the CVISN project has so many unique and undefined aspects to it and similar systems with proven "track records" do not exist elsewhere. Examples include the values of time and cost savings and system costs, the rate of acceptance of technologies by carriers, the percentages of unsafe motor carriers affected, and the safety benefits attributed to it. Due to such uncertainty, a sensitivity analysis of results was done, involving ranges of benefit and cost values and discount rates, in order to see how sensitive the results are to the assumptions underlying them. The benefit/cost analysis proved the economic feasibility of the CVISN project. The benefit/cost ratios ranged from 3.28 to 4.68 for the worst and best case estimates for the benefits modelled. The net present values (NPVs) ranged from $76 million to $123 million. For agencies and carriers, the worst-case benefit-to-cost (B/C) ratios were 1.45 and 6.67, respectively. Due to the competitive nature of the commercial vehicle industry, the benefits accrued by carriers would be passed on to receivers, shippers, and, eventually, the consumers and citizens of Maryland.

In another study, Battelle (2002a) examined CVISN and evaluated the impacts of electronic screening, electronic credentialing, and safety information exchange on commercial vehicle operations in "truck shed" states (*i.e.*, Maryland, Virginia, Connecticut, Kentucky, and Oregon). Program evaluators used model data and field studies to evaluate safety, costs, and customer satisfaction. The results of limited field testing indicated that

Inspection Selection Systems (ISS) used in combination with manual inspection procedures increased out-of-service (OOS) order rates by 2%. The model predicted safety impacts for a number of different potential deployment scenarios that weighted "direct" and "indirect" benefits of CVISN. The "direct" scenario increased the rate of OOS orders if motor carrier targeting was improved. The "indirect" scenario improved motor carrier safety compliance if motor carrier perception of strict enforcement was improved (Battelle 2002a).

Battelle (2002a) conducted in-person interviews to obtain cost data from motor carriers and state agencies participating in the *International Registration Plan* (IRP), and *International Fuel Tax Agreement* (IFTA). The results, however, were limited to only a few states with progressive CVISN programs, which include:

- Three motor carriers indicated that electronic credentialing resulted in less paperwork and saved them 60-75% on credentialing costs.

- In addition, motor carriers were able to print their own credential paperwork without waiting for conventional mail delivery that enabled them to commission new vehicles 60% faster.

- System start-up costs for motor carriers were minimal as training and equipment were limited to typical desktop computer operations.

- Kentucky and Virginia estimated that the state overhead costs for maintaining motor carrier accounts would decrease 35% for each motor carrier participating in electronic credentialing.

The study emphasized that the applicability of these results to other states was unknown. Customer satisfaction was evaluated using mail-in surveys, personal interviews, and focus groups and the following results were reported (Battelle 2002a):

- The major concerns of motor carriers were on the cost-effectiveness of electronic screening methods and the expansion of state regulation.

- Standards governing the rules and procedures for inspection selection were the major concerns of truck drivers.

- Time saving was the general feeling of truck drivers who experienced electronic screening.

- Time savings as well as enhanced speed and accuracy of data reporting were general felt by CVO inspectors participating in interviews and focus groups of CVISN technology.

The report (Battelle 2002a) summarized the nationwide benefits and costs of electronic credentialing and roadside enforcement by evaluating different levels of deployment and system effectiveness over a 25-year period. Three different scenarios of roadside enforcement were modelled, including no screening; screening with no change in compliance; and screening with improved compliance. Two different scenarios of electronic credentialing were modelled that include:

- VISTA (*i.e.*, *Vehicle Information System for Tax Apportionment* to coordinate IRP data between state credentialing administrators and the state's registration database); and

- No VISTA.

The analysis conducted by Battelle (2002a) considered start-up costs, operating costs, and crash avoidance over the expected lifetime of the technology. The future costs and benefits were compared to 1999 dollars using a discount rate of 7%. Benefit/cost ratios ranged from 0.62 (not economically justified for a minimal deployment of roadside enforcement) to approximately 40 (highly beneficial for full deployment of electronic credentialing). The authors noted these results were highly dependent on the level of deployment, integration, and cooperation between states.

In a similar study, Brand *et al.* (2002) conducted a benefit-cost analysis using the results of model deployment of the CVISN program and reported the CVISN benefits and costs and their measures included in their benefit-cost analysis as shown in Table 2.1. The authors used most of the credential cost data from Kentucky and Maryland, and most of the cost information for CVISN electronic screening and safety information exchange services from Connecticut and Kentucky. All of the data used in the benefit-cost analysis were derived from a series of on-site, in-person interviews with state agencies and motor carriers who participate in electronic credentialing programs. This was the first study of actual deployment of CVISN system and therefore, the data collection was limited to the few states that had sufficient experience with the deployment and operation of these systems as well as literature review. The authors concluded, based on the benefit-cost analyses for different roadside enforcement as well as electronic credentialing scenarios that the deployment of CVISN would result in significant benefits to all stakeholders (*i.e.*, the states, motor carriers, and the public). Benefit-cost ratios were found to be the highest for those applications involving more complete CVISN systems for roadside enforcement.

Table 2.1 - CVISN benefits and costs (Brand *et al.* 2002; Battelle 2002a)

CVISN Application	Benefits	Costs
Roadside Enforcement (including safety information exchange and electronic screening)	• Truck crashes avoided • Transit time saving • Air and noise pollution reduction from trucks bypassing inspection stations at highway speeds	• One-time start-up cost to state • Replacement capital costs to states • Increased operating costs to states • Increased operating costs to carriers • Increased out-of-service costs to carriers
Electronic Credentialing	• Operating cost savings to states • Operating cost savings to carriers • Inventory cost savings to carriers	• Electronic credentialing: • One-time start-up cost to states • Replacement capital costs to states in future years

Battelle (2002b) studied the use of SAFER (*i.e.*, *Safety and Fitness Electronic Record*) data mailbox in I-95 commercial vehicle operations in order to evaluate the effectiveness of using current safety performance data, and identify intuitional issues and benefits related to the use of this technology. They proposed a set of tests, representing a variety of data collection and/or analysis efforts to address the evaluation goals and hypotheses, which include inspector interviews, inspector surveys, driver and motor carrier surveys, Connecticut roadside study, SDM utilization/data timeliness/response times, SAFER cost and institutional benefits survey, and ATA (1996).

2.4.2. INTELLIGENT TRANSPORTATION BORDER CROSSING SYSTEM

The *Intelligent Transportation Border Crossing System* (ITBCS) was one of the *North American Trade Operation Prototype* (NATAP) pilot studies at the Peace Bridge, which is a major link between the Queen Elizabeth Way (to Hamilton and Toronto) in Ontario and the New York State Thruway (I-90), as well as direct access to Buffalo, New York. The ITBCS is a transponder-based system that identifies load-driver-vehicle combinations moving across the bridge. It was intended to speed up the processing of both customs and immigration processing. Nozick *et al.* (1999) developed a simulation model to investigate the potential effects of the ITBCS technology at the Peace Bridge as an example of advanced technologies impact study on commercial border crossings. The authors developed U.S. and Canadian models in a similar way. Information about the processing logic and physical layout was obtained via site visits and interviews. The major sources of data used for development and calibration of the model were from a study of the Peace Bridge conducted by McCormick-Rankin, Inc., several unpublished U.S. Customs documents, and data collected on site (Nozick *et al.* 1998, 1999).

The authors reported special interest in processing time for primary and secondary inspection, as well as toll collection, broken down by proper vehicle classifications. The authors recognized six different general classifications of trucks entering the border, which include (Nozick *et al.* 1998, 1999):

- Monthly (are almost precleared for crossing the border; file customs paperwork on a monthly basis; rarely go to secondary inspection; generally carry automobiles or auto parts);

- In-Transit (are passing through one or both countries; rarely sent to secondary inspections);

- Line Release (are part of an expedited crossing program for high volume, low risk repetitive shipments; based on their paperwork can be released directly by primary inspectors; occasionally are sent to secondary inspection);

- ITBCS (have been upgraded with information technology to expedite the clearance process; are the main focus of impact assessment);

- Empty (are empty; see just inspections related to the driver and the truck); and

- General (do not fall into any of the above-mentioned categories; have the longest processing times; highest likelihood of being sent to secondary inspection).

Nozick *et al.* (1998) reported that the time required by any of the vehicles to cross the border is affected by various factors. Inspection rates and procedures can be different based on commodity type, previous history of shipper and the transportation company as well as the level of congestion at the border crossing. However, the process would be faster if more information were available to the primary inspector while or even before the truck enters the booth. Therefore, using advanced information technologies enhances the effectiveness of the system. The simulation model was developed using *Arena*, a commercially available simulation modelling environment. *Arena* is a general-purpose visual simulation environment that has evolved over many years and many versions. It first appeared as the block-oriented SIMAN simulation language, and was later improved by the addition of many functional modules, full visualization of model structure and parameters, improved input and output analysis tools, run control and animation facilities, and output reporting (Altiok and Melamed 2001). Therefore, *Arena* provides the modelling elements for defining the entities, their attributes, logical connection between activities, resource requirements for those activities, as well as animation capabilities and automated statistics collection (Nozick *et al.* 1998). After model calibration and validation, the models were adjusted to create various ITBCS scenarios in order to investigate the range of impacts that might result. The authors stated that the structure of the simulation model was intended to be relatively generic. This was due to high level of similarities among *Ports of Entries* (POEs) in layout and procedures followed for the processing of commercial traffic. Therefore, with minor modifications in the simulation model, it could be used for analysis of border-crossing processes at various POEs. The focus of the simulation model was on processing of trucks and automobiles through various customs and toll activities. The model used probability distributions for representing the times for various activities, which include time between successive truck arrivals, time needed to weigh the vehicle and pay toll, primary inspection time, time to park truck, time needed with broker, time for paperwork inspection in secondary, time needed to move truck into bay, and time needed to inspect cargo. The model generated performance measures, which include (Nozick *et al.* 1998, 1999):

- Total time in system (*i.e.*, the time required for a vehicle to go through the entire crossing process), in aggregate, and disaggregate by vehicle class;
- Delays in the queue waiting for primary inspection;
- The number of trucks in the secondary inspection area, by time of day; and
- Utilization of the primary and secondary inspectors and toll collectors.

The results showed that the introduction of ITBCS technology could clearly have a considerable impact on the performance of the facility. The study also showed that there was a critical interval of time for the system to respond to the presence of a truck entering the primary inspection booth, and reducing the response time so that the information was already on the screen when truck stopped could produce even more savings in delay. Nozick *et al.* (1999) recommended that a strategy of downloading records associated with truck entry to a local computer before the arrival of the truck in the primary lanes would be likely effective to fulfil rapid response times. The study also considered a variety of scenarios for both U.S. and Canadian sides of the bridge, ranging from base-case conditions to extensive market penetration of the ITBCS technology, in order to evaluate the potential effectiveness of implementing advanced information technology at the Peace Bridge. On the U.S. side, scenarios were developed by the study team for transponder usage between 0% and 50% of vehicles equipped. Comparing 0% to 50% of transponder usage, both trucks and autos received significant time savings. Trucks saved an average 66% overall in inspection times. Most of this savings is due to a 64% reduction in the number of trucks sent to secondary inspection. Time is reduced 34% for those trucks sent to secondary inspection. Average time for autos in the system drops 35%. A set of similar scenarios was also developed for the Canadian side. Time for trucks in the system was reduced 40%. Primary inspection times for trucks were reduced 14%. For autos, it was shown that at 35% participation one lane could be dedicated to ITBCS to handle the demand effectively. However, large delays occur at 50% participation if two lanes are not dedicated to ITBCS. Nozick *et al.* (1999) also conducted an investigation of the institutional issues that commenced during the pilot study and those that would have to be overcome to achieve permanent deployment. To achieve the above-mentioned benefits, the authors emphasized on overcoming significant institutional barriers via inter-agency collaboration and cooperation.

2.4.3. AMBASSADOR BRIDGE BORDER CROSSING SYSTEM

The *Ambassador Bridge Border Crossing System* (ABBCS) was another project to examine the *North American Trade Automation Prototype* (NATAP) operations at the U.S. Customs facility at the Ambassador Bridge in Detroit, Michigan. Booz-Allen and Hamilton (2000) evaluated the ABBCS Field Operational Test. The main purpose of this study was to demonstrate the ability of intelligent transportation systems technology to speed up both commercial vehicles and commuter international border crossings in an operational environment. "The ABBCS project objective was to develop and demonstrate an integrated system that would allow pre-processed vehicles, trade goods, and commuters to pass through international border checkpoints with expedited customs, immigration and toll collection processing" (Booz-Allen and Hamilton 2000). In-vehicle transponders and roadside position identification and classification equipment were used to gather pre-processed information for assessing the crossing status of a vehicle, its contents, and its occupants, as well as for toll collection.

Booz-Allen and Hamilton (2000) attempted to evaluate the technical performance capabilities of the technologies being used, its impacts, and user acceptance of provided technology. Simulation modelling techniques were used for evaluating potential benefits derived through improvements in information technologies. The focus of the model was on evaluating how ITS technologies would improve overall efficiencies, time savings, and safety. The data needed for the study was collected via a combination of research, surveys, and interviews. Booz-Allen and Hamilton (2000) found that the decision to use a transponder-based *dedicated short-range communications* (DSRC) system was conceptually sound. The authors also stated that proper combination of system deployment and lane configuration would be expected to have a significant positive impact on the traffic conditions on the bridge. The authors reported that import processing using ABBCS was conducted in parallel with, rather that in place of current processes, which resulted in more workload and delay to bridge users than any efficiency benefits. This is one of the major barriers for implementing the real system because the potential cost advantages of electronic border screening will not be realized until bridge users can be convinced that using the ABBCS will benefit them.

In another study, Mitretek Systems (1999) examined the NATAP operations at the U.S. Customs facility at the Ambassador Bridge in Detroit, Michigan. The authors simulated the deployment of NATAP equipment to cars, trucks, and custom inspection stations at levels greater than could be achieved during the Field Operational Test (FOT). Mitretek Systems (1999) used the *Westa* (weigh Station) simulation model to represent the current and alternate scenarios. Westa is a micro-level simulation tool designed for modelling weigh stations on highways or any vehicle inspection or toll-collection station, which can be used for evaluating operational performance under different scenarios, inspection capabilities, and station configuration. It is capable of simulating inspection and toll collection facilities with a series of straight or curved one-lane links, where each vehicle moves along a series of links from an origin to a final destination. Vehicle characteristics were introduced to model by vehicle class, built-in vehicle characteristics (*i.e.*, weight, length, maximum acceleration rate, and maximum deceleration rate), and user-specified characteristics (for example, presence of transponder, HazMat status, *etc.*). The driver-characteristics component of Westa was another major part of the simulation, which provided a means of simulating variations in driver behaviour, including speeding, aggression, and perception/reaction times. Westa can simulate seven types of links including origin, transit, destination, scale, branch, parking lot, and building. It also uses two independent streams of pseudo-random numbers during the simulation, one for determining vehicle characteristics and arrival times, and another one for determining weighing, inspection, toll payment, and other activities involving delay times (Mitretek Systems 1999).

Data for the base (current) scenario were collected at the bridge by Booz-Allen and Hamilton and by bridge operations authorities. Four separate measures of system impact were identified for the simulation, which include (Mitretek Systems 1999; Booz-Allen and Hamilton 2000):

- Percent of peak hour with truck blocking gore (*i.e.*, the amount of time that the queue of trucks awaiting primary inspection extends back to the bridge span);
- Number of queued trucks awaiting primary inspection (*i.e.*, the total number of trucks in queue for primary inspection);
- Time savings for ABBCS (NATAP) trucks (*i.e.*, reduction in the average time necessary for participating trucks to traverse the entire simulation window); and
- Overall timesaving (*i.e.*, the reduction in the average time necessary for all trucks to traverse the entire simulation window).

Initial investigations for the base-case scenario showed the congestion at the bridge, which could be likely prevented just by providing another customs inspection lane. Based on recommendations from Booz-Allen and Hamilton, Mitretek Systems (1999) designed alternate scenarios and ran multiple iterations of the base and alternate scenarios, using different levels of cars and trucks equipped with electronic NATAP transponders. For truck customs processing, three sets of analyses were conducted accompanying to scenarios where there were three, four or five lanes were available for primary inspection. For each set, the authors considered the proportion of trucks with NATAP transponders to change from 5% to 75%, and the policy for lane usage to vary among (a) dedicated to NATAP trucks, (b) non-NATAP trucks only, and (c) mixed use allowing either type of truck. The results showed shorter queues and reduced risk of gore blocking with sound alteration in primary inspection lane configurations due to increase in NATAP participation. The results of the simulation clearly proved that systems such as ABBCS have the potential to have positive effects on the conditions on and around the U.S. end of the bridge (Booz-Allen and Hamilton 2000).

2.4.4. ELECTRONIC CLEARANCE AND ROADSIDE INSPECTION SYSTEM

In one of the recent studies in Canada, Tri-global Solutions Group (2003) conducted a study for Transport Canada to present feasible business models of an *electronic clearance and roadside inspection* (ECRI) system for Canada, in order to "improve the safety, compliance, efficiency and effectiveness of commercial vehicle operations in Canada and U.S." (Tri-global Solutions Group 2003). The authors attempted to develop ECRI systems based on reviewing existing systems and models in the United States, relevant technologies and technical requirements, and considering Canadian business requirements, as well as goals of the ECRI project. The authors developed five models for ECRI with differences in the degree of public and private sponsorship, three of which were fully implemented by Canadian agencies, and two that could join either U.S. NORPASS or PrePass. The five models, which were qualitatively analyzed and evaluated, were as follows (Tri-global Solutions Group 2003):

Model 1 - Fully Public: All aspects of the system are financed and controlled by government agencies, and the government has full ownership of all data collected in the system. This is similar to U.S. NORPASS; however, in NORPASS carriers may be required to pay for their transponders while here, transponders will be provided to the carriers at no cost or break-even cost. The model would be developed with full interoperability with Canadian system, and the government has full control of clearance checks.

Model 2 – Public/Private Combination: In this model, government pays for the transponder registry maintenance, the data exchange functions and all of the required capital and operating/maintenance costs. The transponders will be provided by a private agency and purchased by the carriers from this agency at a price selected by the private agency, which may be subject to government regulations. The government sets national standards for transponders and the model would be fully interoperable using these standards. The government has full control of clearance checks. The information would be collected and transferred via a government owned and operated system.

Model 3 – Fully Private: All aspects of the system are financed and operated by private agencies similar to U.S. PrePass; however, the government would monitor and audit the system to ensure that all regulatory, safety and security issues are being adhered to. Carriers pay for the transponders as well as for the ability to bypass either in a pre-pass or a regular monthly or annual fee. The government will be involved in setting standards to ensure full interoperability of the model. The model requires a monitoring/auditing system by the government in order to ensure that all regulations and safety checks are being fully enforced. "The data exchange system would be linked to government-held information regarding safety status, insurance, *etc.*" There are also requirements for technical standards for communicating between third parties, as well as concerns for privacy and security of data exchange that should be resolved before implementing the system.

Models 4 and 5 – Join an Existing U.S. Program: These models assume that a Province or Canada as a whole joins an existing U.S. ECRI program such as NORPASS or PrePass. The models also allow that provinces join different programs depending on their needs and philosophy. Before making a decision on joining a U.S. program, the models require reviewing issues such as interoperability, compliance control, national security, costs, technical standards, data access and exchange, as well as negotiating with U.S. program operators. Program interoperability would be one of the major issues for discussion within Canada and with the program(s) being joined. The Federal Government should set up rules and standards for interoperability at least within Canada, clearance checks, and data exchange system.

Tri-global Solutions Group (2003) evaluated the above-mentioned models qualitatively assuming a participation rate (percent of trucks participating with an OBU) rising to 50% over a period of 10 years, starting at 2005 where the participation rate is 10%. The criteria for qualitative analysis and evaluation of models included effectiveness at meeting the goals of Transport Canada, expected carrier impacts and attitudes, Government philosophy, and interoperability. The study team also conducted benefit-cost analyses to economically evaluate benefits and costs associated with the project. The authors included three different business models in the analyses, which were characterized mainly based on who was paying for each component of the ECRI system, namely, Public, Public/Private, and Private. Tri-global Solutions Group (2003) considered four different perspectives in analyzing the benefits and costs associated with each model, including Social, Carrier, Concessionaire, and Government. The authors also developed a spreadsheet model to evaluate benefits and costs of a national ECRI system.

The results of the benefit-cost analysis showed that an ECRI program could be economically justified from different perspectives. The Social B/C ratio varied from 2.7 for the Private Model to 4.4 for the Public and Public/Private Models. Carrier B/C ratios showed positive impacts, ranging from 1.1 for Private Model (due to paying for transponders and bypass fees) to 7.5 and more than 10 for Public/Private and Public Models. The authors described that for the Concessionaire, the economic performance was related to the market price charged by the concessionaires, which was outside the scope of a benefit-cost analysis. The Concessionaire B/C was estimated to be 1.1 for Public/Private and 2.1 for Private Model. The Government B/C ratio varied from 1.1 for the Public Model to 1.9 and 5.0 for Public/Private and Private, respectively. Sensitivity testing was performed to test the models by varying model variables such as station volume, participation rate, billing costs, and social discount rate. Tri-global Solutions Group (2003) found that some variation of a Public/Private model was the best model for maximizing the net benefits from the social perspective while achieving equity between the costs and benefits to each sector.

2.5. ITS/CVO BENEFITS

Reviewing the literature (Bapna *et al.* 1998; Booz-Allen and Hamilton 2000; Brand *et al.* 2002; Battelle 2002a; Nozick *et al.* 1998, 1999) clearly shows that applications of intelligent transportation systems for commercial vehicle operations (ITS/CVO) are expected to have many positive impacts. Examples of these impacts include less costly commercial vehicle credentialing, more effective safety inspections, and transit time savings for commercial vehicles with good safety compliance records by enabling them to bypass inspection stations at highway speeds in most cases. The latter may also result in motivating carriers to improve their safety compliance behaviour. Commercial vehicles bypassing inspection stations will not only save time for themselves and their cargo, but also they provide energy savings and air and noise pollution benefits for the public. Of most importance to the public, however, are the cost savings and enhanced efficiency to the states and carriers, and the improved targeting for inspection of unsafe vehicles via new information systems available. Removing unsafe commercial vehicles from highways will have positive impacts in the value of lives saved, injuries avoided, reduced property damage to trucks, their cargo, and to other vehicles, and reduced delay to all vehicles from congestion due to crashes. Most of the benefits and costs included in various evaluation studies have been derived from the hypothetical impacts of the CVISN pilots on the customers of CVISN. Some of the benefits will be discussed in following sections.

2.5.1. SAFETY

Bapna *et al.* (1998) stated that safety is an integral and important feature of CVISN and investigated that safety benefits include decreased accidents and decreased travel time by legal and safe carriers. The authors attempted to model two factors that result in decreased accidents: high-risk vehicle and/or driver identification, and identification of illegally overweight vehicles. In a study on using SAFER data mailbox in I-95 commercial vehicle operations, Battelle (2002b) found that using more current and accurate inspection data, as provided by computer-based inspection technologies, helped inspectors (a) target their inspection efforts better, (b) find recent out-of-service orders more readily, and (c) spot patterns in motor carrier violations more easily. Battelle (2002a) investigated that most important benefit expected from the deployment of CVISN technologies, especially electronic screening and safety information exchange, was a reduction in commercial vehicle related crashes through improved enforcement of the U.S. *Federal Motor Carrier Safety Regulations* (FMCSRs). They tested two hypotheses (Battelle 2002a):

- CVISN technologies would help enforcement staff focus inspection resources on high-risk carriers.
- The increased attention on high-risk carriers would encourage motor carriers to improve their compliance with safety regulations.

The former would result in more *out-of-service* (OOS) orders for the same number of inspections—thereby removing from service additional trucks and drivers that would have caused crashes because of vehicle defects and driver violations of safety regulations. The latter refers to the number of crashes that would have been caused by violations in safety regulations, but are avoided due to improved compliance.

Bapna *et al.* (1998) derived the safety benefits by the additional numbers of vehicles and drivers placed out-of-service by CVISN at roadside inspections. The authors believe that additional out-of-service vehicles and drivers would result in decreasing the accident rate, and therefore, it was quantitatively modelled in that analysis. For such an analysis, the benefits of placing vehicles and drivers out of service were first calculated in the existing inspection system. These figures were then used to estimate the benefits of CVISN to aid in identifying high-risk carriers. The study team developed a methodology based on methodologies used in the Office of Motor Carrier study (Sienicki 1998) and that of Moses and Savage (1997). While those studies evaluated the benefits and costs of existing programs at a particular point in time, the study by Bapna *et al.* (1998) evaluated the future deployment of CVISN technology and resulting changes of benefits and costs.

The CVISN safety benefits analysis conducted by Battelle (2002a) utilized a probability model that predicts the number of crashes avoided under various scenarios. Each scenario was defined by specific assumptions concerning the future deployment of CVISN. The probability model related the number of crashes avoided to several input parameters, including:

- The probability that a CMV has an OOS condition;
- The number of inspections performed;
- Historical rates at which OOS orders were issued;
- National crash/injury/fatality rates involving large trucks; and
- Probabilities that certain OOS conditions will contribute to a crash.

The study (Battelle 2002a) relied on the estimation of parameters using either results from the open literature on crashes and highway statistics or data collected in special studies involving participating CVISN states. Both types of estimates are subject to uncertainty and errors of unknown magnitude; therefore, additional data are needed to support these results.

The anticipated safety benefits of CVISN from increased motor carrier compliance with state safety regulations are extremely important. Battelle (2002a) found that the safety benefits consist primarily of reductions in truck-related crashes caused by violations of vehicle or driver safety regulations. They stated that crashes were avoided because either additional trucks or drivers were placed out of service due to more efficient enforcement practices or the number of violations was reduced in response to enhanced enforcement (the indirect effect). Therefore, the safety benefit would take the form of decreased fatalities and personal injuries, and decreased property damage costs from accidents. In quantifying this benefit, they included the total cost to society of crashes, including the losses and delays to other motorists due to these accidents. Further, they did not subtract the costs covered by insurance from the cost savings since the cost savings would lower insurance costs for everyone and all the accident cost savings should be included in this benefit.

Bapna *et al.* (1998) also found that the safety benefits would be driven by the decrease in the number of accidents resulting from identifying more carriers that are overweight. For this analysis, it was assumed that overweight vehicles that had the necessary OW permits were legally overweight and therefore were likely to comply with OW safety regulations. Those carriers that had not obtained OW permits were illegally overweight and less likely to comply with OW safety regulations. The authors found that compared to other safety-related benefits, the benefit of accident reduction due to identifying overweight vehicles is much smaller. They investigated this benefit is approximately half the benefit of identifying high-risk carriers, and one-sixth the preclearance benefits, and therefore, its net impact is negligible to the overall B/C ratios. There might be unquantifiable safety benefits from motor carriers maintaining mainline speeds on highways if significantly fewer trucks must decelerate to enter a queue at a weigh and inspection station or accelerate to enter a highway lane. Further, automated identification of vehicles and drivers will decrease the crawling around and under commercial vehicles by the inspection and enforcement staff, which makes the working area safer for inspection and enforcement personnel (Bapna *et al.* 1998).

Tri-global Solutions Group (2003) described that using an ECRI system would enable inspectors have more time to concentrate on non-compliant operators or trucks, while the number of non-compliant trucks allowed to bypass a station during peak congested period might be reduced. The authors found that there would be little evidence of a direct safety benefit from an ECRI program; however, there would likely be a safety benefit from enhanced enforcement and compliance. As a result, the authors assumed a 0.5% reduction in truck accidents "within the zone of influence of an inspection station for participating trucks."

2.5.2. EFFICIENCY

Brand *et al.* (2002) stated that measures of achievement of the engineering efficiency goal do not enter into a benefit-cost analysis because increased output per unit of input is best measured in transportation as increased throughput or capacity (for example, vehicles per hour, inspections per hour, inspections per person-hour). Therefore, they converted this benefit to a dollar value to society under the productivity goal in the form of cost savings, which includes the savings to motor carriers and government agencies that result from CVISN. Battelle (2002b) investigated using SAFER data mailbox in I-95 commercial vehicle operations and concluded that computer technology was seen as helping inspectors (a) gather more complete inspection information, (b) work more efficiently, and (c) save time compared with traditional paper-based inspection systems. However, they stated that findings on actual time savings versus paper were vague because some inspectors reported a net time savings, while others reported that computer-based systems required just as much time as paper-based systems to conduct inspections at roadside or at weigh stations.

In an ITS/CVO Qualitative Benefit-Cost Analysis (ATA Foundations 1996), the potential benefits of electronic clearance to motor carriers were measured as the reduced cost of driver time resulting from fewer stops for roadside compliance checks. The analysis assumed that electronic clearance would decrease the amount of time spent undergoing roadside compliance checks by 50% to 100%. However, the study concluded that this measure of benefit might be considered only directly applicable to motor carriers who pay their drivers based on time worked, and not for those carriers whose driver settlements were not time-based (ATA Foundations 1996). Nozick *et al.* (1998, 1999) studied the potential effects of advanced technologies at commercial border crossings and utilized the following measures:

- The time required for a vehicle to go through the entire crossing process (time in system), in aggregate, and disaggregate by vehicle class;

- Delays in the queue waiting for primary inspection;

- The number of trucks in the secondary inspection area, by time of day; and

- Utilization of toll collectors and custom inspectors.

Four separate measures of system impact were identified for the simulation of *Ambassador Bridge Border Crossing System* (ABBCS) Field Operational Test, which include (Mitretek Systems 1999; Booz-Allen and Hamilton 2000):

- Percent of peak hour with truck blocking gore (that is, the amount of time that the queue of trucks awaiting primary inspection extends back to the bridge span).

- Number of queued tracks awaiting primary inspection.

- Time savings for ABBCS (NATAP) trucks.

- Overall time saving.

The results of simulation clearly proved that systems such as ABBCS have the potential to positively impact the conditions on and around the U.S. end of the bridge. The simulation also showed that with the increase in the percentage of commercial vehicle participants, there would be lower number of vehicles requiring a stop to work with custom brokers, which would result in less demand for parking facilities within the U.S. customs compound (Booz-Allen and Hamilton 2000). Nozick *et al.* (1998, 1999) found that the introduction of ITBCS can have major impacts on productivity at the Peace Bridge, a major border-crossing facility between Buffalo, NY and Fort Erie, ON. They investigated that reductions in time in system ranging up to 50% seem possible even if the technological standards for the system were not made extremely high. However, the authors emphasized that a significant institutional hurdle must be overcome for achieving these impacts (Nozick *et al.* 1999).

Bapna *et al.* (1998) stated that the feature of preclearing legal vehicles and drivers on highways is at the heart of CVISN, which is achieved by means of several technologies such as *weigh-in-motion* (WIM) scales and transponder systems. Several benefits accrue due to the preclearance systems. The major benefits to carriers include less travel time since a vehicle equipped with a transponder may continue to travel at mainline speeds without stopping at the weigh facility. Agency benefits are because of automating the weighing functions, which leads to resources being used more efficiently, thereby allowing the safety enforcement agencies to concentrate their efforts on poor-safety carriers and/or drivers. Targeting high-risk carriers and/or drivers will lead to lowering the accident rate and is therefore beneficial to society, as described in the next section.

2.5.3. PRODUCTIVITY

Tri-global Solutions Group (2003) stated that time savings to carriers to be the single largest benefit of an ECRI system. The authors included driver's wage plus wage burden and the fixed costs of truck ownership as the value of truck time in the benefit-cost analyses. Tri-global Solutions Group (2003) discussed that there would also be a potential 10% time saving for inspectors and drivers by speeding up the data recording process using online data because of employing an ECRI program. The authors assumed that these savings apply only to trucks participating in an ECRI program. The authors also found that implementing an ECRI program could increase capacity of a station and decrease the corresponding staff requirements.

Regarding roadside enforcement, Battelle (2002a) referred to the productivity-related cost savings to compliant motor carriers to which resulted from saving time by bypassing inspection sites at highway speeds. They did not assume any shortening of the time to inspect each truck selected for inspection, nor was it assumed that the number of truck inspections would change. Rather, CVISN may be expected to result in a better targeting of truck inspections since more of these trucks will have been prescreened for violations using the real-time access to timely and accurate data for targeting high-risk carriers provided by CVISN. Battelle (2002a) concluded that rather than a cost savings to states, the benefit to the states was increased numbers of OOS violations and improved compliance resulting in fewer crashes. Cost savings to states are preceded for the benefit of increased output from the inspection process in the form of increased safety as measured by fewer crashes. This increased output provided by CVISN is an important benefit.

Bapna *et al.* (1998) estimated the carrier cost/minute based on the analysis of Titus (1995). They reported that Titus (1995) considered two methods of estimating the value of a carrier's time for truckload carriers: the average hourly income of drivers, and the equivalent distance. "The equivalent distance method requires determining the distance a vehicle could have travelled had enforcement stops not been made. A decrease in travel time would have enabled the vehicle to travel greater distances. Thus, the carrier cost per minute represents the cost to the carrier irrespective of whether the driver is paid by miles or by time" (Bapna *et al.* , 1998). The authors used the average of the truckload ($13/hour) and non-truckload carriers ($24.60) as estimated by Titus (1995) and adjusted the wage rate based on the wage rate change in Maryland during the period 1995 to 1998. Bapna *et al.* (1998) considered CVISN preclearance benefits due to transponder penetration only for those vehicles that travel the routes that had weigh and inspection stations at the study time. Their analysis did not include the entire population of commercial motor vehicles travelling on all highways in Maryland. Their worst-case scenario assumed that the entire population of vehicles in Maryland travelled regularly on these routes and therefore would buy transponders at the transponder growth rate. This was conservative, since only those carriers that travel the routes with weigh and inspection stations need to buy transponders. Thus, the actual costs incurred to carriers for transponders would be much lower than those used in the benefit-cost model.

Bapna *et al.* (1998) qualitatively analyzed the cost reduction benefits of CVISN. They explained that CVISN combined with WIM provides large roadside safety and carrier efficiency benefits and in theory, WIM will weigh all motor carriers, resulting in long-term cost savings to the State from extended physical lives of highways. Therefore, highways will need less reconstruction and maintenance for a given period of time due to detection of all overweight commercial vehicles. The authors argued that operating costs may increase during the initial stages of CVISN because a larger number of high-risk vehicles and/or drivers will enter the inspection and weigh facilities and tie up inspectors; however, during the latter stages of CVISN, these operating costs will decline when a large number of vehicles get precleared. They also reported that the integration of information systems from deployment of CVISN should reduce the use of resources devoted to redundant systems. Bapna *et al.* (1998) also qualitatively analyzed the revenue benefits of CVISN. The authors believe that additional revenues for IRP and IFTA taxes will be collected due to the increased monitoring of carrier activities. Tri-global Solutions Group (2003) found that with an ECRI system in place, there could be an increase in the number of permits sold, and a one-time increase in fine revenue in the year of implementing the system at a station.

Regarding electronic credentialing, Battle (2002a) found that the benefits of CVISN to both states and motor carriers were limited to cost savings (possibly substantial). States can change their credentialing output only with legislative changes in the number of transactions required. Such changes are exogenous to the CVISN Model Deployment Initiative (MDI) and do not enter this BCA. Similarly, motor carriers can benefit from the cost savings that electronic credentialing's speed and increased operating flexibility provides them. The benefits include both direct operating cost savings and increased fleet utilization from the increased speed with which carriers can get their trucks on the road due to faster credentialing. They assumed that carriers could register new trucks faster and thus save on truck inventory costs. Registration renewals were assumed to be scheduled, with or without electronic credentialing, to keep existing truck fleets in service. In addition, oversize/overweight (OS/OW) permits were not included in the electronic credentialing portions of the CVISN MDI, so no benefits for faster credentialing of these permits were included in the BCA. Finally, significant or measurable levels of increased revenue to motor carriers from goods shipped were not anticipated because of the CVISN program. This is discussed in the mobility section below.

2.5.4. MOBILITY

Battelle (2002a) identified three non-motor carrier cost saving mobility measures in evaluating CVISN:

- Reduced highway delays to the public due to reduced commercial vehicle crashes;
- Reduced time in transit that reduces shipper/receiver inventory costs; and

- Increased shipper/receiver satisfaction with carriers (*e.g.*, use of safety rating data).

Battelle (2002a) described that the first measure is included in the accident cost saving benefit since the literature includes this in the cost of accidents. Similarly, the value to shippers/receivers of decreasing time in transit to reduce inventory costs is included in the motor carrier value of commercial vehicle travel time. Regarding the third measure, to the extent that shippers are willing to pay separately for (*i.e.*, that they value) the safety rating data, this benefit is additive to the carrier cost savings from reduced accidents; however, the authors were not able to measure it in their evaluation; however, it was qualitatively discussed under customer satisfaction.

2.5.5. ENERGY AND ENVIRONMENT BENEFITS

Bapna *et al.* (1998) qualitatively analyzed environmental impacts as societal benefits of CVISN. The authors discussed that the weighing of all vehicles at mainline speeds results in environmental benefits because WIM will obviate the need for stopping and queuing for static weighing and therefore, there will be less idling of diesel engines at weigh and inspection stations as well as less wear and tear of brakes and other associated motor vehicle components. This will lead to fuel savings and fewer emissions.

The result of another study by McCall (1997) showed that preclearance systems would result in fuel savings between 0.05 and 0.18 gallons per avoided stop for commercial vehicles, not including fuel savings from reduced queues. Battelle (2002a) stated that energy savings in the form of decreased fuel use could be included in the value of transit-time-related operating cost savings to motor carriers. Similarly, they separately calculated the values of air and noise pollution reductions from CVISN, but included in the transit-time-related benefits input to their benefit-cost analysis. An additional environmental benefit could be to increased water quality from reduced air pollution and particulate matter from vehicular use and wear. Bapna *et al.* (1998) described that preclearance of vehicles at mainline speeds would decrease noise pollution at weigh and inspection stations; however, they did not include these impacts in their benefit-cost analysis. Bapna *et al.* (1998) doubted about major environmental benefit resulting from CVISN-enhanced roadside inspection, as similar numbers of trucks would be inspected as before CVISN; although they stated that targeting high-risk carriers and allowing freer flow of safe carriers might have some environmental benefit.

Tri-global Solutions Group (2003) discusses that ECRI allows safe and legal trucks to bypass a scale, which results in less fuel consumption. This is due to eliminating the speed change cycle and idle time associated with a static weigh scale. The authors utilized a fuel consumption model to estimate the fuel consumption for three cases, namely, stopping at a static scale, an in-scale bypass, and a mainline bypass.

2.5.6. OTHER BENEFITS

Use of CVISN technologies and resulting improved efficiencies at international *points-of-entry* (POE) can also lead to increased trade flows between nations that can lead to an increase in welfare. Fox *et al.* (2003) Utilized the *General Trade Analysis Project* (GTAP) model to model the U.S.-Mexico trade at the Laredo border crossing to measure the microeconomic impact of the inefficiencies at the border crossing on shippers and the institutional factors and vested interests that permit the inefficiencies to appear and last for extended periods of time. These inefficiencies were defined as money paid by shippers for charges for non-essential border crossing services and times involved in each step of the border crossing operation.

In a research of the movements, times, and costs of each procedure in the transport of manufactured products across the Laredo to Nuevo Laredo border, Haralambides and Londoño-Kent (2002) found the most serious congestion-causing constraints in the Laredo border crossing. These included infrastructure limitations, and costs and time-consuming hurdles that take the form of long standing practices of government, transportation interests, customs brokers, and trade businesses. Fox *et al.* (2003) found that the implementation of CVISN technologies and related management practices do not guarantee the reduction or removal of non-tariff barriers (*e.g.*, social, political, infrastructure, corruption, and pollution costs). However, delays at the border were shown to be a major contributor to price differences between the United States and Mexico, which results in the loss of potential for increased trade that could benefit both countries.

Pavement cost saving (*i.e.*, increased pavement life or productivity) is another potential cost saving that can be included in the model. Bapna *et al.* (1998) discussed that commercial vehicles need to be weighed primarily out of the necessity for public safety and to prevent damage to roads. Battelle (2002a) stated that pavement cost savings could be the result of fewer unpermitted overweight trucks on the road. This saving can be expected to materialize over the long term, well beyond the term of the CVISN MDI and therefore, it was excluded from the quantitative results of the benefit-cost analysis (BCA). Tri-global Solutions Group (2003) discussed that the pavement benefits from implementing an ECRI program could be estimated as a proportion of the potential savings based on the participation rate and number of scales; that is, the higher the enforcement condition, the lower the percentage of overloaded trucks. The authors assumed that pavement cost savings was only for the government account.

CVISN may improve on-time delivery of goods by motor carriers. Especially with *just-in-time* (JIT) inventory delivery systems, where smaller shipments occur more frequently as needed (and thereby reducing the huge costs of large static inventories in warehouses), time saved during weighing and inspection may be of critical importance (Bapna *et al.* 1998). Fewer stops for weighing and inspection can result in faster delivery of goods and consequently, lower transportation and inventory costs to wholesaler and retailers. This may lead to lower prices for consumers. Enhanced service to commercial vehicles is also reflected in terms of less damage to goods from transport accidents, which is estimated to be $5,000 savings per truck accident avoided (Moses and Savage 1997). Review of literature (Bapna *et al.* 1998; Booz-Allen and Hamilton 2000; Brand *et al.* 2002; Mitretek Systems 1999; Battelle 2002a; Nozick *et al.* 1998 1999) shows that different studies have quantified only those benefits that can be modelled with reasonable assumptions. It is clear that there are several other benefits of CVISN, which increase the worth of the CVISN project.

2.6. CHAPTER SUMMARY

This chapter represents a comprehensive review of ITS/CVO applications, their evaluation studies, and resulted benefits. An ITS/CVO evaluation framework includes the identification of evaluation criteria and variables pertaining to the impact of the proposed

ITS/CVO application to society and various stakeholders. This will employ operational tests, and modelling and simulation methods that will be used to evaluate the proposed application and quantify some of the evaluation criteria. Evaluation criteria that cannot be easily measured will be qualitatively analyzed.

Recent research in the evaluation of the impacts and benefits of ITS for commercial vehicle operations was reviewed and their results were discussed. An important finding is that the benefits and costs of such systems are in direct proportion to the level of participation of motor carriers and their implementation of the proposed technology-based solutions. Benefit/cost analyses resulting in B/C ratios ranging from 0.62 (worst) to 40 (best) proved the economic feasibility of projects such as CVISN; however, these results being highly dependent on the level of deployment, integration, and cooperation between jurisdictions.

The literature review revealed that the various evaluation methodologies employed to evaluate electronic commercial vehicle preclearance systems considered criteria such as time savings, processing efficiencies, air and noise pollution, fuel use, removal of unsafe vehicles, crash reduction, border infrastructure savings, and reductions in pavement maintenance and rehabilitation. The results of these criteria show that ITS/CVO applications are expected to make commercial vehicle credentialing less costly, safety inspections more effective, and save transit time for commercial vehicles with good safety compliance records by enabling them to bypass inspection stations at highway speeds in most cases.

3. CANADIAN ITS ARCHITECTURE AND COMMERCIAL VEHICLE OPERATIONS

3.1. INTRODUCTION

As described earlier, intelligent transportation systems (ITS) can be defined as employing information, communication, sensor, and control technologies to improve the mobility, safety, and productivity of transportation systems. On the other hand, commercial vehicle operations (CVO) is a term that refers to those operations associated with the movement of goods and passengers via commercial vehicles over the highway system, and the activities necessary to regulate such operations. ITS for CVO (ITS/CVO) applications comprise many application areas that are designed to improve operational aspects of commercial vehicles and goods movement by enhancing highway safety and more efficiently administer tax collection, safety inspection, log maintenance, border clearance, licensing, and vehicle registration. The main objective of this chapter is to review the Canadian ITS Architecture and its components for commercial vehicle operations. All Canadian ITS/CVO market packages will also be analyzed to identify the potential benefits of employing each market package.

3.2. THE CANADIAN ITS ARCHITECTURE

The development of the *Canadian ITS Architecture* started in August 1999 under the guidance of a steering committee of public and private sector representatives from the Canadian transportation industry. The Canadian effort includes the entire *U.S. National ITS Architecture* work, extends and modifies it to provide new services and areas of coverage, and reflects differences between the nations and the existence of new and different stakeholders. "The Canadian ITS Architecture provides a unified framework for integration to guide the coordinated deployment of ITS programs within the public and private sectors. It offers a starting point from which stakeholders can work together to achieve compatibility among ITS elements to ensure unified ITS deployment for a given region" (IBI Group 2000).

The Canadian ITS Architecture includes user services and user sub-services, logical architecture, physical architecture, and market packages. *User services and user sub-services* describe what the system will do from the user's perspective. The Canadian ITS Architecture consists of eight *user service bundles* as opposed to the seven bundles in the U.S. National ITS Architecture. The major difference is in separating the *travel and traffic management* user service bundle into two separate bundles: *travel information services* and *traffic management services*. It also includes thirty-five *user services*, as opposed to thirty-one user services in the U.S. National ITS Architecture. Table 3.1 describes these service bundles. Based on the thirty-five user services, ninety *user sub-services* were introduced to help the definition of the physical and logical architectures, which provide a level of detail consistent with the market package definitions under the U.S. National ITS Architecture (IBI Group 2000).

The *logical architecture* defines the processes (*i.e.*, activities or functions) required to satisfy the ITS user services. It is based on a high level *computer aided systems engineering* (CASE) model of the functional requirements for the flow of data and control through ITS. Process specifications, data flow diagrams, and data dictionary entries are major parts of the logical architecture. Various processes must work together and share information to provide a user service. Data flows recognize the information that is shared by the processes (IBI Group 2000).

The *physical architecture* composes a high-level structure around the processes and data flows in the logical architecture. The physical architecture defines the *subsystems* and *terminators* that form an intelligent transportation system. These subsystems and terminators are separate but interoperable; therefore, the physical architecture defines the architecture flows that connect the various subsystems and terminators into an integrated system. The boundary of the Canadian ITS Architecture is defined by terminators, which represent the people, systems, and general environment that interface to ITS. Examples of terminators include environment, roadway, driver, traveller, commercial vehicles, location data source, and map update provider. The logical and physical architectures both have exactly the same set of terminators; however, logical architecture processes communicate with terminators using data flows and physical architecture subsystems use architecture flows. The physical architecture of the Canadian ITS Architecture partitions the functions defined in the logical architecture into four systems and twenty-three subsystems as shown in Figure 3.1. "The subsystems generally provide a rich set of capabilities, more than would be implemented at any one place or time" (IBI Group 2000). They are grouped into four types of systems, namely, travellers, centres, vehicles, and wayside.

The *travellers* include two subsystems for ITS functions related to travellers or carriers in support of multimodal transportation. These two subsystems are "remote traveller support" at a fixed location (*e.g.*, transit stations) and "personal information access" through home or portable computers for traveller information and emergency requests. The *centres* consist of ten subsystems that are not required to be on or adjacent roadways. This group of ITS subsystems is often implemented at *traffic management centres* (TMCs) and communicate with other subsystems through *wide area network* (WAN) wireline communications. *Vehicles* cover the subsystems installed in a vehicle. Communication needs include one-way or two-way wide area wireless (mobile) communications to the centres, vehicle-to-wayside communications for functions such as electronic toll collection, and vehicle-to-vehicle communications in an automated highway system. The five subsystems comprising the *wayside* require wayside locations for deployment of sensors, signals, or other interfaces with travellers and vehicles. These subsystems generally need wireline communications with centres and dedicated short-range communications with vehicles passing the roadside location where a wayside subsystem is deployed (Miller and Shaw 2001; IBI Group 2000).

Market packages represent portions of the physical architecture that deal with specific services like surface street control. A market package collects various subsystems, equipment packages, terminators, and architecture flows that provide the desired service. The Canadian ITS Architecture includes a total of seventy-nine market packages, among which sixteen new market packages were developed, and six were modified from the U.S. national Architecture in order to address the new user services of the Canadian ITS Architecture (IBI Group 2000).

As mentioned earlier, the Canadian ITS Architecture defines various kinds of communication systems required between the subsystems. Wide area network (WAN) *wireline* communication elements are fixed-point to fixed-point; that is, they can be implemented physically as fibre, coaxial, twisted-pair, or microwave networks between two locations. Wide area *wireless* (mobile) communication elements are similar to wireline communication elements but do not require physical connections between two locations (*e.g.*, cellular phone-based systems). These are ideal for ITS services that disseminate information to users who require wireless coverage. *Vehicle-to-vehicle* communications is one kind of short-range wireless communication, which is critical for ITS user services such as collision avoidance and automated highway systems (AHS). *Dedicated short-range communications* (DSRC) are one-way (read only) or two-way (read-write) communication channels that provide direct communication paths between vehicles (*e.g.*, toll tags) and wayside equipment (*e.g.*, beacons) (Miller and Shaw 2001).

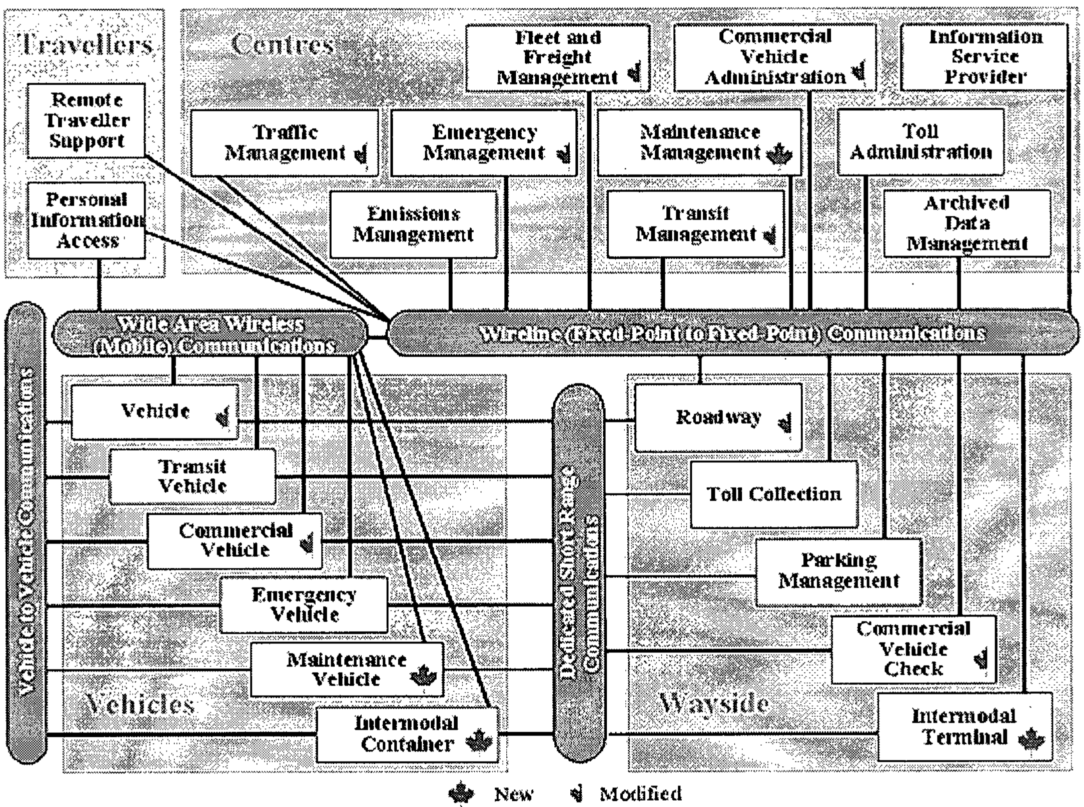


Figure 3.1 - Canadian ITS physical architecture subsystems and communication elements (IBI Group 2000)

A critical issue for ITS architecture is to ensure the ability of communicating and sharing information within and across geographic and jurisdictional boundaries. Therefore, ITS Standards are fundamental to the establishment of an open ITS environment. Standards help deployment of interoperable systems at local, regional, national, and international levels without blocking improvement as technology advances and new approaches are developed. The Canadian ITS Architecture is a reference framework that forms all ITS standards activities and provides a means of detecting gaps, overlaps, and inconsistencies between the standards (IBI Group 2000). *The Transportation Equity Act for the 21st Century* (TEA-21) identifies two types of critical ITS standards: ***national standards*** for national interoperability and *foundation standards* for the development of other critical standards (*e.g.*, location-referencing standards, which are to develop national standards for various ITS user services) (Miller and Shaw 2001). Miller and Shaw (2001) explained that ITS standards alone would not guarantee a national or global interoperability of ITS and other factors such as institutional issues, and performance of information exchange could present problems to national interoperability.

3.3. ITS/CVO USER SERVICES AND USER SUB-SERVICES

The primary focus of commercial vehicle operations (CVO) is on freight movement and on services that enhance private sector fleet management and freight mobility as well as the effectiveness of government/regulatory functions. The Canadian ITS Architecture defines six user services under commercial vehicle operations user service bundle, namely, commercial vehicle electronic clearance, automated roadside safety inspection, on-board safety monitoring, commercial vehicle administrative processes, intermodal freight management, and commercial fleet management. Each of these user services includes some user sub-services. Table 3.2 represents various CVO user services and sub-services as defined by Canadian ITS Architecture. The following sections briefly describe each of these user services and sub-services as defined by the Canadian ITS Architecture (IBI Group 2000).

Table 3.1 - ITS user services under Canadian ITS program (IBI Group 2000)

User Services Bundle	User Services
Traveller Information Services	Traveller Information; Route Guidance and Navigation; Ride Matching and Reservation; Traveller Services and Reservations
Traffic Management Services	Traffic Control; Incident Management; Travel Demand Management; Environmental Conditions Management; Operations and Maintenance; Automated Dynamic Warning and Enforcement; Non-Vehicular Road User Safety; Multi-Modal Junction Safety and Control
Public Transport Services	Public Transport Management; En-Route Transit Information; Demand Responsive Transit; Public Travel Security
Electronic Payment Services	Electronic Payment Services
Commercial Vehicle Operations	Commercial Vehicle Electronic Clearance; Automated Roadside Safety Inspection; On-board Safety Monitoring; Commercial Vehicle Administrative Processes; Intermodal Freight Management; Commercial Fleet Management
Emergency Management Services	Emergency Notification and Personal Security; Hazardous Material Planning and Incident Response; Disaster Response and Management; Emergency Vehicle Management
Vehicle Safety and Control Systems	Vehicle-Based Collision Avoidance; Infrastructure-Based Collision Avoidance; Sensor-Based Driving Safety Enhancement; Safety Readiness; Pre-Collision Restraint Deployment; Automated Vehicle Operation
Information Warehousing Services	Weather and Environmental Data Management; Archived Data Management

Table 3.2 – ITS/CVO user services and user sub-services under Canadian ITS program (IBI Group 2000)

User Services	User Sub-Services
Commercial Vehicle Electronic Clearance	Electronic Clearance; International Border Crossing Clearance; Weigh-In-Motion (WIM)
Automated Roadside Safety Inspection	Inspection Support Systems; Automated Vehicle Safety Read Out
On-board Safety Monitoring	On-Board Safety Monitoring
Commercial Vehicle Administrative Processes	Commercial Vehicle Administrative Processes
Intermodal Freight Management	Freight In-Transit Monitoring; Intermodal Interface Management
Commercial Fleet Management	Fleet Administration; Freight Administration; CVO Fleet Maintenance

3.3.1. COMMERCIAL VEHICLE ELECTRONIC CLEARANCE

Both domestic and international border electronic clearance are part of the *commercial vehicle electronic clearance* user service, which allows commercial vehicles to bypass inspection stations (or international border checkpoints) with expedited checks, or even without stopping. As a vehicle approaches an inspection station or checkpoint, the transmission of necessary data (*e.g.*, credentials, vehicle weight, safety status, cargo, occupants) to authorities enables enforcement personnel select potentially unsafe vehicles for inspection and allow safe and legal vehicles to bypass the inspection station/checkpoint. This user service has three user sub-services, including electronic clearance focusing on automated clearance at roadside check facilities, international border crossing clearance focusing on automated clearance specific to international border crossings, and weigh-in-motion (WIM) that provides the roadside with additional equipment to allow high-speed weigh-in-motion with or without AVI attachment.

3.3.2. AUTOMATED ROADSIDE SAFETY INSPECTION

A rolling dynamometer that checks brake performance is an example of the *automated roadside safety inspection* user service whose focus is on automated inspection capabilities. This user service allows safety requirements be checked more quickly and accurately during a safety inspection. The safety check may be performed by pulling a vehicle off the highway at a fixed or mobile inspection site. It has two user sub-services, namely, inspection support systems that allows automated roadside safety monitoring and reporting be performed by automating commercial vehicle safety inspections at the commercial vehicle check roadside element, and automated vehicle safety read out that supports and facilitates safety inspection of vehicles that have been pulled in.

3.3.3. ON-BOARD SAFETY MONITORING

The focus of the *on-board safety monitoring* user service is on the ability to realize the safety status of a vehicle, cargo, and the driver at mainline speeds. The primary outcome will be rapid notification of the driver about any problem that has been detected. The carrier and appropriate agencies can then be notified of detected safety problems. This CVO user service has one user sub-service, namely, on-board safety monitoring user sub-service that includes roadside support for reading on-board safety data via tags.

3.3.4. COMMERCIAL VEHICLE ADMINISTRATIVE PROCESSES

This user service includes electronic purchase of credentials, automated mileage and fuel reporting and auditing, and international border electronic clearance. The focus of commercial vehicle administrative processes user sub-service is on electronic application, processing, fee collection, issuance, and distribution of CVO credential and tax filing to allow commercial vehicles be screened at mainline speeds at commercial vehicle checkpoints.

3.3.5. INTERMODAL FREIGHT MANAGEMENT

The focus of the *intermodal freight management* user service is on providing systems for monitoring the status of freight in-transit, and at freight terminals. This CVO user service has two user sub-services, namely, freight in-transit monitoring focusing on tracking and monitoring intermodal containers and intermodal freight shipments, and providing the information to freight customers, fleet managers, and logistics service providers; and intermodal interface management focusing on the operation of the roadway aspects of an intermodal terminal.

3.3.6. Commercial Fleet Management

The provision of real-time communications for vehicle location, dispatching and tracking between commercial vehicle drivers, dispatchers, and intermodal transportation providers is the main focus of the *commercial fleet management* user service. This results in less delays for drivers as commercial drivers and dispatchers receive real-time routing information in response to congestion or incidents. This CVO user service has three user sub-services, namely, fleet administration that keeps track of vehicle location, itineraries, and fuel usage; freight administration that keeps the track of cargo and the cargo condition, and communicating this information with the Fleet and Freight Management Subsystem via wireless infrastructure; and CVO fleet maintenance focusing on maintenance of CVO fleet vehicles through close interface with on-board monitoring equipment and AVLS capabilities within the Fleet and Freight Management Subsystem. Records of vehicle mileage, repairs, and safety violations are maintained to assure safe vehicles on the highway.

3.4. ITS/CVO MARKET PACKAGES AND THE ASSOCIATED BENEFITS

Market packages represent a deployment-oriented aspect of the Architecture in response to real-world transportation problems and needs. In fact, they "identify the pieces of the Physical Architecture that are required to implement a particular transportation service" (IBI Group 2000). The Canadian ITS Architecture defines twelve market packages for commercial vehicle operations, including fleet administration, freight administration, electronic clearance, commercial vehicle administration processes, international border crossing clearance, weigh-in-motion (WIM), roadside CVO safety, on-board safety monitoring, CVO fleet maintenance, hazardous material planning and incident response, freight in-transit monitoring, and freight terminal management. The following sections describe ITS/CVO goal areas, and ITS/CVO market packages as defined by the Canadian ITS Architecture (IBI Group 2000). Furthermore, each market package will be thoroughly analyzed to identify potential benefits expected from deploying these market packages. It is worth noting that these market packages may be implement separately or in combination, based on the transportation problem they are responding to.

3.4.1. ITS/CVO GOAL AREAS

ITS/CVO projects should be evaluated based on their impacts on the overall ITS goal areas, including safety, security, efficiency, productivity, mobility, energy and environment, and customer satisfaction. These goal areas will be described briefly in following sections.

Safety

Fewer crashes involving trucks as well as improved personal safety of motoring public are examples of safety goal area. An explicit objective of the transportation system is to provide a safe environment for travel while continuing attempts to improve the performance of the system. Although undesirable, crashes and fatalities are unavoidable. Several ITS/CVO services aim to minimize the risk of crash occurrence through identifying high-risk drivers and carriers, and encouraging and working with them to enhance their safety management processes and compliance. This goal area focuses on reducing the number of crashes, and decreasing the probability of a fatality a crash occurrence.

Security

Protecting transportation information and infrastructure are the major concerns of security goal area. Surveillance of commercial vehicles and freight equipment (*i.e.*, containers, the chassis, or trailers) as well as the interface with intermodal facilities are major security areas of ITS/CVO applications that must be considered carefully in order to improve the security of the freight and commercial vehicles (USDOT 2003). Wolf (2002) describes freight security and productivity in the context of freight-related threats, vulnerability, and countermeasures. ITS/CVO systems are subject to security threats like any other information technology system and they must be protected to assure that their applications are reliable and available when they are needed. It is very difficult to predict specific threats to specific targets; however, it is obvious that threats exist to freight infrastructure and operations. Additionally, transportation assets may be turned to weapons by terrorists. There is also an agreement among knowledgeable observers on multi-faceted vulnerability of freight transportation systems to terrorist attack, due to the diversity, ubiquity, and openness of freight transportation systems. Vulnerability analyses must consider both point attacks against a single element, and systemic attacks against the infrastructure as a whole. Freight-related countermeasures can either prevent attacks or mitigate the impacts of attacks. As preventive countermeasures cannot stop all attacks and guarantee the security, therefore, only well-managed mitigation countermeasures are important. Primary impacts resulted from successful terrorist incidents include damage, casualties, and disruption, while secondary impacts include the effects of the rescue and recovery effort as well as long-run economic impacts (Wolf 2002). The U.S. National ITS Architecture (USDOT 2003) defines four functions for ITS/CVO security area that includes:

1. Tracking commercial vehicle or freight equipment locations to determine if an asset has deviated from its planned route;
2. Monitoring the identities of the driver, commercial vehicle and freight equipment for consistency with the planned assignment;
3. Monitoring freight equipment for a breach or tamper event; and
4. Monitoring the commercial vehicle for a breach or tamper event.

Efficiency

Efficiency can be defined as "increased throughput or capacity" (Battelle 2002a) or "more output per unit of input" (Brand *et al.* 2002) (*e.g.*, increased throughput at inspection sites, increased throughput of credentialing process). Capacity can be defined as the "maximum hourly rate at which persons or vehicles can reasonably be expected to traverse a given point or uniform section of a lane or roadway during a given time period under prevailing roadway, traffic, and control conditions" (TRB 2000). Capacity is generally measured under typical conditions for the facility, such as good weather and pavement conditions, with no incidents affecting the system. Effective capacity, on the other hand, can be defined as the "maximum potential rate at which persons or vehicles may traverse a link, node, or network under a representative composite of roadway conditions, including weather, incidents, and variation in traffic demand patterns" (McGurrin and Wunderlich 1999). It is clear that effective capacity changes as typical conditions change, or different management and operational strategies are used. Throughput can be defined as the number of persons, goods, or vehicles traversing a roadway section or network per unit time.

Productivity

Productivity can be defined as cost saving. There are two ways to calculate the costs savings of ITS/CVO: calculating the difference in costs before and after installation of a system, or comparing the cost of an ITS application to traditional transportation improvements that are designed to address the same problem. The cost of an ITS/CVO system or any transportation improvement is composed of several component elements that include the acquisition cost (capital cost), operating/maintenance cost, and income in the case of revenue-generating transportation facilities (ITS/JPO 2002).

Mobility

Reduced highway delays, reduced cost of goods movement, and decreased goods transit times and increased reliability of delivery schedules to/from shippers/receivers are examples of benefits that can be grouped under mobility goal area. In fact, a major goal of many ITS/CVO applications is improving mobility by reducing delay and travel time. The reduction in the variability of travel time improves the reliability of arrival time estimates that travellers or companies use to make planning and scheduling decisions. It is expected that ITS/CVO services can reduce the variability of travel time in transportation networks by improving operations (*e.g.*, better incident response, more information on delays, preclearance of compliant trucks).

Energy and Environment

Energy and environment goal area includes reduced energy consumption and environmental impacts of trucks. Energy and environment impacts of ITS/CVO services are very important, and can be estimated through analysis and simulation. Small-scale studies are generally expected to show positive impacts on the environment because of smoother and more efficient flows in the transportation system. However, there is still lack of knowledge and understanding about environmental impacts of travellers reacting to large-scale deployment in the long term.

Customer Satisfaction

Many ITS projects have been developed to serve the public; therefore, it is very important to ensure that traveller expectations are being met or exceeded. This can be measured through customer satisfaction that can be defined as the difference between users' expectations and experiences in relation to a service or product. The key question in a customer satisfaction evaluation is, "Does the product deliver sufficient value (or benefits) in exchange for the customer's investment, whether the investment is measured in money or time?" (Mitretek Systems 2003) The impacts of customer satisfaction with a product or service can be evaluated based on product awareness, expectations of product benefit(s), product use, response (*i.e.*, decision-making or behaviour change), realization of benefits, and assessment of value. Satisfaction is difficult to measure directly; however, measures related to satisfaction can be observed, such as amount of travel in various modes, mode choices, and the quality of service as well as the volume of complaints and/or compliments received by the service provider. Improved customer satisfaction is a vital part for success of an ITS/CVO deployment, and ITS/CVO customers must value the incremental benefits they experience more highly than the incremental costs they bear. Customers or users of ITS/CVO technologies include independent and company drivers, motor carrier operators, national and provincial transportation and CVO administrators, law enforcement, highway and public safety personnel, and the businesses and industries that engage the services of motor carriers. Customer satisfaction with an ITS/CVO deployment can be measured through conducting surveys, such as national motor carrier survey, driver survey, and surveys on focus groups involving provincial inspectors and law enforcement personnel.

3.4.2. ITS/CVO MARKET PACKAGES AND ASSOCIATED BENEFITS

Fleet Administration

The focus of Fleet Administration market package is on keeping track of vehicle location, itineraries, and fuel usage at the Fleet and Freight Management Subsystem via wireless communications as well as through connecting Fleet Manager to intermodal transportation providers using the existing wireline infrastructure. The interface to vehicle's sensor (*e.g.*, fuel gauge) and to the cellular data link is through processor equipped in the vehicle. The vehicle receives dispatch information and responses to other requests for assistance through the cellular data link from the Fleet and Freight Management Subsystem. This market package includes Commercial vehicle Subsystem, Fleet and Freight Management Subsystem, and Information Service Provider Subsystem. Table 3.3 represents the potential benefits of this market package.

Table 3.3 – Potential benefits of Fleet Administration

Goal Area	Potential Benefits
Efficiency	• Minor increased throughput
Productivity	• Increased productivity of vehicle/driver/carrier • Transit time reduced by keeping track of vehicle location and itineraries • Reduced operating costs • Reduced commercial and public administrative costs
Mobility	• Reduced cost of goods movement to shippers/receivers and the public • Reduced goods movement transit time • Increased reliability of delivery schedules to/from shippers/receivers
Energy and Environment	• Reduced energy consumption of trucks • Reduced environmental impacts of trucks
Security	• Increased security through better monitoring vehicle location and itineraries

Freight Administration

Keeping track of cargo and the cargo condition, and communicating this information with the Fleet and Freight Management Subsystem via wireless infrastructure is the main focus of Freight Administration market package. Intermodal shippers and intermodal freight terminals can then utilize the information for tracking the cargo from source to destination. This market package includes Commercial Vehicle Subsystem, Fleet and Freight Management Subsystem, Intermodal Terminal Subsystem, and vehicle Subsystem. Table 3.4 represents the potential benefits of this market package.

Table 3.4 – Potential benefits of Freight Administration

Goal Area	**Potential benefits**
Efficiency	• Minor increased throughput
Productivity	• Increased productivity of carrier • Transit time reduced by keeping track of cargo and cargo condition • Reduced operating costs
Mobility	• Reduced cost of goods movement to shippers/receivers and the public • Decreased goods movement transit time • Increased reliability of delivery schedules to/from shippers/receivers
Energy and Environment	• Reduced energy consumption of trucks • Reduced environmental impacts of trucks
Security	• Increased security through better monitoring cargo and cargo condition

Electronic Clearance

The focus of the Electronic Clearance market package is on automated clearance at roadside check facilities. It allows a compliant driver/vehicle/carrier equipped with a transponder to pass roadside facilities at mainline speeds. The roadside check facility may be equipped with necessary equipments (*e.g.*, transponder read/write devices, AVI, weighing sensors, computer workstation processing hardware, software, and databases) to communicate with the Commercial Vehicle Administration Subsystem to retrieve infrastructure snapshots of critical driver/vehicle/carrier data used for sorting passing vehicles. This package includes Commercial Vehicle Administration Subsystem, Commercial Vehicle Check Subsystem, Commercial Vehicle Subsystem, and Fleet and Freight Management Subsystem. Table 3.5 represents the potential benefits of this market package. The major benefit of this market package is increasing productivity through decreasing the administrative costs, expediting the inspection process, and decreasing the number of inspection staff. Commercial vehicles and drivers, especially long-haul carriers, benefit from preclearance those results in travel time savings and less delay for them. This improves the productivity of driver/vehicle/carrier, and increases the mobility.

Table 3.5 – Potential benefits of Electronic Clearance

Goal Area	Potential Benefits
Safety	• Safer working area from less crawling around and under trucks by inspection staff • Minor reduction in number of crashes (less speed variability from preclearance)
Efficiency	• Increased throughput at inspection sites
Productivity	• Reduced inspection costs • Reduced commercial and public administrative costs • Reduced inspection staff • Reduced inspection times • Reduced truck transit times by shorter stops at inspection sites or bypassing inspection sites • Enhanced productivity for vehicle/driver/carrier • Reduced cost of pavement maintenance
Mobility	• Reduced cost of goods movement to shippers/receivers and the public • Decreased goods movement transit time • Increased reliability of delivery schedules to/from shippers/receivers
Energy and Environment	• Reduced energy consumption of trucks • Reduced environmental impacts of trucks
Security	• Improved targeting of vehicle/driver/carrier for inspections

Commercial Vehicle Administration Processes

The focus of Commercial Vehicle Administrative Processes market package is on electronic application, processing, fee collection, issuance, and distribution of CVO credential and tax filing. This process enables carriers, drivers, and vehicles to be enrolled in the electronic clearance program (provided by a separate market package) that allows commercial vehicles to be screened at mainline speeds at commercial vehicle checkpoints. As a result, current profile databases enrolled through this market package are maintained in the Commercial Vehicle Administration Subsystem. The commercial vehicle check facilities at the roadside utilize snapshots of this database for the electronic clearance process. This package includes Commercial Vehicle Administration Subsystem, and Fleet and Freight Management Subsystem. Table 3.6 represents the potential benefits of this market package.

Table 3.6 – Potential benefits of Commercial Vehicle Administration Processes

Goal Area	Potential Benefits
Efficiency	• Increased throughput at inspection sites • Increased throughput of credentialing process
Productivity	• Reduced time, cost, and uncertainty in credentialing • Reduced operating costs • Reduced number of staff • Transit time reduced by shorter stops at inspection sites • Decreased tax and fee evasion • More equitable treatment in paying taxes and fees
Mobility	• Reduced cost of goods movement to shippers/receivers and the public • Decreased goods movement transit time and increased reliability of delivery schedules to/from shippers/receivers
Energy and Environment	• Reduced energy consumption of trucks • Reduced environmental impacts of trucks

International Border Crossing Clearance

The focus of International Border Crossing Clearance market package is on automated clearance specific to international border crossings for both commercial and private vehicles. This market package is a supplement to the electronic clearance package. It allows interface with customs-related functions and permits NAFTA required entry and exit from Canada to the United States and Mexico. This market package includes Commercial Vehicle Administration Subsystem, Commercial Vehicle Check Subsystem, and Commercial Vehicle Subsystem. Table 3.7 represents the potential benefits of this market package.

Table 3.7 – Potential benefits of International Border Crossing Clearance

Goal Area	Potential Benefits
Efficiency	• Increased throughput at inspection sites
Productivity	• Reduced inspection costs • Reduced commercial and public administrative costs • Reduced inspection staff • Reduced inspection times • Reduced truck transit times by shorter stops at inspection sites • Enhanced productivity for vehicle/driver/carrier • Reduced cost of pavement maintenance
Mobility	• Reduced cost of goods movement to shippers/receivers and the public • Decreased goods movement transit time • Increased reliability of delivery schedules to/from shippers/receivers
Energy and Environment	• Reduced energy consumption of trucks • Reduced environmental impacts of trucks
Security	• Improved targeting of vehicle/driver/carrier for inspections

Weigh-In-Motion (WIM)

The Weigh-In-Motion (WIM) market package primarily provides the roadside with additional equipment, either fixed or removable, in order to allow high-speed weigh-in-motion with or without AVI attachment. This market package includes Commercial Vehicle Check Subsystem, and Commercial Vehicle Subsystem. Table 3.8 represents the potential benefits of this market package. The major benefits of this market package include savings in travel time and administrative costs for both commercial and public. This results in less delay and more productivity for vehicle/driver/carrier due to lower operating costs.

Table 3.8 – Potential benefits of Weigh-In-Motion (WIM)

Goal Area	Potential Benefits
Safety	• Safer working area from less crawling around and under trucks by inspection staff • Minor reduction in number of crashes from identifying more overweight carriers • Minor reduction in number of crashes (less speed variability from preclearance)
Efficiency	• Increased throughput at inspection sites
Productivity	• Reduced weighing costs • Reduced truck weighing times • Reduced commercial and public administrative costs • Reduced inspection staff • Reduced truck transit times by bypassing/shorter stops at weighing facilities • Enhanced productivity for vehicle/driver/carrier • Reduced cost of pavement maintenance
Mobility	• Reduced cost of goods movement to shippers/receivers and the public • Decreased goods movement transit time • Increased reliability of delivery schedules to/from shippers/receivers
Energy and Environment	• Reduced energy consumption of trucks • Reduced environmental impacts of trucks

Roadside CVO Safety

The Roadside CVO Safety market package allows automated roadside safety monitoring and reporting to be performed by automating commercial vehicle safety inspections at the Commercial Vehicle Check roadside element. This market package shares the capabilities for performing the safety inspection with CVO On-Board Safety market package. This market package supports and facilitates safety inspection of vehicles that have been pulled in, perhaps as a result of the automated screening process provided by the Electronic Clearance market package, by reading basic identification data and status information from the electronic tag on the commercial vehicle, and subsequently, by accessing to additional safety data maintained in the infrastructure in favour of the safety inspection. The roadside safety check can be enhanced by employing additional vehicle safety monitoring and reporting capabilities in the commercial vehicle through more advanced implementations, supported by the On-Board CVO Safety market package. This package includes Commercial Vehicle Administration Subsystem, Commercial Vehicle Check Subsystem, and Commercial Vehicle Subsystem. Table 3.9 represents the potential benefits of this market package.

The roadside safety check can be enhanced by employing additional vehicle safety monitoring and reporting capabilities in the commercial vehicle through more advanced implementations, supported by the On-Board CVO Safety market package. This package includes Commercial Vehicle Administration Subsystem, Commercial Vehicle Check Subsystem, and Commercial Vehicle Subsystem. Table 3.9 represents the potential benefits of this market package.

On-Board Safety Monitoring

The focus of On-Board Safety Monitoring market package, which is an enhancement of the Roadside CVO Safety market package, is on on-board commercial vehicle safety monitoring and reporting by providing the commercial vehicle with a wireless link (data and possibly voice) to the Fleet and Freight Management and the Emergency Management Subsystems. The result is to provide primarily the driver with safety warnings, and then to notify the Fleet and Freight Management and Commercial Vehicle Check roadside elements. This market package includes Commercial Vehicle Administration Subsystem, Commercial vehicle Check subsystem, and Commercial Vehicle Subsystem. Table 3.10 represents the potential benefits of this market package.

Table 3.9 – Potential benefits of Roadside CVO Safety

Goal Area	Potential Benefits
Safety	• Fewer crashes involving trucks due to 1) more out-of-service orders, 2) improved compliance
Efficiency	• Increased throughput at inspection sites • Increased capacity due to less crashes
Productivity	• Reduced cost of safety inspection • Reduced time of safety inspection • Reduced commercial and public administrative costs • Reduced inspection staff • Transit time reduced by shorter stops at safety inspection sites • Reduced accident costs • Transit time decreased as a result of fewer crashes • Reduced accident cleanup costs • Reduced costs of truck maintenance and depreciation • Reduced truck insurance costs
Mobility	• Reduced cost of goods movement to shippers/receivers and the public • Decreased goods movement transit time • Increased reliability of delivery schedules to/from shippers/receivers • Reduced highway delays to public from fewer crashes
Energy and Environment	• Reduced energy consumption of trucks • Reduced environmental impacts of trucks
Security	• Increased cargo safety and security

Table 3.10 – Potential benefits of On-Board CVO Safety Monitoring

Goal Area	Potential Benefits
Safety	• Fewer crashes involving trucks due to 1) safety warnings to driver, 2) more out-of-service orders, 3) improved compliance
Efficiency	• Increased throughput at inspection sites • Increased capacity due to less crashes
Productivity	• Reduced cost of safety inspection • Reduced time of safety inspection • Reduced commercial and public administrative costs • Reduced inspection staff • Transit time reduced by shorter stops at safety inspection sites • Reduced accident costs • Transit time decreased as a result of fewer crashes • Reduced accident cleanup costs • Reduced costs of truck maintenance and depreciation • Reduced truck insurance costs
Mobility	• Reduced cost of goods movement to shippers/receivers and the public • Decreased goods movement transit time • Increased reliability of delivery schedules to/from shippers/receivers • Reduced highway delays to public from fewer crashes
Energy and Environment	• Reduced energy consumption of trucks • Reduced environmental impacts of trucks
Security	• Increased cargo safety and security

CVO Fleet Maintenance

Maintenance of CVO fleet vehicles can be realized by CVO Fleet Maintenance market package through close interface with on-board monitoring equipment and AVLS capabilities within the Fleet and Freight Management Subsystem. Records of vehicle mileage, repairs, and safety violations are maintained to assure safe vehicles on the highway. This package includes Commercial Vehicle Subsystem, and Fleet and Freight Management Subsystem. Table 3.11 represents the potential benefits of this market package.

Table 3.11 – Potential benefits of CVO Fleet Maintenance

Goal Area	Potential benefits
Safety	• Fewer crashes involving trucks due to better maintained vehicles
Efficiency	• Increased throughput at inspection sites • Increased capacity due to less crashes
Productivity	• Reduced cost of safety inspection • Reduced time of safety inspection • Reduced commercial and public administrative costs • Reduced inspection staff • Transit time reduced by shorter stops at safety inspection sites • Reduced accident costs • Transit time decreased as a result of fewer crashes • Reduced accident cleanup costs • Reduced costs of truck maintenance and depreciation • Reduced truck insurance costs
Mobility	• Reduced cost of goods movement to shippers/receivers and the public • Decreased goods movement transit time and increased reliability of delivery schedules to/from shippers/receivers • Increased cargo safety and security • Reduced highway delays to public from fewer crashes
Energy and Environment	• Reduced energy consumption of trucks • Reduced environmental impacts of trucks
Security	• Increased cargo safety and security

Hazardous Material Planning and Incident Response

The focus of Hazardous Material Planning and Incident Response market package is on integration of incident management capabilities with commercial vehicle tracking to guarantee effective treatment of HAZMAT material and incidents. The Emergency Management subsystem receives information about occurrence of any incident from the Commercial Vehicle and coordinates the response The Fleet and Freight management Subsystem then performs HAZMAT tracking and provides supplemental information. This market package includes Commercial Vehicle Administration Subsystem, Commercial Vehicle Subsystem, Emergency Management Subsystem, Fleet and Freight Management subsystem, and Vehicle Subsystem. Table 3.12 represents the potential benefits of this market package.

Freight In-Transit Monitoring

The focus of Freight In-Transit Monitoring market package is on tracking and monitoring intermodal containers and intermodal freight shipments anywhere in the transportation system during the entire pickup-transport-drop-off period, and providing the information to freight customers, fleet managers, and logistics service providers. This package includes Commercial Vehicle Subsystem, Fleet and Freight Management Subsystem, and Intermodal Container Subsystem. Table 3.13 represents the potential benefits of this market package.

Freight Terminal Management

The focus of Freight Terminal Management market package is on the operation of the roadway aspects of an intermodal terminal (*i.e.*, the transfer point between roadway and one or more other modes of container transport, an actual terminal facility, or a private intermodal transfer facility). This market package can provide truck weight and safety assessments for vehicles prior to departing the facility if deployed in conjunction with Weigh-In-Motion and Roadside CVO Safety. Some of the capabilities of this market package include identification and control of vehicle traffic entering and departing the facility, maintaining site security and monitoring container integrity, allowing data exchange between different terminals of the same mode or different modes, and tracking container locations within the facility. This package includes Commercial Vehicle Subsystem, Fleet and Freight Management Subsystem, Intermodal Container Subsystem, and Intermodal Terminal Subsystem. Table 3.14 represents the potential benefits of this market package.

Table 3.12 – Potential benefits of Hazardous Material Planning and Incident Response

Goal Area	Potential Benefits
Safety	• Faster incident notification and response to incidents involving HAZMAT • Fewer crashes involving hazardous materials • Increased personal safety of the motoring public
Efficiency	• Increased capacity due to less crashes and faster incident response
Productivity	• Reduced accident costs • Transit time decreased as a result of fewer crashes • Reduced accident cleanup costs • Reduced truck insurance costs
Mobility	• Reduced cost of goods movement to shippers/receivers and the public • Decreased goods movement transit time • Increased reliability of delivery schedules to/from shippers/receivers • Reduced highway delays to public from fewer crashes and better response to crashes
Energy and Environment	• Reduced environmental impacts of HAZMAT incidents • Reduced energy consumption of trucks • Reduced environmental impacts of trucks
Security	• Increased security due to faster and more appropriate response to incidents involving HAZMAT

Table 3.13 – Potential benefits of Freight In-Transit Monitoring

Goal Area	Potential Benefits
Efficiency	• Minor increased throughput
Productivity	• Increased productivity of carrier • Transit time reduced by keeping track of intermodal containers and intermodal freight shipments • Reduced operating costs • Reduced commercial and public administrative costs
Mobility	• Reduced cost of goods movement to shippers/receivers and the public • Reduced goods movement transit time • Increased reliability of delivery schedules to/from shippers/receivers
Energy and Environment	• Reduced energy consumption • Reduced environmental impacts
Security	• Increased security through better monitoring intermodal containers and intermodal freight shipments

Table 3.14 – Potential benefits of Freight Terminal Management

Goal Area	Potential Benefits
Safety	• Reduction in number of crashes through improved truck weigh and safety assessments prior departure
Efficiency	• Increased throughput
Productivity	• Reduced weighing costs • Reduced truck weighing times • Reduced cost of safety inspection • Reduced time of safety inspection • Reduced commercial and public administrative costs • Reduced inspection staff • Reduced truck transit times by bypassing/shorter stops at weighing facilities • Transit time reduced by shorter stops at safety inspection sites • Enhanced productivity for vehicle/driver/carrier • Reduced accident costs • Transit time decreased as a result of fewer crashes • Reduced accident cleanup costs • Reduced costs of truck maintenance and depreciation • Reduced truck insurance costs
Mobility	• Reduced cost of goods movement to shippers/receivers and the public • Decreased goods movement transit time • Increased reliability of delivery schedules to/from shippers/receivers
Energy and Environment	• Reduced energy consumption of trucks • Reduced environmental impacts of trucks
Security	• Improved site security and monitoring container integrity

3.6. CHAPTER SUMMARY

This chapter represented a review on user services, user sub-services, and market packages of intelligent transportation systems for commercial vehicle operations (ITS/CVO) as defined by the Canadian ITS Architecture. Each market package was then analyzed to identify the associated potential benefits of deployment. It is worth noting that these tables should be used with certain care to avoid double counting of benefits, as some the potential benefits of market packages shown in Tables 3.3 to 3.14 are interrelated, especially with regard to efficiency, productivity, and mobility goal areas.

4. ITS/CVO EVALUATION FRAMEWORK

4.1. INTRODUCTION

The previous sections described ITS/CVO applications, current evaluation practices, and potential benefits from ITS/CVO deployments. A review of the ITS/CVO evaluation studies suggests that the evaluators have adopted different methodologies for their evaluation studies, and the evaluation results and the reported benefits of various ITS/CVO deployments are neither consistent nor reliable. This is mainly because of the innovative nature of ITS/CVO concept and lack of widespread deployment of its application areas. An ITS/CVO evaluation framework includes the identification of evaluation criteria and variables pertaining to the impact of the proposed ITS/CVO application to society and various stakeholders. This will employ operational tests, modelling, simulation, interviews, surveys, and economic techniques that will be used to evaluate the proposed application and to quantify some of the evaluation criteria. Evaluation criteria that cannot be easily measured will be qualitatively analyzed. This chapter begins with a brief description of major challenges for ITS/CVO projects, such as lack of consistent terminologies for categorizing ITS/CVO application areas and its benefits, lack of data, institutional issues, etc. The next part of this chapter introduces a step-by-step guide for ITS/CVO project evaluation that can be employed as a framework for evaluation to lessen the negative effects of the described issues. The practicality of this framework will be examined in Chapter 5.

4.2. MAJOR ISSUES FOR ITS/CVO EVALUATION

This section discusses some of the issues that should be considered during an evaluation process. It is worth noting that coordination between stakeholders involved in the project as well as stakeholders and project evaluators can help to overcome many challenges during the evaluation processes such as selection of the performance criteria and the collection of corresponding data.

4.2.1. TERMINOLOGY

Lack of a consistent terminology among transportation professionals in describing various ITS/CVO applications seems to be one of the challenges in evaluation studies. For instance, there are differences in the components of ITS taxonomy for commercial vehicle operations among the U.S. ITS Architecture, Canadian ITS Architecture, and the intelligent transportation systems benefits and cost, 2003 update (Mitretek Systems 2003). Further, the review of literature shows that there is not an agreement among professionals in the reported benefits associated with each application area. One of the reasons is that some of the benefits are interrelated. Lack of understanding of such interrelationships may result in double counting of benefits in an evaluation study. The use of an evaluation framework that proposes employing a common ITS taxonomy for commercial vehicle operations (*i.e.*, Canadian ITS Architecture) and identifies the potential benefits for each application area, can help transportation professionals to lessen the negative impacts of such inconsistencies in their ITS/CVO evaluation studies.

4.2.2. PUBLIC VERSUS PRIVATE BENEFITS

Most ITS/CVO applications provide benefits to both public and private sectors. For instance, increasing efficiency or throughput at a border crossing facility via deploying ITS/CVO International Border Crossing Clearance market package can result in various benefits to the public, such as reduced inspection and public administration costs for the public, reduced cost of goods movement to the public, reduced negative environmental impacts, and improved security by better targeting of vehicle/deriver/carrier for inspection. On the other hand, this market package can help the private carrier companies to increase their productivity, and improve reliability of delivery schedules. Evaluation can help public decision-makings on comparing investment and support of ITS/CVO deployment programs with other worthwhile public programs. If this is the major issue, then ITS/CVO deployment should be justified on the potential benefits to the public. Another major issue can be considering private funding possibilities for ITS/CVO deployments in addition to the purely public sector funding. The result of an evaluation that has considered both public and private benefits can then help the decision makers to identify and define the possibilities for public/private partnership of ITS/CVO deployments. It is important to note that the availability of private sector funding may be more dependent on a short window of opportunity and considering timing and investment costs of deployments (McQueen and McQueen 1999).

4.2.3. DATA AVAILABILITY

One of the major challenges for ITS evaluation is the availability of the required data for evaluation. Further, finding resources for data collection can also be a major barrier due to limited budget assigned for evaluation. Identifying data requirements in the early phase of the planning stage can help the evaluation team to periodically collect field data. Coordination among stakeholder agencies in data collection and analysis may result in lessening the problems associated with data collection. Lack of widespread deployment of ITS/CVO applications and therefore, lack of before-and-after data are other important issues. In many ITS/CVO applications the extent of deployment has not reached a level that can be evaluated or generate real-life benefit results. An alternative can be using statistical techniques such as meta-analysis; thereby an estimate of the average effect of an ITS deployment is developed based on summarizing the results of similar studies. This type of statistical analysis tool could be employed for impact study of ITS deployment when there is lack of required data for direct analysis.

4.2.4. DATA TRANSFERABILITY

Data transferability among regions and the interpretation of the impact data are also important issues. For instance, how does an evaluation team use the data from a study that reported that implementing intelligent border crossing has been found to save inspection time by a certain percentage? There might be differences in various exposure conditions between the study site and a region that is using data. Before using any data, it should be considered how the results can be transferred and calibrated for a particular region. More benefits will be achieved in the case of availability of adequate description on how data calibration of existing impact data should be performed for a different region.

4.2.5. UNCERTAINTY ABOUT USING NEW TECHNOLOGIES

ITS applications propose new concepts and technologies that are unfamiliar to many people, including decision makers and implementers. This means that decision makers are not sure about the cost-effectiveness of an investment in ITS projects. The result may be a great reluctance among decision makers to accept a new ITS project. An evaluation framework can be a helpful tool for transportation professionals to evaluate ITS/CVO projects and report the benefits in a consistent manner to decision makers. The evaluation results of similar projects, data from the similar studies, and simulation modelling can be employed to assess the impacts of a planned system. These help decision makers to overcome the uncertainty associated with the proposed ITS/CVO application. A major challenging aspect of any ITS project is rapid changes in the technology that serves various functions of ITS. This makes evaluation very important because it minimizes the risk of project failure through unrealistic objectives that cannot be met through the proposed ITS application.

4.2.6. USER'S WILLINGNESS TO PAY FOR THE PRODUCT

User acceptance and especially, user's willingness to pay are very important issues that should be estimated, especially for those ITS/CVO products that are completely new and do not exist yet. The user's willingness to pay is especially important for converting the impacts of ITS/CVO from their natural units to monetary values for a conducting a benefit/cost analysis (BCA). The unit values applied to the impacts are the prices that the ITS/CVO users are willing to pay as revealed by their actual or stated preferences in response to the proposed ITS/CVO deployment and it varies by customer and marketplace or choice situation (Brand 1998). Chen and Miles (1999) doubt about the reliability of employing alleged preference obtained from questionnaires for predicting revealed preference in future market behaviour. This is because the value a person says about their willingness to pay after trying a new product cannot exactly translated as person's willingness to buy that product once it is available on the market at that price. Therefore, market uncertainty and other risks (*e.g.*, product liability and technical obsolescence) should be taken into account before any investment decisions.

4.2.7. INSTITUTIONAL ISSUES

Institutional issues are usually one of the major barriers in all ITS/CVO evaluation processes. ITS/CVO will be deployed in institutional environments that may or may not advocate their intended functions (Underwood and Gehring 1994). FHWA/FTA (2001) found institutional issues to be the most significant barrier in deploying and using technology as a tool for enhancing processes at international borders. An example can be a border-crossing facility that is a complex institutional environment involving different agencies from both countries that have significant stakes in the operation. It is clear that these agencies have different fundamental missions, different internal cultures, and most importantly various viewpoints on any considerable changes in operational procedures at the border (Nozick *et al.* 1999). Booz-Allen and Hamilton (2000) identified various issues during the evaluation interviews, and grouped them into one of three categories: information management, inter-jurisdictional coordination, and sustainability. The major concerns regarding information management can be the issue of ownership and control of data as well as the security of potentially sensitive data. Inter-jurisdictional coordination is another significant challenge for ITS/CVO programs and the main issues in this category are technology standards, data sharing practices, and law enforcement jurisdictional authority. Another major issue is in answering the question of how to encourage a level of participation adequate to actualize some of the potential benefits illustrated in different studies (Booz-Allen and Hamilton 2000).

4.3. A SYSTEMATIC GUIDE FOR ITS/CVO PROJECT EVALUATION

There is always considerable uncertainty about what can be achieved with new applications. Therefore, it is very important to examine and document the impacts of the implementation in order to learn more about the proposed application and to answer the main question on whether the implementation should be extended or dismantled. This makes an evaluation process a very important and vital component in the various stages of the decision-making processes. A well-defined evaluation process enables decision makers to avoid mistakes and erroneous decisions in future. Evaluation should begin in the planning phase when the goals are being established and the type and extent of the system are being investigated.

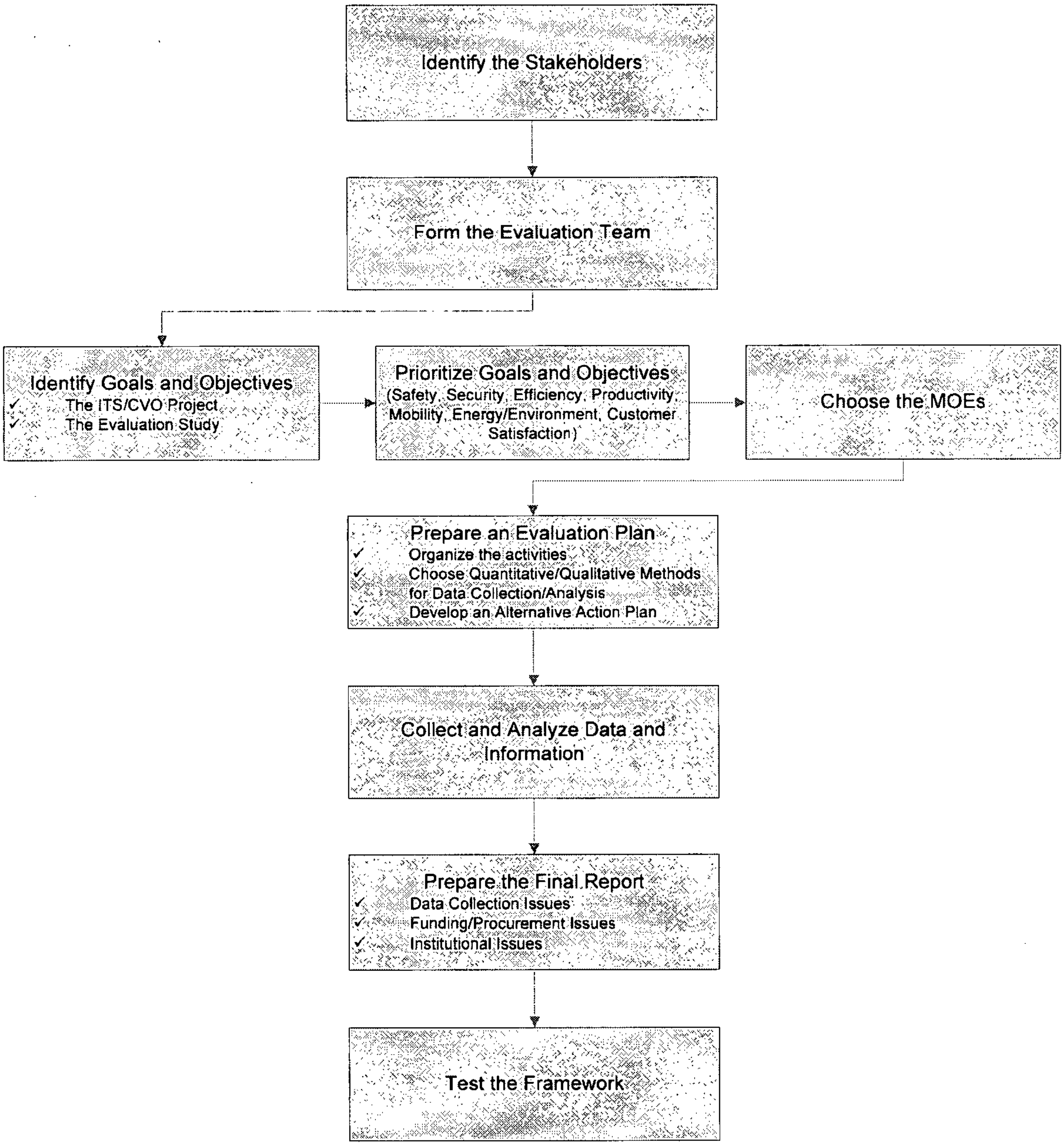
Evaluation should continue until the full system is implemented and the system becomes operational. Data collection should also begin in the early stages of the project and continue until the system is operational. This makes comparison of before and after implementation easier and the results of the evaluation more accurate.

This section describes the different steps of an ITS/CVO evaluation process and the issues that should be considered to make the whole evaluation process more reliable. It is worth noting that there are certain reasons behind the implementation of any ITS/CVO application that are mainly in response to identified problems. This means that identified goals in each ITS/CVO project are a decisive factor in determining the focus of the evaluation as well as the system function, type, scale, and geographic sphere of implementation. As each implementation has its own characteristics that make it unique, the evaluation process should be consistent to make the comparison among projects easier. Further, evaluation should not be considered as an advance assessment. Rather, evaluation should look back and assess what the actual impacts and costs of the implementation are or have been in order to guide for the future developments. The following sections represent a framework for the evaluation process that describes different steps in an ITS/CVO evaluation study. These steps have been shown in Figure 4.1.

4.3.1. IDENTIFY THE PROJECT STAKEHOLDERS

One of the important issues in any evaluation process is to consider the interests of stakeholders or customers in the early stages of the planning process. Therefore, one of the first steps is to identify the "customer" groups affected by the deployment of ITS/CVO application area. Based on the project, these may include Federal government (*e.g.*, Transport Canada, Canadian Border Services Agency), Provincial/State governments (*e.g.*, B.C. Ministry of Transportation, Solicitor General's Office of B.C.), Regional and Municipal governments (*e.g.*, Greater Vancouver Transportation Authority, City of Surrey), associate national and local agencies, law enforcement agencies, trucking industry (*e.g.*, B.C. Trucking Association), Motor Carriers, shippers/ receivers, and members of the public.

Figure 4.1 – An ITS/CVO Evaluation Framework



4.3.2. FORM AN EVALUATION TEAM

It is very important that evaluation be conducted by an independent party without any vested interest or risk in the project. The independent evaluator should have an early involvement in the project to identify key stakeholder partners and a meaningful set of goals, objectives, and measures for the project. Furthermore, the independent evaluator should have a close interaction with an evaluation team that consists of one member from each of the project partners and stakeholder. The formation of an evaluation team, especially with participation of all stakeholders, can facilitate planning of the project and developing the evaluation strategy, and reduces the chance of having surprises in later stages of the project.

4.3.3. IDENTIFY GOALS, OBJECTIVES, AND MEASURES OF EFFECTIVENESS (MOEs)

At this stage, the goals and objectives of the project and the evaluation should be identified, confirmed, and agreed. This requires the type of problem(s) and need(s) to be clearly identified as well as the reason for introducing the specific ITS/CVO application.

Identify Goals and Objectives of the Project

It is very important to make sure that there is an agreement among all parties involved in the project on the goals, objectives, and expectations from the proposed ITS/CVO deployment and when they are expected to be achieved. This includes the geographical extent of the project, the area covered, the time aspect, the expected impacts over the course of time (*i.e.*, what percentage of the objective can be achieved in short-, medium-, and long-term) as well as the groups being impacted by the deployment. A comprehensive literature review on similar projects and participants brainstorming can assist the evaluator to identify the potential changes of the transportation system as well as the groups impacted form the proposed ITS/CVO deployment.

For instance, elements of two major ITS/CVO user services involved in the CVISN Model Deployment Initiative (MDI) were Credential Administration (including electronic credentialing and clearinghouses) and Roadside Enforcement (including electronic screening of commercial vehicles at mainline speeds and strategies for transmitting data to and from the roadside). Battelle (1998) found that the expected changes from electronic credentialing and clearinghouses were faster turn-around time, fewer errors, reduced costs to carriers, increased information sharing among agencies, increased fairness and uniformity of fee collection among jurisdictions, improved accuracy and data completeness, increased costs for network and information system support, and time saved. For roadside enforcement, the expected changes of the transportation system include fewer delays at roadside, reduced industry costs for noncompliant carriers, more effective use of inspection resources, real-time out-of-service verification, better decisions on whom to inspect, increased safety compliance, crash reductions, improved throughput at scales, increased revenue recovery, and increased access to information from other states. Battelle (1998) also identified major customers of CVISN as motor carriers, state governments, law enforcement agencies, members of the public, and federal government. Each of these parties has certain interests and expectations from the deployment.

Identify Goals and Objectives of the Evaluation

It is very important to clarify the main reasons for the evaluation. All parties involved should agree on what can or cannot be accomplished in the evaluation and why. To do so, all limitations of the project and the evaluation study, both known and anticipated, should be discussed clearly to avoid overestimating the positive outcomes of the project/evaluation and hoping for the results that might not be achievable. This is extremely important in the ITS/CVO evaluation process as in most cases there are high limitations on the input data due to innovative nature of these kinds of the projects.

The evaluator should also have a thorough understanding on how the results of the evaluation will be used and what decision will be made. The purpose of evaluation should be determined clearly in order to identify the measurable effects of the implementation and the focus of the evaluation. The results of the evaluation may be just used for research purposes and increase in knowledge, or it can be used for investigating the practicality of the application in an specific region, or it may be used for high-level decision making on whether the new application should be implemented in specific region or not. These different purposes can highly affect the focus of the evaluation and the presentation of the results. For instance, if the evaluation is just for research purposes, it will mainly be used for scientific orientation and initial data gathering on how the implementation may work. However, if the results are planning to be used for decision-making, the evaluation should clearly represent the cost-effectiveness of the implementation, its impacts on transportation systems, and details of evaluation/ implementation process. For higher-level discussions (*e.g.*, political discussions), the results of the evaluation should clearly emphasize on important tasks such as profitability rather than details of the evaluation/implementation.

Prioritize Goals and Objectives

ITS/CVO projects should be evaluated based on their impacts on the overall ITS goal areas, including safety, security, efficiency, productivity, mobility, energy and environment, and customer satisfaction. It is very important to identify which of the aforementioned goal areas have priority in the project from the viewpoints of different stakeholders. This can be realized by asking each stakeholder to assign numerical ratings of the magnitude of importance to the goal areas, and as a result, rating the potential benefits according to their perceived importance. Furthermore, the evaluation objective should be developed and prioritized through a combination of a literature review and participants brainstorming. The objectives should be well enough defined to be measurable. If it is not measurable, there is probably no direct benefit of its own and it should not be an objective, although it might be qualitatively analyzed.

Choose the Measures of Effectiveness

The whole evaluation process and consequently the selection of the measures of effectiveness (MOEs) to quantify the improvements are integrated parts of the decision-making process and therefore, the measures of effectiveness should be selected based on the information needs of decision makers. The level of detail and the presentation of the measures of effectiveness must match the evaluation goals and needs of decision makers. Measures of effectiveness should be easily understandable while addressing the goals of stakeholder involved (*i.e.*, customer groups) as well as the public. Other major issues to note include:

- In ITS/CVO projects, similar to other transportation improvement projects, there might be conflicting goals and associated measures of effectiveness that should explicitly recognized, and the techniques for balancing these interests should be addressed; and

- Interrelation between some goals and associated measures of effectiveness (*e.g.*, economic efficiency and productivity) should be recognized and the techniques for minimizing double counting and misplacing the same sequence under different names should be addressed. This also includes transfer of impacts between affected groups.

4.3.4. PREPARE AN EVALUATION PLAN

After having the project goals, objectives, and measures of effectiveness identified, the evaluation plan should develop the evaluation approach by outlining the necessary activities to measure the evaluation parameter, describing the analysis work, and defining the product of analysis. The evaluation plan is a vital part of the evaluation process that identifies the expected outcome of the project, the methodology used for analysis, and the associated data requirements. An evaluation plan should usually consider comparison between the conditions of a base-case scenario (*i.e.*, before implementation) with the condition(s) when the application is in operation. A risk assessment should also be part of an evaluation plan to describe the actions that should be applied if the planned evaluation activities cannot be completed as planned.

Generally, an evaluation plan is formed based on the external conditions that govern the whole evaluation process. Established goals and objectives of the project, the expected impacts, available resources, time aspects, quality requirements, and the purpose of the evaluation are among factors that affect the evaluation plan. Furthermore, the system function, type, scale, and geographic sphere of implementation are influential factors in setting the plan. For instance, variations in seasonal conditions (*e.g.*, the weather, light) and other external circumstances may impair the use of certain methods. Table 4.1 represents an example of a framework for evaluating the benefits of an ITS/CVO project with hypothetical impacts, measures of effectiveness, impacted groups, and different methods of variable estimations.

Data Collection/Analysis Methods

Various methods can be used for the evaluation purpose, including methods for data collection, and for analysis and assessment. These methods can be grouped in several categories, such as field studies, modelling and simulation, surveys, interviews, and traffic counting. For instance, valuation based on modelling and simulation is generally more cost effective as opposed to evaluation based on field studies. Modelling-based evaluation allows for the modelling of various alternatives and sensitivity analyses; however, the accuracy of the evaluation depends on input variables and model calibration. A model developed without calibration to field data is solely a "conceptual model" and its usefulness would be primarily for relative comparison of various scenarios and not necessarily in the validity of the model outputs in an absolute sense. On the other hand, evaluation based on field studies enables evaluator to compare before and after scenarios that result in minimum assumption requirements for deriving conclusions. Field evaluation is costly, as it requires field implementation of the technology and large field data collection efforts. Employing only one method usually cannot provide enough information required for the evaluation and therefore, a combination of different methods will be used to strengthen the value of evaluation. For instance, the combined field and modelling evaluations can be more expensive than modelling evaluation; nevertheless, the results are more credible as simulation results are validated against field observations.

Qualitative Analysis

There are also some non-technical issues of ITS/CVO implementation, which should be addressed by the evaluation plan, such as consumer acceptance, institutional issues, implications of achieving consistency with the National ITS Architecture, and standards implementation. These are among issues that usually cannot be analyzed quantitatively and therefore, it is vital to identify qualitative studies that will be performed. Qualitative analyses are used in order to account of any impacts that are not quantifiable and of any "costs and benefits" for which dollar values cannot be assigned.

Benefit-Cost Analysis

In an evaluation process, it may be useful to conduct benefit-cost analysis (BCA) to measure the total net benefits of ITS/CVO project investment to the public. Benefit-cost analysis is used to compare two or more alternatives based on their benefits, costs, and total net benefits. One of the alternatives is the base-case scenario without ITS/CVO deployment. Identifying the right inputs and estimating their values is one of the most important and most difficult tasks of any benefit-cost analysis, especially when it requires new data collection and analyses. All the major benefits and associated costs of the alternatives should be included only once and without any double counting, and without transfers of benefits and costs between affected groups. Another challenging part of a benefit-cost analysis is to convert the impacts of ITS/CVO to monetary values. The unit values applied to the impacts or prices used to convert nonmonetary impacts to monetary benefits or costs must be estimated based on the ITS/CVO user's willingness to pay that varies by customer and market place or choice situation. Therefore, market uncertainty and other risks (*e.g.*, product liability and technical obsolescence) should be taken into account before any investment decisions (Chen and Miles 1999).

It is also important to note that measures of achievement of the engineering efficiency goal do not enter into a benefit-cost analysis because increased output per unit of input is best measured in transportation as increased throughput or capacity (for example, vehicles per hour, inspections per hour, inspections per person-hour). This benefit can be converted to a dollar value to society under the productivity goal in the form of cost savings, which includes the savings to motor carriers and government agencies that result from ITS/CVO deployment (Brand *et al.* 2002).

4.3.5. COLLECT AND ANALYZE EVALUATION DATA AND INFORMATION

Data collection is one of the most challenging parts of any evaluation process and requires careful cooperation between parties involved in the project. Based on the project, data collection might be performed via survey work, automated data collection as direct output from the implemented system, on-site through interviews with different stakeholders, and/or from similar studies on ITS/CVO deployments and evaluation studies. Different types of data include quantitative, objective data based on direct measurements of parameters, or qualitative, subjective data based behavioural response to proposals or customer acceptance of products and services. Data collection stage requires recruiting and training field staff, and designing and installing measuring equipment (*e.g.*, questionnaire forms, data storage systems). It is very important to make sure that field staff have clear understanding about how the study should be performed and that all equipment are working properly.

The evaluation methodology may require "before" data collection for the base-case scenario in addition to the "after" data collection for an evaluation of the proposed ITS/CVO implementation. The "before" data can serve for characterization of the before conditions in the case of field evaluation as well as for calibration of the model in the case of a modelling evaluation. The evaluator should examine potential ways to reduce data collection expenses by integrating data collection efforts across various MOEs. In some circumstances and due to difficulty in collecting some input data to the evaluation of a new ITS/CVO application, it may be necessary to make some assumptions as to the values of time and cost savings and system costs, the percentages of unsafe motor carriers affected, the safety/security benefits attributed to it, *etc.*

After required data and information are collected, the material collected will be analyzed with the methods chosen and described in previous stages. The creditability of the results is important so that in case of repeating the evaluation under similar condition, the same results can be reached. However, it is important to note that the results of the evaluation cannot simply be generalized rather they should be interpreted with certain care. This is an important issue because observable benefits of an ITS/CVO deployment usually emerge after systems have been implemented for some time, and the results may change with time as users change their behaviour in response to system.

Table 4.1 – Example of a framework for evaluating the benefits of ITS/CVO projects

Goal	Expected Impacts	MOE	Impacted Group(s)	Estimation
Safety	Fewer crashes involving trucks	• Change in number of crashes • Change in severity of crashes • Change in speed variability (S) • Change in number of conflicts (S)	• Carriers and shippers • Public	• Field studies • Before and after studies using crash statistics from police, ICBC, or hospital reports • Truck crash prediction model • Simulation
	Increase compliance	• Change in speed compliance	• Province	• Out of service orders issued • Interviews • Surveys • Police statistics
	Improve emergency response	• Change in response time • Change in clearance time • Change in number of fatalities	• Carriers and shippers • Public	• Automatic traffic monitoring • Field studies • Interviews • Surveys
Security	Improve targeting for truck inspections	• Change in percentage of non-compliant trucks detected (S)	• Province • Public	• Interviews • Surveys • Field studies • Qualitative analyses • Simulation
	Improve compliance			
Efficiency	Improve infrastructure efficiency (*e.g.*, throughput at inspection sites)	• Change in throughput or effective capacity at inspection sites • Change in vehicle speed differential by vehicle type at inspection sites (S) • Change in speed of inspection process • Change in number of stops at inspection sites • Change in delay at inspection sites	• Province • Carriers and shippers • Public	• Automatic traffic monitoring • Field studies • Simulation

Table 4.1 – Example of a framework for evaluating the benefits of an ITS/CVO project (cont'd)

Goal	Expected Impacts	MOE	Impacted Group(s)	Estimation
Efficiency (cont'd)	Improve goods movement efficiency	• Increased throughput for goods movement (*i.e.*, volumes of goods moved by the existing fleet)	• Carriers and shippers • Public	• Survey • Simulation • Monitoring of business operations • Analyses of financial statements
Productivity (cost savings and increased output)	Reduce public administrative costs	• Change in vehicles inspected per site hour • Change in vehicles credentialed per labour hour • Change in number of inspection staff	• Province	• Survey • Field studies • Simulation • Interviews
	Reduce costs and improve productivity of commercial vehicle operations	• Change in time from application to issuance of credentials • Change in number of trucks stopping at inspection sites • Change in time from bypassing inspection sites at highway speeds • Change in costs of truck maintenance and depreciation (S) • Change in truck insurance costs (S)	• Carriers and shippers • Public	• Survey • Interviews • Simulation • Monitoring of business operations • Analyses of financial statements
Mobility	Reduce transit time for trucks and shipments	• Change in truck transit time • Change in queue length at inspection sites (S)	• Carriers and shippers • Public	• Field studies • Simulation • Automatic traffic monitoring • Trip diaries • Timetables • Interviews • Surveys

Table 4.1 – Example of a framework for evaluating the benefits of an ITS/CVO project (cont'd)

Goal	Expected Impacts	MOE	Impacted Group(s)	Estimation
Mobility (cont'd)	Reduce highway delays to public	• Change in delay for trucks • Change in overall travel time • Change in travel time variability	• Carriers and shippers • Public	• Field studies • Automatic traffic monitoring • Simulation • Interviews • Surveys
Energy and Environment	Reduce energy consumption	• Change in fuel consumption of trucks and cars	• Carriers and shippers	• Automatic traffic monitoring • Fuel consumption models • Simulation
	Reduce environmental impacts	• Change in vehicle emissions • Change in noise pollutions	• Public	• Emission models • Simulation • Traffic survey • Automatic traffic monitoring • Noise studies
Customer satisfaction	Improve service satisfaction for shippers		• Carriers and shippers	• Surveys • Interviews • Qualitative analyses
	Improve service satisfaction for inspection staff		• Province	

4.3.6. Prepare the Final Report

The purpose of this stage in the evaluation process is to provide the final report that contains documentation of evaluation methodology, plans, results, conclusions, and recommendations. The final report represents how well program goals and objectives have been achieved. The results section of the report should include information about findings, and availability and usefulness of data. The recommendations section is one of the important parts of the report that describes the lessons learned, recommendations for the revisions of the procedure, and other case study material. Based on the review of the literature (Booz-Allen and Hamilton 2000; ITS/JPO 2001; McQueen and McQueen 1999;

Nozick *et al.* 1999; VTTI 2003), the major issues that should be addressed in addition to conventional technical results report will be discussed briefly in the following sections. The focus should be on identification and documentation of barriers and problems, and on the strategies employed to overcome these barriers during different phases of the ITS/CVO project.

Data collection issues

As discussed earlier, data collection is one of the major challenging parts for ITS/CVO evaluation process. It is recommended that the final report include a description of data sources and data collection process (*i.e.*, how and what type of data was recorded), the barriers encountered during the process, how these barriers were overcome, data analyses methodologies, and data storage techniques. If the study utilized data from other studies, the report should also describe how the data was interpreted for the study and what data transferability issues were.

Funding/procurement issues

Due to innovative nature of ITS/CVO projects, there may be no prior model or procedure that can be followed when identifying funding and procurement opportunities. This makes the process of justifying the expenditure and procuring financial support for the new ITS/CVO project very difficult. It is recommended including a section in the final report to represent lessons learned form project funding process with detailed description of what strategies were used and what could be done to better the process. Some of the issues that should be considered and documented include:

- Sources of project funding sources (Who pays for the system implementation? Who pays for the maintenance? *etc.*)
- Type of financing used for the project, the structure of public-private partnership
- Type and level of success of project contracting (*e.g.*, federal competitive process, low bid, sole source, design/build, *etc.*)

- Method for choosing, work allocating, and paying the contractor(s)
- Method to identify the procurement capabilities of the project participants
- Financial problems for project development and the solutions
- Lessons learned from other similar deployments applied to this deployment

Institutional issues

Institutional issues involved in an ITS/CVO implementation program include both non-technical challenges for having public sector agencies cooperated and technical challenges for integrating ITS/CVO components. The former focuses on "people" and organizational issues associated with ITS/CVO project implementation and operation, such as participant responsibilities, role expectations, staffing levels, inter-jurisdictional coordination, and other inter-agency partnership issues. The latter deals with issues such as interoperability among systems, standards and protocol compliance, infrastructure readiness, integrating new ITS/CVO components with existing legacy systems, and cost and budget constraints. A successful ITS/CVO implementation program requires high level of cooperation between participating organizations to overcome or lessen institutional challenges by developing common goals that meets needs of all parties involved, and achieving formal arrangements for cooperation and integration. Some of the issues that should be considered and documented include:

- Types of organizations involved with the project (*i.e.*, public, private, non-profit)
- Strategies to define the responsibilities of participating organizations, and to make it clear to all partners
- Strategies to achieve project's goals and objectives that suit all partners
- Level of involvement of private-sector
- Strategies to improve communication and coordination between participating organizations

- Risk and benefit assessment methodology of each project partner
- Institutional barriers encountered by the project participants, their causes, and the strategies to overcome them
- The role and involvement of the steering committee
- Who owns the system? Who operates? Who takes the profit?
- Utilizing lessons learned from similar deployments to the current deployment
- Software development and rights to intellectual property
- The level of data sharing: what data or information can or cannot be shared between agencies? Why? How?
- What is the liability?
- What are the security issues? Who is responsible for information security?
- What are the technical issues for integrating different components of the new system with the existing legacy systems? What are the causes? Solutions?
- How is a provincial/national ITS architecture referenced throughout the design of the project? What are the strategies to ensure consistency with the provincial/national ITS architecture?
- Does the ITS/CVO application fit with regional and national transportation planning processes?

4.3.7. TEST THE FRAMEWORK

The final step in the evaluation process is to examine the evaluation framework and its viability. The usefulness of the framework should be examined by employing it for evaluating several ITS/CVO projects. The framework can then be modified, improved, and updated based on the outcomes from the evaluation tests. As data collection is one of the most challenging parts of the evaluation processes, the continuous usage of the framework can help evaluators to identify data availability as well as data requirements that should be generated through future infrastructure investments. Continuous usage of the framework also helps consistency and coordination in ITS/CVO deployments and performance evaluations.

5. CASE STUDY

5.1. INTRODUCTION

The main purpose of this chapter is to investigate the practicality of the proposed evaluation framework through a case study, a commercial vehicle operations *data clearinghouse/brokerage facility* (DCBF) project. A DCBF is a technology that synergistically integrates current technologies such as stakeholder information systems, electronic seals (e-seals), automatic vehicle identification (AVI) and automated vehicle location (AVL) devices, and provides enhanced capabilities, mainly efficiency (*i.e.*, faster inspections through the standardization and automation of data exchange), security (*i.e.*, secure, rule-based exchange of data through a fast, secure mechanism), and safety (*i.e.*, more timely identification of potential safety issues though a more complete, controlled, and standardized exchange of data) (MDA 2003, 2004). There are a number of entities and data that need to be accessed and integrated to achieve transportation efficiency and security, including (MDA 2003):

- Driver – identification and credentials of the driver, driver's log, work assignment, planned route;
- Tractor – identification, carrier registration/ownership, location and tracking of the vehicle;
- Trailer – identification, e-seals and status, ownership, location and tracking; and
- Cargo – identification, container e-seals and status, ownership, location and tracking, identification of goods.

A DCBF can be used for integrating and controlling the visibility of this information. This will provide various benefits to the transportation carrier, the shipper, the owner of the goods, and the customer. Further, a DCBF will help federal, provincial and international agencies monitor freight movements more efficiently by identifying those elements of the system that require closer security and manual inspection, while allowing trustworthy elements to be processed electronically and more efficiently. The DBCF utilizes new technologies to help cost-effective information exchange, as well as controlled and secure data integration. Figure 1 illustrates a typical DCBF information exchange, and Figure 2 shows that the DCBF can support many levels of stakeholder participation and provides a simplified overview of the main components of the facility. It is notable that the DCBF manages the mutually agreed upon rules to provide secure access to the data while each stakeholder owns their data and controls the visibility and access to their data through rules submitted with the XML schema (MDA 2003, 2004).

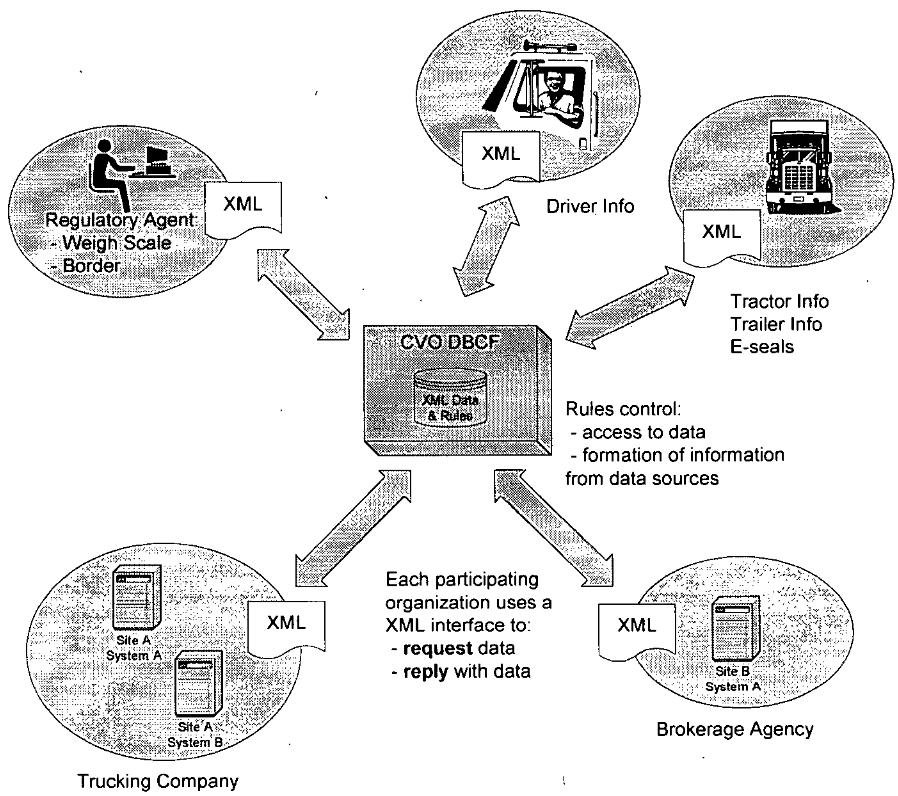


Figure 5.1 - DBCF information exchange (MDA 2004)

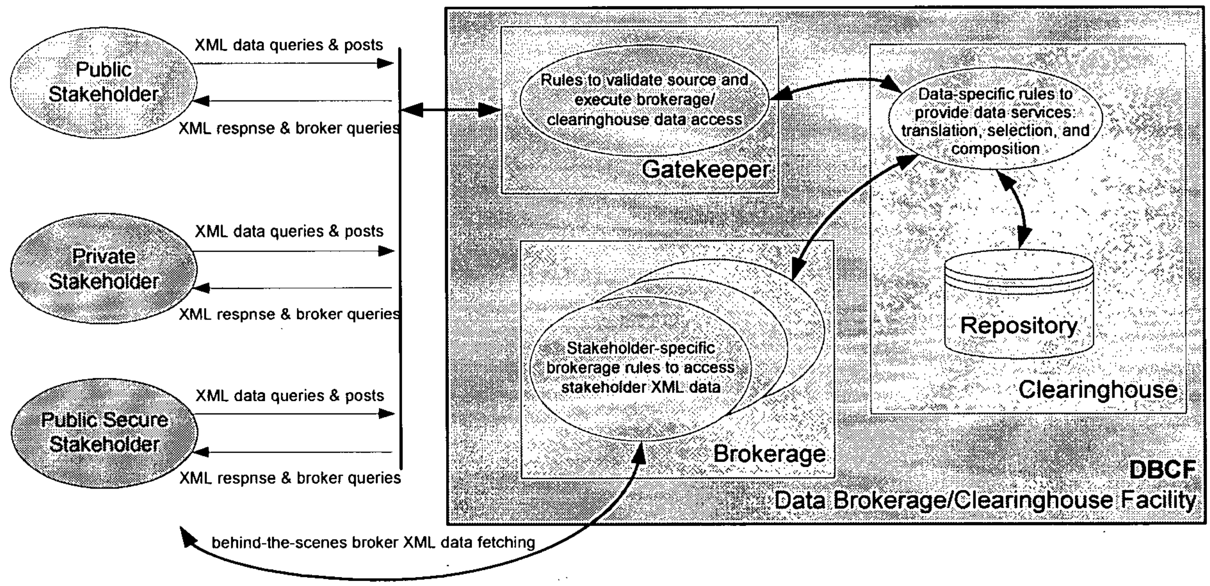


Figure 5.2 - Stakeholder participation (MDA 2004)

This chapter describes how the evaluation framework proposed in Chapter 4 can be utilized for evaluating an ITS/CVO project. One of the major applications of a DCBF is on inspection processes and therefore, both roadside and border-crossing inspection processes will be described briefly later in this chapter. Based on the understanding of the DCBF and inspection processes, a general framework will be developed that can be adopted for evaluating a DCBF in all inspection processes. The general framework is then modified to reflect the actual benefits of a DCBF application if employed at border crossing. Arena, a simulation modelling software, is selected for modelling the general operations at a border-crossing facility. The final part of this section illustrates the results of this case study.

5.2. CVO DCBF STAKEHOLDERS

The CVO DCBF project stakeholders include a wide range of international, national, and regional organizations. The project steering committee was composed of representatives from the following organizations:

- Transport Canada (Ottawa), ITS Office,
- Transport Canada (Pacific Region),
- Transportation Development Centre (TDC),
- Canadian Border Services Agency (CBSA),
- Solicitor General's Office of B.C.,
- B.C. Ministry of Transportation (MoT),
- Greater Vancouver Transportation Authority (TransLink),
- B.C. Trucking Association,
- Washington State Department of Transport (WSDOT), and
- International Mobility and Trade Corridor Project (IMTC).

5.3. PROJECT AND EVALUATION TEAM

The CVO DCBF research team was composed of a commercial partner, MacDonald Dettwiler and Associates (MDA), and the transportation research group at the University of British Columbia (UBC). The MacDonald Dettwiler team focused on developing the DCBF concept and prototyping its capabilities. The UBC team developed a framework for modelling and evaluating the proposed DCBF capability.

5.4. PROJECT/EVALUATION GOALS AND OBJECTIVES

The goal of the project is to enhance the efficiency and security of freight transportation system. The DCBF project develops an integrated, information system concept (*i.e.*, the DCBF) to support goals of efficient and secure commercial transportation within Canada and along the major trade corridors shared with the United States. The project develops the conceptual architecture for the facility and prototype elements to demonstrate the capabilities and benefits of a DCBF deployment.

The goal of the evaluation is to document potential benefits associated with the proposed conceptual DCBF goals and investigate how the DCBF can influence the way in which commercial vehicle operations are carried out at border crossings. The evaluation framework will help decision makers to conduct benefit/cost analysis of adopting a DCBF approach.

5.4. UNDERSTANDING THE INSPECTION PROCESSES

5.4.1. GENERAL ROADSIDE INSPECTION PROCESS

Preclearing of legal vehicles and drivers is at the heart of the DCBF concept, which can be achieved by means of several technologies, most importantly weigh-in-motion scales (WIM), transponders, and e-seals. *Weigh-in-motion* (WIM) is a technology that dynamically measures axle weight of all vehicles at mainline speeds. A WIM scale can be modelled as somewhat similar to the conventional scale with relatively smaller average times and different number of vehicles being visually inspected. Preclearance has several benefits that benefit carriers, regulatory agencies, and society. At fixed weigh and inspection facilities, vehicles with a gross weight over a pre-defined value must enter the weigh/inspection facility. Upon entrance, there may be two lanes in which a vehicle can travel: one for weighing vehicles, and another for allowing vehicles to bypass the scale. There is a signal on the entrance ramp to notify a vehicle of which lane it should travel. A vehicle is allowed to continue on to its destination without being weighed if it is signalled to go through the bypass lane. Vehicles are allowed to bypass the scale at times of heavy traffic on the road due to safety considerations. On the other hand, when a vehicle is signalled to enter the scale lane, it is weighed and visually inspected. Based on several factors available, the vehicle might be requested to pull into the inspection area to receive a Level I, II, III, IV, V, or VI inspection, written warning, or citation for the violation. Three main categories include overweight violations, visual violations, and random selection.

If the gross vehicle weight, axle weight, or the bridge formula of a commercial vehicle exceeds the allowable limit as specified by the provincial and federal regulations, it falls into the *overweight violations* category. While a commercial vehicle is on the weigh scale, it will be checked for *visual violations* that may cause a vehicle to undergo closer inspections, namely Level I, II, III, IV, V, or VI. The inspection is based on guidelines associated with the weighing and measurement of vehicles as established by both federal and provincial regulations. There are various violations that are noted, such as missing IFTA (*i.e.*, International Fuel Tax Association) decals, improperly secured cargo, cracked windshield, damaged/bald tires, obvious equipment violations, *etc.*

Most states and provinces use the *North American Uniform Out-of-Service Criteria* developed by the *Commercial Vehicle Safety Alliance* (CVSA). Inspectors use the criteria in order to identify critical inspection items and provide a rationale for placing vehicles out of service. Once a vehicle has been declared out-of-service, a driver is not allowed to operate the commercial vehicle before completing any repairs specified in the out-of-service notice. There are generally six levels of roadside inspections. *Level I* inspection is the most common and comprehensive one that includes a detailed inspection of both vehicle and driver. The six levels are as follows (Driving Force Web site):

- Level I – North American Standard (NAS) Inspection (*i.e.*, most comprehensive; includes examination of compliance with critical elements of driver and vehicle regulations; takes 45-60 minutes);

- Level II – Walk-Around Driver/Vehicle Inspection (*i.e.*, similar to Level I inspection, with the exception that the inspector will not check items that require getting under the vehicle; takes about 30 minutes);

- Level III – Driver-Only Inspection (*i.e.*, examination of documents that pertain to the driver and any hazmat cargo; driver's license, medical certificate, logbook and HOS status, and documentation of last annual inspection are examined; the inspector will also check for hazardous materials);

- Level IV – Special Inspection (*i.e.*, one-time examination of a particular item; normally made in support of a study or to verify/refute a trend);

- Level V – Vehicle-Only Inspection (*i.e.*, inspection that follows vehicle portion of the Level I inspection; may take place without driver present; usually conducted at a carrier's location during a compliance review); and

- Level VI – Enhanced NAS Inspection for Radioactive Shipments (*i.e.*, inspection for select radiological shipments, which include inspection procedures, enhancements to Level I inspection, radiological requirements, and enhanced Out-of-Service Criteria).

Bapna *et al.* (1998) reported that vehicles spend approximately 1.25 minutes to travel the distance of the weigh station at mainline speeds (*i.e.*, the vehicles do not come into the weigh facility). The authors also assumed that it would take an additional 1 minute each for deceleration and acceleration for vehicles that bypass the visual inspection. They utilized the analysis of Titus (1996) that commercial vehicles could save five minutes for each weigh enforcement stop bypassed, including three minutes for queuing and weighing, and two minutes for deceleration and acceleration. The authors also assumed that an additional 2 minutes are taken for overweight vehicles to verify their credentials. Bapna *et al.* (1998) found that for non-overweight vehicles that were only visually inspected and then released spent an additional 1 minute each for deceleration, acceleration, and stoppage over mainline times. The authors further assumed that an additional 2 minutes is taken for overweight vehicles to verify their credentials. The same amount of time similar to a conventional scale is required for vehicles that bypass the visual inspection. The major benefits of WIM comparing to conventional scale can be mentioned as travel time benefit sand safety benefits (*i.e.*, due to weighing more vehicles which result in identifying overweight carriers).

5.4.2. Service Options in the Canada-U.S. Border

Information on the Canada Border Services Agency Web site (CBSA 2004) shows that Release on Minimum Documentation (RMD) shipments are required to be processed by customs inspectors in the warehouse and are not released directly from the primary inspection line. Rather, the inspector in the primary booth fills out a specific form and gives it to the driver. This extends the processing time at the primary line. Therefore, the commercial vehicles can be modelled in two major categories: those that require more attention and referral to the warehouse, and those that can be released directly from the primary line. There are also many other options introduced by CBSA to established importers. Many of these processes employ Electronic data interchange (EDI) technology, and replace the standard paper alternatives available to clients with RMD privileges.

Prearrival Review System (PARS) shipments, for example, have documentation filed prior to arrival. The PARS release information contains the shipment's estimated time and date of arrival, the invoice data and the original copy of any required permits. PARS documentation/data can be submitted up to 30 days before the goods arrive in Canada, so the documentation can be processed and a recommendation for release or examination be made into the customs computer system before the commercial vehicle's arrival to the primary inspection. The release recommendation is ready when the goods arrive if PARS requests are submitted at least 1 hour in advance for EDI and 2 hours in advance for paper documentations. When the shipment arrives, it is released in minutes unless an examination is required. It is most likely that these shipments are released directly from the primary inspection line.

Frequent Importer Release System (FIRST) is another line release option for those shippers that have established a sound compliance record, so they can apply for FIRST privileges to obtain release of low-risk, low-revenue shipments carried on a regular basis. If a shipper qualifies, an authorization number will appear on its pre-approved import document identifying it a FIRST shipment. When the goods arrive at the border, the shipper presents the import document with the bar-coded authorization and transaction number, a description of the goods, and related invoices. The barcode is input into the customs computer system to confirm the availability of FIRST privileges for the goods on hand. The customs officer then decides whether to release the shipment or refer it for examination. In most cases, these commercial vehicles can be released directly by primary inspectors based on their paperwork.

It is worth noting that there are other line release options that speed up the release processing times of commercial goods and reduce traffic congestion at border crossings in Canada, such as G7 Import One Step Release on Full Documentation (RFD), and Customs/Canadian Food Inspection Agency (CFIA) interface. However, all of these aforementioned programs will soon be replaced by new joint Canada-U.S. programs. Some of these bi-national programs will be described in the following sections based on the information from the Canada Border Services Agency Web site (CBSA 2004) and the U.S. Customs and Border Protection Web site (USCBP 2004).

Advance Commercial Information (ACI)

The Advance Commercial Information (ACI) is a new initiative that presents improved risk management processes and tools to identify health/safety/security threats prior to the arrival of cargo and conveyances in Canada. This requires electronic transmission of key data before arrival of goods and conveyances in the country. High-risk shipments will then be detected by analyzing data via a sophisticated targeting tool and legitimate low-risk shipments will be cleared more quickly. ACI has been scheduled for three phases wherein the Phase 3 is planned for Fall 2005 that includes mandatory advance electronic transmission of highway cargo and conveyance data, mandatory advance electronic transmission of Secondary cargo data for all modes, and mandatory electronic release data for all modes.

The Customs Self Assessment (CSA) Program

The Customs Self Assessment (CSA) program is a progressive trade option for clients who invest in compliance. The CSA program is part of the Customs Action Plan of the Canada Border Services Agency (CBSA) that offers approved importers the benefits of a streamlined accounting and payment process within extended timeframes as well as a simplified clearance process for eligible goods when approved carriers and registered drivers are responsible for the movement of freight. The former allows importers to use their own business systems to fully self assess and meet their customs obligations, and the latter allows for the clearance of goods based on the identification of the approved importer, approved carrier, and registered driver. The CSA program is mutually beneficial to the importing community and the CBSA. The benefits for the clients include notably reduced cost of compliance while improving their ability to comply with customs requirements. The CSA program will reduce costs for the private sector by:

- Ending the transactional transmissions of data elements;

- Ending the need for artificial customs systems;
- Increasing the certainty of expedited customs processing;
- Making it easier for clients to meet their obligations; and
- Streamlining legitimate trade.

The benefit to CBSA includes the opportunity to better arrange its resources to support trade of higher or unknown risk. "To qualify for the program, clients must have a history of compliance and adequate business systems in place with links, controls and audit trails to support program requirements and verification activities." Carriers and importers must complete an independent, three-part application and approval process, as follows:

- Part I - A risk assessment of the applicant against established CBSA criteria.
- Part II - A review of the applicant's business systems to ensure support of the CSA program requirements.
- Part III - A "Client Undertaking" document outlining the terms and conditions of the CSA Program being signed by approved importers and carriers.

The Free and Secure Trade (FAST) Program

The Free and Secure Trade (FAST) program is a harmonized commercial process, supported by both Canada and the United States, offered to pre-approved importers and carriers who use pre-approved registered drivers. The FAST program involves the Canada Border Services Agency (CBSA), Citizenship and Immigration Canada (CIC), and the United States Bureau of Customs and Border Protection (CBP). Importers and carriers may apply for FAST in Canada and/or the United States; however, drivers must apply to Canada and the United States and they must be approved by both countries. All participants must have a demonstrated history of compliance with all relevant legislation and regulations, and have acceptable books, records and audit trails. Through FAST, trade compliance can be verified away from the border and pre-approved eligible goods can quickly move across the border.

In Canada, FAST relies on CSA principals of pre-approval and self-assessment as well as increased security measures under the PIP program, which supports the U.S. Customs Trade Partnership Against Terrorism (C-TPAT) program. FAST employs sound risk management techniques to improve speed and certainty at the border and reduce the cost of compliance by:

- Reducing the information requirements for customs clearance
- Eliminating the need for importers to transmit data for each transaction
- Dedicating lanes for FAST clearances
- Reducing the rate of border examinations
- Verifying trade compliance away from the border
- Streamlining accounting and payment processes for all goods imported by approved importers (Canada only)

Expedited Customs clearance processes to pre-authorized drivers, carriers and importers as well as a FAST commercial driver enrolment centre are currently in operation at Pacific Highway, BC/Blaine, WA border crossing.

The Partners in Protection (PIP) Program

The Partners in Protection (PIP) program is designed to employ the cooperation of private industry to improve border security, combat organized crime and terrorism, increase awareness of customs compliance issues, and help detect and prevent contraband smuggling by signing a cooperative agreement with the CBSA, known as a Memorandum of Understanding (MOU). Upon the approval of the agreement, the CBSA assigns a regional representative with each partner to further the goals of the program. Participants in the program must complete a security questionnaire within 60 days of submitting the MOU in order to provide a self-assessment of their existing security measures. The CBSA provides participants with security recommendations for completing the security questionnaire and treats the information received as confidential. The CBSA will review the responses, identify the security concerns, and make recommendations on how to improve security. Some of the benefits of participating in the program are:

- Quicker movement of low-risk goods and travellers through customs;
- Improved security levels;
- Enhanced reputation for the participated organization;
- Improved understanding of customs requirements;
- Better communication between participant's employees and the CBSA; and
- Fulfills a requirement to participate in the Customs Self Assessment (CSA) and the Free and Secure Trade (FAST) initiatives.

The NEXUS Highway Program

The NEXUS Highway is a joint customs/immigration program implemented by both the Canadian and American governments for frequent travellers designed to simplify border crossings for pre-approved, low-risk travellers. NEXUS helps Canadian and U.S. customs and immigration authorities to uphold security and protection standards at the border by enabling them to concentrate their efforts on potentially high-risk travellers and goods. This improves the security and integrity of the borders. NEXUS members must be approved by both Canada and the United States as low-risk travellers in order to take advantage of a simplified entry process while travelling back and forth across the Canada/U.S. border. Upon the approval, the NEXUS members are able to use dedicated lanes at various border crossings with a minimum questioning in their customs and immigration processes. These lanes result in less traffic congestion and delays at bridge and land crossings while the border maintains safe and secure. The NEXUS Highway Program is currently in operation at the following British Columbia/Washington border crossings:

- Boundary Bay, BC and Point Roberts, WA

- Pacific Highway, BC and Blaine, WA
- Douglas, BC and Peace Arch, WA

5.5. DCBF BENEFITS AND MEASURES OF EFFECTIVENESS

5.5.1. DCBF Benefits and MOEs for Inspection Processes

The selection and inclusion of benefit measures in the framework for evaluation of the DCBF is one of the major parts of the project. Based on the review of the literature, the proposed DCBF concept, and both roadside and border-crossing inspection processes, the major potential benefits of a DCBF are identified as efficiency, security, safety, mobility, and energy and environment. These benefits will be described briefly in the following sections.

Efficiency

It is expected that implementing a DCBF technology will help inspection staff to gather more complete prearrival inspection information and work more efficiently. A DCBF could speed up the process of primary inspection by providing information of commercial vehicles equipped with transponders to inspectors in advance of arrival at inspection facilities. In roadside inspection, a DCBF helps inspection staff to allow more commercial vehicles equipped with transponders to be precleared. Further, a DCBF could speed up the process of border crossings by allowing more commercial vehicles equipped with transponders to be released directly from the primary line. Therefore, a DCBF is expected to result in less costly credentialing of commercial vehicles, more effective safety and security inspections, and most importantly, transit time savings for transponder-equipped commercial vehicles with good compliance records. Transponder-equipped commercial vehicles are part of an expedited crossing program utilizing a DCBF and the participation of vehicles equipped with transponders increases the effectiveness of the DCBF. Transponder-equipped commercial vehicles can be released directly by primary inspectors based on their information available via DCBF if the credential and safety records are in order. There may be some random secondary inspections for them; however, as most of the information required is available via DCBF, the processing time of these vehicles would be less than the usual processing times experienced by non-transponder-equipped vehicles. The processing time for transponder-equipped commercial vehicles with e-seals will be further reduced if the credential and all records are in order. For roadside inspections, transponder-equipped commercial vehicles with e-seals are precleared if the credential and safety records are in order and are allowed to bypass inspection stations at highway speeds in most cases.

As a result, it is assumed that there will be some shortening of the time to inspect transponder-equipped commercial vehicles as inspection staff would readily have access to most of required information before the vehicle enters the inspection area. The time to inspect each commercial vehicle selected for the secondary inspection, and the number of commercial vehicle inspections may be the same after introducing a DCBF; however, a DCBF enhanced inspection facility may be expected to result in a better targeting of truck inspections since more of these trucks will have been prescreened for violations using the real-time access to timely and accurate data for targeting high-risk carriers provided by the DCBF. It is also expected that with the increase in the percentage of commercial vehicle participants, there would be lower numbers of vehicles requiring a stop to work with customs brokers, which would result in less demand for parking facilities within the customs compound. Efficiency impacts of implementing a DCBF can be measured by changes in total time in system, delays in the queue waiting for primary inspection, number of vehicles in queue for primary inspection, number of vehicles in the secondary inspection area, and utilization of toll collectors and customs inspectors.

Security

Freight transportation systems are diverse, ubiquitous, and open and consequently are quite vulnerable. Freight transportation systems are subject to security threats and there is no doubt that improving the security of the freight and commercial vehicles is a very important issue. Freight-related countermeasures can either prevent attacks or mitigate the impacts of attacks. As preventive countermeasures cannot stop all attacks and guarantee the security, therefore, only well-managed mitigation countermeasures are important. The vital components of a secure freight transportation system include:

- assured integrity of loading and documentation;

- secure transit, that is tracking commercial vehicle or freight equipment locations to determine if an asset has deviated from its planned route;

- accurate, complete, and timely information about the identities of the driver, commercial vehicle, freight equipment, and shipment for consistency with the planned assignment without disclosure to unauthorized users; and

- an adequate government infrastructure that can screen information about shipments and inspect any commercial vehicle that raises a security concern.

Using real-time access to timely and accurate data via a DCBF with all the information from several border programs and the associated participants (*e.g.*, SCA, FAST, ACI, PIP) enables enforcement staff to pre-screen more commercial vehicles for violations and identify high-risk carriers. The commercial vehicles can be grouped in two major categories: those that require more attention and referral to the warehouse, and those that can be released directly from the primary line. This means that those commercial vehicles that have a demonstrated history of compliance with all relevant legislation and regulations, and have acceptable books, records and audit trails can be categorized as low risk and consequently be released directly from primary inspection via expedited lanes. As a result, a DCBF enables Customs and border protection staff focuses security efforts and inspection resources on commercial vehicles that are high risk, or unknown risk by tracking the history of commercial vehicles/drivers/carriers. Security improvements can be measured as increased number of non-compliant trucks detected via a DCBF surveillance of commercial vehicles and freight equipment.

Safety

Of most importance to the public is improved targeting for inspection of unsafe vehicles via new information systems available. Removing unsafe commercial vehicles from highways will result in less crashes -and consequently, less fatalities, injuries, and property damage to commercial vehicles, their cargo, and to other vehicles, as well as reduced delay to all vehicles from congestion due to crashes. Using real-time access to timely and accurate data via DCBF enables enforcement staff the ability to pre-screen more commercial vehicles for violations and identify high-risk carriers. A DCBF helps enforcement staff focus inspection resources on high-risk carriers by tracking the history of commercial vehicles and drivers that would result in more out-of-service orders for the same number of inspections. Such carriers and drivers cause a majority of accidents and they can be deemed as a hazard to society. This leads to the removal of trucks and drivers from services that are most likely to cause crashes because of vehicle defects and driver violations of safety regulations. Furthermore, the increased attention on high-risk carriers via DCBF will have secondary benefit by motivating carriers to improve their safety compliance behaviour and rating to avoid increased inspections for the purpose of safety. The safety improvement can be measured by the estimated number of crashes, injuries, and fatalities avoided due to implementing the DCBF. Appendix I details the equations that can be employed to assess the safety impact of various DCBF-implemented inspection scenarios based on a previous study (Orban *et al.* 2002).

Mobility

As described under efficiency benefits, employing a DCBF can help inspection staff to have prearrival information about driver/carrier/shipment that speeds up the inspection process and reduces the delays (*i.e.*, preclearance in roadside inspection and expedited release from primary inspection in border crossing). Therefore, it is expected that employing a DCBF results in reduced time in transit for commercial vehicles and consequently reduces shippers/receivers inventory costs. It is also expected that a DCBF technology can reduce the variability of travel time in transportation networks by improving operations (*e.g.*, preclearance of compliant trucks) that can be viewed as a mobility benefit. Another mobility benefit of a DCBF can be reduced highway delays to public due to fewer truck-related crashes due to better and more efficient roadside inspections. Increased shipper or receiver satisfaction with carriers due to enhanced quality of service and fewer delays can be another potential benefit of a DCBF that can be grouped under mobility benefits. Mobility impacts of implementing a DCBF can be measured by changes in total time of commercial vehicles in system and changes in delays (*e.g.*, fewer delays in inspection sites for commercial vehicles, fewer delays for all vehicles due to less crashes involved commercial vehicles).

Energy and Environment

Less inspection times for commercial vehicles result in not only time saving for the trucks and their cargo, but they also provide energy savings and air and noise pollution benefits for the public. A DCBF will help inspection staff to identify and allow safe and legal trucks to be released directly from primary inspection faster and without pulling in for inspection. The prearrival information of more commercial vehicles and their reduced inspection times will result in less idling of diesel engines at inspection stations, less commercial vehicles accelerating and decelerating for inspections, less noise pollution, and less wear and tear of brakes and other associated motor vehicle components. Energy and environmental impacts of implementing a DCBF can be measured by changes in fuel consumption, vehicle emissions, and noise pollution. Appendix II further discusses the approach that will be employed to assess the energy and environmental impacts of various DCBF-implemented inspection scenarios.

Other Benefits

Cost reduction, revenue, economic benefits, and customer satisfaction are other benefits of a DCBF. Examples include increased revenue from taxes due to monitoring activities, and increased trade flows. These benefits can be evaluated qualitatively using the results of similar projects. Table 5.1 present a summary of general benefits and measures of effectiveness for evaluating a DCBF deployment.

Table 5.1 – A DCBF general evaluation framework

DCBF Goal Area	Expected Impacts	MOE	Impacted Groups	Estimation
Efficiency	• Time savings, improved resource utilization, and improved targeting of commercial vehicle inspections due to real-time access to timely and accurate data for targeting high-risk carriers, and more prescreening of commercial vehicles for violations • In border-crossing inspection processes: prearrival information results in faster processing time for participated commercial vehicles and direct release of participated commercial vehicles from primary line • In roadside inspection processes: prearrival information results in faster processing time for participated commercial vehicles and preclearance of participants (*i.e.*, participated commercial vehicles may bypass inspection sites at mainline speeds)	• Total time in system • Delays in the queue waiting for and performing primary inspection • Utilization of toll collectors and customs inspectors • Change in throughput or effective capacity at inspection sites • Change in vehicle speed differential by vehicle type at inspection sites (S) • Change in speed of inspection process • Change in number of stops at inspection sites	• Province • Carrier and shippers • Public	• Simulation • Field studies • Automatic traffic monitoring

Table 5.1 – A DCBF general evaluation framework (cont'd)

DCBF Goal Area	Expected Impacts	MOE	Impacted Groups	Estimation
Security	Improved targeting of commercial vehicle inspections due to • Real-time access to timely and accurate data for targeting high-risk carriers • More prescreening of commercial vehicles for violations • Enhanced compliance	• Percentage of non-compliant commercial vehicles detected	• Federal Govern ment • Province • Public	• Interviews • Surveys • Field studies • Qualitative analyses • Simulation
Safety	In roadside inspections: decreased number of crashes involving commercial vehicles, and improved targeting of commercial vehicle inspections due to • Real-time access to timely and accurate data for targeting high-risk carriers • More prescreening of commercial vehicles for violations • More out-of service orders for the same number of inspections • Enhanced compliance	• Expected number of crashes avoided associated with commercial vehicles • Change in speed compliance	• Carriers and shippers • Public • Province	• Field studies • Before and after studies using crash statistics from police, ICBC, or hospital reports • Truck crash prediction model • Simulation

Table 5.1 – A DCBF general evaluation framework (cont'd)

DCBF Goal Area	Expected Impacts	MOE	Impacted Groups	Estimation
Mobility	• Reduced time in transit for trucks and shipments due to preclearance of participated trucks in roadside inspections, and due to prearrival information in border-crossing processes, that reduces shipper or receiver inventory costs • Reduced highway delays to public due to fewer truck-related crashes in roadside inspections	• Total truck transit time • Length of queue in inspection sites	• Carriers and shippers • Public	• Field studies • Simulation • Automatic traffic monitoring • Trip diaries • Timetables • Interviews • Surveys
Energy & Environment	Fuel savings and fewer emissions as more commercial vehicles will be released directly from primary line that results in: • Less idling of diesel engines at weigh and inspection stations, reduced energy use from reduced accelerations and less wear and tear of brakes and other associated motor vehicle components due to less need for stopping and queuing for inspection	• Fuel consumption • Vehicle emissions • Noise pollution	• Public • Carriers and shippers	• Simulation • Fuel consumptio n models • Emission models • Traffic survey • Automatic traffic monitoring • Noise studies

Table 5.1 – A DCBF general evaluation framework (cont'd)

DCBF Goal Area	Expected Impacts	MOE	Impacted Groups	Estimation
Other Benefits	Cost reduction, revenue, economic benefits, and customer satisfaction • Increased trade flows • DCBF customers value the incremental benefits they experience more highly than the incremental costs they bear • Increased shipper or receiver satisfaction with carriers due to enhanced quality of service and less delays			• Surveys • Interviews • Qualitative analyses • Simulation

5.5.2. DCBF BENEFITS/MOEs FOR BORDER-CROSSING INSPECTION

As described in the Section 5.4 there are clear differences between a roadside inspection and an inspection for border crossing. Therefore, not all the benefits described in Section 5.5.1 can be counted as the benefits of a DCBF in border crossing. Based on the goals and objectives of both the DCBF project and the evaluation, the major benefits of employing a DCBF for border-crossing inspection process include efficiency, security, and energy and environment.

5.6. DCBF EVALUATION PLAN

The evaluation plan was developed based on thorough understanding of project/evaluation goals and objectives, potential DCBF benefits, and MOEs identified in previous sections of this chapter. Tables 5.1 demonstrates the major elements of the DCBF evaluation framework and the general methods that can be used to estimate benefits of implementing a DCBF for inspection processes (both roadside and border inspections). The DCBF evaluation framework proposes both quantitative and qualitative analyses of the impacts of DCBF implementation. The qualitative analysis includes the simulation of the general operation at a border crossing that clearly shows how implementing a DCBF can improve the overall efficiency of the commercial vehicles operations. The results of the simulation demonstrate improvements in overall commercial vehicle travel time and other operational aspects based on the DCBF capabilities (*e.g.*, less queue length, better utilization of parking facilities and inspectors, *etc.*). Table 5.2 presents the elements and methodologies adopted for DCBF evaluation if deployed for border-crossing inspections.

As discussed in the literature review, one of the major assumptions for evaluating ITS/CVO is that the net benefits and costs to different stakeholders due to the deployment of the various ITS applications are in direct proportion to the level of participation of motor carriers and their implementation of the proposed technology-based solutions. This means that total benefits and costs increase as the level of carrier participation in the program grows. Therefore, it is very important to predict the likely level of carrier participation as the program grows.

Table 5.2 – A DCBF evaluation framework for border crossing

DCBF Goal Area	Expected Impacts	MOE	Impacted Groups	Estimation
Efficiency	• Time savings, improved resource utilization, and improved targeting of commercial vehicle inspections due to real-time access to timely and accurate data for targeting high-risk carriers, and more prescreening of commercial vehicles for violations • Prearrival information results in faster processing time for participated commercial vehicles and direct release of participated commercial vehicles from primary line • More prescreening of commercial vehicles for violations	• Total time in system • Delays in the queue waiting for and performing primary inspection • Number of vehicles in queue for primary inspection	• Province • Carrier and shippers • Public	• Simulation
Security	Improved security resulted from better targeting of commercial vehicle inspections due to • Real-time access to timely and accurate data for targeting high-risk carriers • More pre-screening of commercial vehicles for violations • Enhanced compliance	• Increased number of potential violations identified	• Federal Govern ment • Province • Public	• Application of DCBF rules in Simulation

Table 5.2 – A DCBF evaluation framework for border crossing (cont'd)

DCBF Goal Area	Expected Impacts	MOE	Impacted Groups	Estimation
Energy & Environment	Fuel savings and fewer emissions as more commercial vehicles will be released directly from primary line that results in: • Less idling of diesel engines at inspection stations, reduced energy use from reduced accelerations and less wear and tear of brakes and other associated motor vehicle components due to less need for stopping and queuing for inspection	• Fuel consumption • Vehicle emissions	• Public • Carriers and shipper	• Using the results of simulation and available literature
Other Benefits	Cost reduction, revenue, economic benefits, and customer satisfaction • Increased revenue from taxes due to monitoring activities, • Increased trade flows • DCBF customers value the incremental benefits they experience more highly than the incremental costs they bear			• Beyond the scope of this study

5.7. DATA COLLECTION

Lack of data is the major problem in the evaluation process of all ITS applications, including DCBF. Therefore, the potential benefits of implementing a DCBF technology included in the evaluation model were estimated based on similar studies (*e.g.*, CVISN, ITBCS, and ECRI); however, some assumptions were made due to so many unique and undefined aspects of DCBF and the lack of "track record" of its operation (*e.g.*, the rate of acceptance of technologies by carriers).

Due to such uncertainty and in order to see how sensitive the results are to the assumptions underlying them, a sensitivity analysis of the results of the modelling work is recommended while performing benefit-cost analysis, involving ranges of benefit (as identified in this study) and cost values and discount rates. It is notable that the DCBF project may change the administration of commercial vehicle enforcement and regulatory processes in various ways, but the net economic benefits cannot be assessed until the real impacts are empirically examined and translated into the relative measures.

5.8. SIMULATION MODEL DEVELOPMENT

The development of a computer simulation model begins with the study of the system and entities that are to be modelled in order to obtain a detailed systematic understanding of the various components and dynamic behaviours. This process requires a general understanding of the various components and entities of the real system and processes, translation of these components and behaviours into mathematical and heuristic models and algorithms, and finally coding the models and algorithms into a computer simulation environment.

5.8.1. MODELLING AN INSPECTION PROCESS

A DCBF can be used to expedite the release of participant commercial vehicles from the primary line. This means that commercial vehicles equipped with a read and write transponder can benefit from real-time transponder-to-DCBF data exchange and DCBF expedited lanes, and if all requirements are met, they can be released directly from primary inspection line. To be eligible for pre-screening, a commercial vehicle should meet legal requirements: the vehicle should be within the weight limits and all of its credentials have been checked (*e.g.*, IFTA permits, IRP registrations, and proof of payment of fuel taxes); and the vehicle and/or driver has been cleared by the automated inspection system. Commercial vehicles are classified based on their type in three major categories:

1. CFI (fully inspected) – CFI commercial vehicles are sent to secondary inspection by the primary inspectors.

2. CPI (partly inspected) – CPI commercial vehicles are released directly by primary inspectors based on their paperwork.

3. CTE (transponder equipped) – CTE commercial vehicles are equipped with transponders and are part of an expedited crossing program via DCBF. These commercial vehicles can be released directly by primary inspectors based on their information available via DCBF if the credential and safety records are in order. There may be some random spot-check inspections for them; however, as most of the information required is available via DCBF the processing time of these vehicles are less than the processing times of non-transponder-equipped vehicles. It is obvious that the inspection time will be shorter and the probability of sending non-violating commercial vehicles to secondary inspection is lower if commercial vehicles are equipped with transponders and e-seal.

It is understood that a fraction of the transponder-equipped vehicles, even though they can be released from primary line, can be sent to secondary inspection. This is to maintain the deterrence and will be implemented by randomly selecting vehicles for spot-checks. Further, the number of vehicles not released from primary line is determined by the adoption of transponders by the carriers. As transponder acceptance and use by the shipping and carrier industry becomes more common, the number of vehicles being released from primary inspection should increase so that there are no constraints to completely inspect all vehicles that come into the secondary inspection. This will result in less resource utilization for secondary inspection.

The degree of industry participation in the use of transponders, and industry and government agency participation in the DCBF program, provide the context for which the simulation models are tested under. Ten simulation scenarios, which vary in industry and agency participation, have been developed for which to test the effectiveness of the DCBF concept as shown in Table 5.3, where:

- Scenario 1 represents a base scenario of no transponder-equipped vehicles and no DCBF implementation.

- Scenarios 2 to 4 represents a scenario with a DCBF implementation with only driver information provided (check for correct driver), and 10%, 50%, and 100% of commercial vehicles equipped with a transponder, respectively.

- Scenarios 5 to 7 represents a scenario with a DCBF implementation with driver, E-Seal status, and cargo-ID information provided, and 10%, 50%, and 100% of commercial vehicles equipped with a transponder, respectively.

- Scenarios 8 to 10 represents a scenario with a DCBF implementation with driver, E-Seal status, cargo-ID, and schedule (ETA check) information provided, and 10%, 50%, and 100% of commercial vehicles equipped with a transponder, respectively.

It is worth noting that these scenarios are not real, per se; however they have been developed assuming hypothetical participation levels of a DCBF implementation. Their value is in playing the role of incrementally changing "test" environments that will provide indications as to how each of the MOEs in the evaluation framework will perform. In each scenario, a set of specific attributes are defined for the model, including:

- Percentage of vehicles in each category, including percentage allocation of transponders and driver, e-seal, cargo, and schedule attributes, if applicable;

- Probability distribution of primary inspection times;

- Probability of commercial vehicles being sent to secondary inspection; and

- Probability of spot-checks.

Table 5.3 – Simulation modelling scenarios

		Industry Participation			
		Base	10%	50%	100%
Agency Participation	Base	Sc.1			
	Low		Sc.2	Sc.3	Sc.4
	Med		Sc.5	Sc.6	Sc.7
	High		Sc.8	Sc.9	Sc.10

Commercial vehicles are assigned as CFI, CPI, or CTE based on the various rates for DCBF participation. After a commercial vehicle arrives in the inspection area, a service time is assigned to it based on the associated distribution (i.e., CFI, CPI, or CTE). There are two primary inspection booths that can accommodate both DCBF and non-DCBF commercial vehicles. If the credentials and safety records of commercial vehicles equipped with transponders are in order, they can be released directly from primary inspection with shorter processing times. Following the inspection, the customs inspector would make a decision on whether the commercial vehicle is allowed to be released or referred to secondary inspection. The time required by any of the commercial vehicles to cross the border is affected by various factors (e.g., the type of goods; previous history of carrier, vehicle and driver; level of congestion at the particular border crossing). Generally, the more information available to the primary inspector while the commercial vehicle enters the booth, the faster that inspector can process the entry (Nozick *et al.* 1998, 1999).

Using a DCBF enables the customs staff to have all required information about the commercial vehicle and its load prior to loading. A commercial vehicle equipped with a transponder can be interrogated electronically as it is approaching the border crossing. The DCBF can then combine the information transmitted from the commercial vehicle with associated information residing in other databases from various stakeholders and government agencies before the commercial vehicle reaches the border. The integrated information from the DCBF provides inspection staff the required information about the shipment, the vehicle and the driver that can be used for making a more systematic, thorough, and reliable decisions to allowing the commercial vehicle to bypass the inspections or not.

5.8.2. MODELLING ASSUMPTION

A discrete-event simulation model was developed representing a hypothetical form of the Pacific Highway Border Crossing, at the national border between British Columbia and Washington State, with a general geometry that resembles the planned expansion of the approach lanes in the near future. The basic geometry consists of truck traffic lanes separating from general traffic 250 m prior to the border inspection facility with two truck lanes (one for FAST and one for general trucks) approaching into three Primary Inspection Lanes (one FAST, two manned booths) as per discussions with CBSA officers. As the evaluation of benefits are based on simulated estimates of a number of hypothetical scenarios (including border inspection operations), it is not the intent, nor within the scope of this research, to provide accurate (*e.g.*, real) results. However, given the wide range of scenarios developed, the simulation model and associated experimental design should be sufficient enough to adequately demonstrate the effectiveness of a potential DCBF implementation at the border crossing.

For each of the 10 scenarios, 20 24-hour period simulation runs were made, each consisting of different "random seeds" to simulate 20 different days of a specific day of week (*i.e.*, Friday). This essentially provides 20 daily samples for each scenario, or 200 simulation runs in total, allowing for estimates that are of greater precision. From the assessment of the real-life components of a border-crossing inspection facility, the following entities have been identified as being significant enough for modelling:

- Commercial Vehicles
    - Trucks, assigned with truck, driver, cargo, schedule and DCBF characteristics (General passenger automobile traffic was not modelled as it was assumed the implementation of a DCBF system would occur after the planned lane improvements at the Pacific Highway Border Crossing, of which the simulation model is based on. Based on the planned lane improvement, general traffic and commercial vehicles are separated 250 metres prior to the inspection facilities.);

- Inspection Officers

- Primary inspection officers manning booths
- Border Crossing/Inspection Facility Traffic Lanes
  - Entry highway
  - Traffic queue lanes for servicing by primary inspection booths
  - Primary inspection booth servicing area during inspection
  - Exit lane to exit highway from primary inspection
  - Lane to secondary inspection (Secondary inspection process modelling is beyond the scope of this project)
- Inspection Facilities
  - Primary inspection booths

These components will determine the static and dynamic components of the simulation model and will require behavioural parameters such as arrival rates, service rates, delay, and other stochastic characteristics. There are several basic processes on vehicles entering a border that require parameter estimation for calibration of the simulation model. The major parameters required for the simulation model include:

- Arrival rates of commercial vehicles
- Distribution of the types and characteristics of commercial vehicles
- Time distribution for primary inspection processing for commercial vehicles
- Probability of referral to secondary inspection for further processing

As DCBF is a new concept that has not been implemented elsewhere, the aforementioned parameters are assumed based past inspection performance statistics (general information regarding arrival rates, commercial vehicle types, and average inspection processing times, were provided by Ms. Janice Baird of the Strategy and Co-ordination

Branch of CCRA) and previous studies, such as Nozick *et al.* (1999). Appendix III describes the details of the arrival, service, and delay distributions used in the various components of the simulation model. Figure 5.3 illustrates the basic border inspection process. A more detailed flowchart that illustrates the interaction of the model components to the model processes is shown in Appendix III.

5.9. RESULTS

5.9.1. EFFICIENCY BENEFITS

Efficiency in terms of commercial vehicle border crossing can be best measured in terms of timesavings. The DCBF allows for the pre-screening of information which results in faster processing time for participating commercial vehicles. As for the actual measures of effectiveness that quantify the efficiency benefit of DCBF implementation, they are as follows:

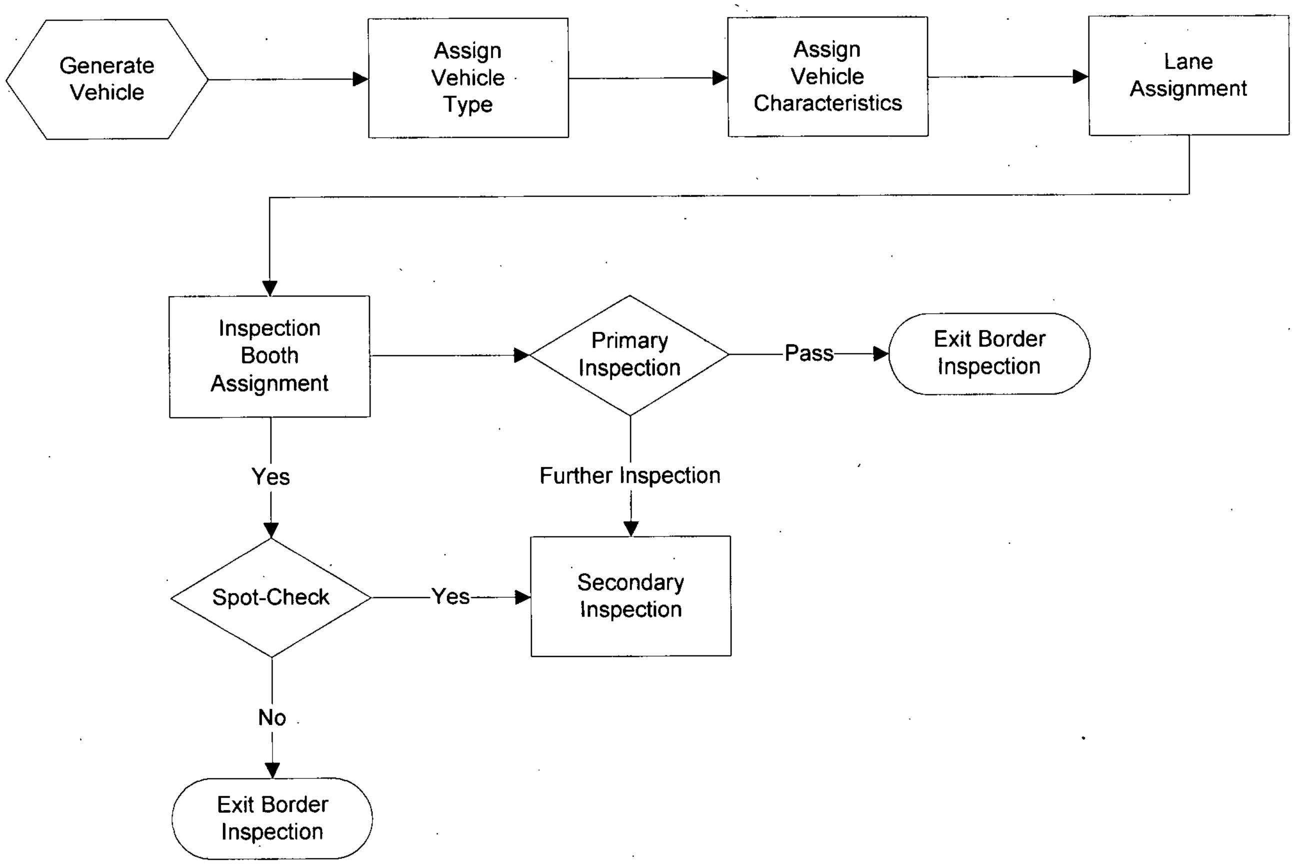
- Average total time in system per truck (minutes),
- Average total delay time per truck (minutes), and
- Average and maximum number of trucks in queue per lane.

The resulting outputs of the simulation model runs were summarized for these MOEs and are presented in the following sub-sections.

Average Total System Time per Truck

Table and Figure 5.4 summarize the average total time for commercial vehicles to pass through the border primary inspection facility. This time includes travel to the border inspection booths from the I-5 freeway, time in queues, and primary inspection service time. This time does not include secondary inspection times, which are beyond the scope of this project. The longest average time was estimated to be in Scenario 1 at approximately 5.5 minutes. For each of the DCBF implementation scenarios, a pattern is noticeable, which shows the average total time decreasing as both the agency participation and industry participation goes up. However, the rate of decline is more sensitive to the industry participation rate, with commercial vehicle utilization of transponders at levels of 50% to 100% showing substantially larger decreases in total times. Similarly, the additional gain in time savings tends to decrease from medium to high agency participation, irrespective of industry participation rate. The fastest average times were estimated for Scenarios 7 and 10, of below 2 minutes, of which both consist of 100% industry participation.

Figure 5.3 - Basic border inspection process



Average Total Delay Time per Truck

The total system time per truck has within it the time component to physically cross the border facility. This time is consistent for all vehicles; however the delay experienced by each vehicle varies as a function of demand to use the border crossing facility. Table and Figure 5.5 summarize the average delay time experienced by truck for each of the 10 scenarios. Delay in this case is defined as the delay imposed onto a particular vehicle by the presence of other vehicles ahead if it (*i.e.*, queues) plus the time for primary inspection service.

Table 5.4 - Average total system time per truck by scenario (minutes)

		Industry Participation			
		Base	10%	50%	100%
Agency Participation	Base	Sc.1			
		5.5			
	Low		Sc.2	Sc.3	Sc.4
			4.7	3.5	2.7
	Med		Sc.5	Sc.6	Sc.7
			4.2	2.5	1.7
	High		Sc.8	Sc.9	Sc.10
			4.0	2.2	1.5

Figure 5.4 - Average total system time per truck by scenario (minutes)

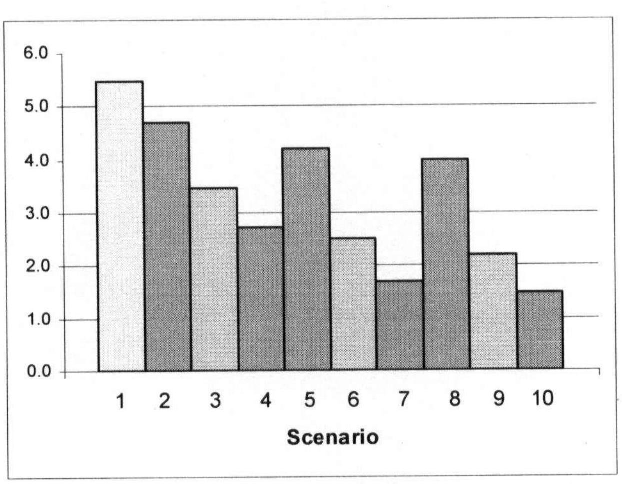
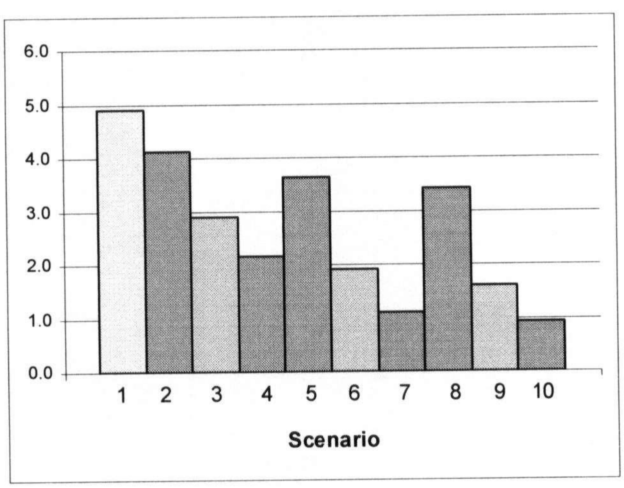


Figure 5.5 demonstrates the profile of average total delay time per truck being similar to that of the average total system time per truck, although with lower times. This is to be expected as the difference between the two measures is the non-stop travel time through the border crossing. Again, Scenarios 7 and 10 resulted in the lowest average delay times at 1.1 and 0.9 minutes, respectively.

Table 5.5 - Average total delay time per truck by scenario (minutes)

			Industry Participation		
		Base	10%	50%	100%
Agency Participation	Base	Sc.1			
		4.9			
	Low		Sc.2	Sc.3	Sc.4
			4.1	2.9	2.1
	Med		Sc.5	Sc.6	Sc.7
			3.6	1.9	1.1
	High		Sc.8	Sc.9	Sc.10
			3.4	1.6	0.9

Figure 5.5 - Average total delay time per truck by scenario (minutes)



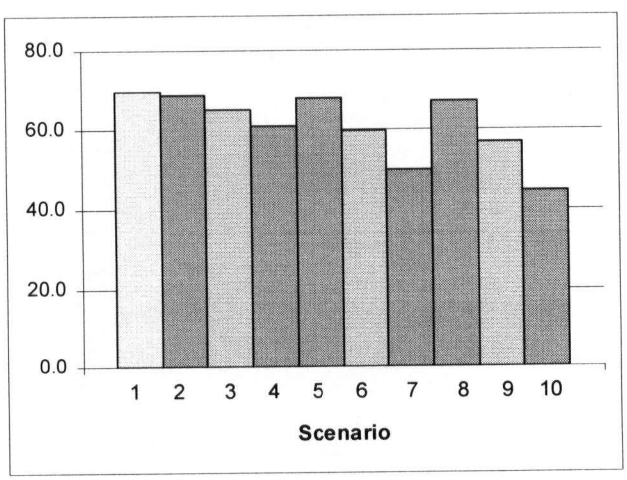
Average Primary Inspection Service Time

Average primary inspection service times varied from approximately 70 seconds for the Base Scenario, to a low of 44.3 seconds for Scenario 10 (*i.e.*, high agency participation and 100% industry participation). While the service times dropped as industry and agency participation rates went up, the decrease was more gradual for Scenarios 2, 5, and 8, which all have 10% industry participation. The trend of faster rates of decrease again appeared the most evident for the scenarios with 100% industry participation. Table and Figure 5.6 demonstrate the results.

Table 5.6 - Average primary inspection service time per truck by scenario (seconds)

		Industry Participation			
		Base	10%	50%	100%
Agency Participation	Base	Sc.1			
		69.6			
	Low		Sc.2	Sc.3	Sc.4
			68.9	65.3	61.0
	Med		Sc.5	Sc.6	Sc.7
			67.8	59.7	49.7
	High		Sc.8	Sc.9	Sc.10
			67.3	56.8	44.3

Figure 5.6 - Average primary inspection service time per truck by scenario (seconds)



Average and Maximum Queue per Lane

As the average delay time decreased with increase in agency and industry participation, it is expected for the average and maximum queue per lane to follow the same pattern. Tables and Figures 5.7 and 5.8 illustrate this to be true with queues decreasing as industry and agency participation increases. Average queues range from a high of 4.5 trucks for the Base Scenario to 1.5 and 1.4 for Scenarios 7 and 10 respectively.

Table 5.7 - Average queue per lane (trucks)

		Industry Participation			
		Base	10%	50%	100%
Agency Participation	Base	Sc.1			
		4.5			
	Low		Sc.2	Sc.3	Sc.4
			3.8	2.9	2.3
	Med		Sc.5	Sc.6	Sc.7
			3.5	2.1	1.5
	High		Sc.8	Sc.9	Sc.10
			3.3	1.9	1.4

Figure 5.7 - Average queue per lane (trucks)

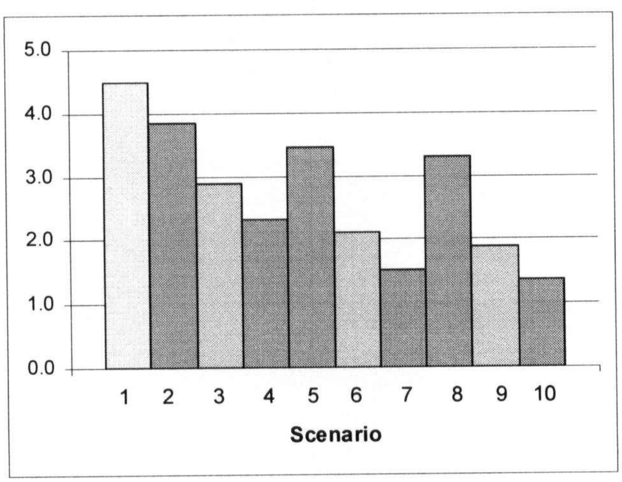
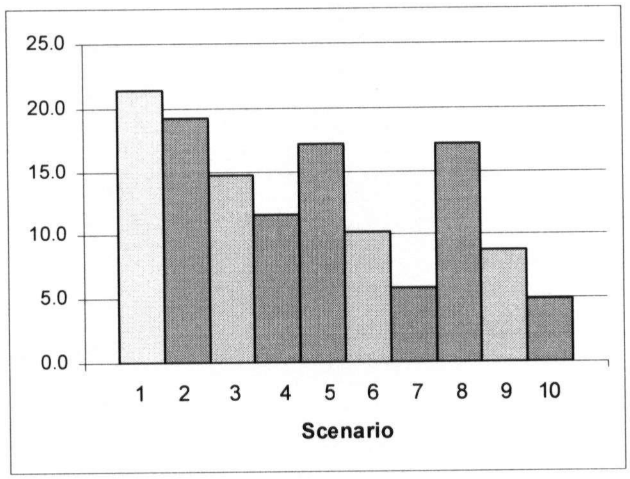


Table 5.8 - Maximum queue per lane (trucks)

		Industry Participation			
		Base	10%	50%	100%
Agency Participation	Base	Sc.1			
		21.4			
	Low		Sc.2	Sc.3	Sc.4
			19.3	14.7	11.6
	Med		Sc.5	Sc.6	Sc.7
			17.2	10.1	5.7
	High		Sc.8	Sc.9	Sc.10
			17.1	8.8	4.8

Figure 5.8 - Maximum queue per lane (trucks)



The significance of industry participation is illustrated in both Figures 5.7 and 5.8; the figures show a slow decline of queue lengths in scenarios with lower industry participation (*i.e.*, 10%) than ones with higher participation rates (*i.e.*, 100%). The maximum queue measure illustrates the significant effects of greater delays with the Base Scenario having a maximum queue of 21.4 trucks whereas half of the scenarios with high industry or agency participation rates (*i.e.*, Scenarios 4, 6, 7, 9, and 10) have maximum queues that are one-half to one-quarter of the Base Scenario. This is a key indicator when planning for infrastructure requirements and it demonstrates that presumed cost savings in reduced inspection service can end up costing more in terms of future infrastructure requirements.

5.9.2. SECURITY BENEFITS

Secure trade is of paramount importance to both Canadian and U.S. trading partners. The primary reason for the existence of the border inspection facility is to ensure safe and secure movement of goods in commercial vehicles. The use of technologies such as pre-screening and DCBF allows the timely acquisition of vital information regarding the goods, carrier, and driver of a commercial vehicle. This allows for a more thorough and automated inspection process that can increase the identification of potential violations while expediting the throughput of goods across the border. The measures of effectiveness that has been considered to quantify the security benefit of DCBF implementation is average percent of potential violators sent to secondary inspection.

Average Percent of Potential Violators Sent to Secondary Inspection

The average percent of potential violators sent to secondary inspection varied from a low 17.3% to an efficient 90.5%. Both Scenarios 1 and 2 shared the low percentage of 17.3% while Scenario 10 held the highest percentage value. In fact, the top three highest percent values were from the three 100% industry participation scenarios (Scenarios 4, 7, & 10). Conversely, the 10% industry participation scenarios (Scenarios 2, 5, an 8) showed the lowest rate of increase for increasing agency participation rates.

This measure demonstrates the "simulated" effectiveness of high agency and industry participation rates, however this indicator is highly subject to the assumptions made in the simulation model as, understandably for the purposes of national security, no information regarding the effectiveness of the primary inspection service was provided, nor could it ever be absolutely measured without much cost and/or difficulty.

5.9.3. ENERGY AND ENVIRONMENT BENEFITS

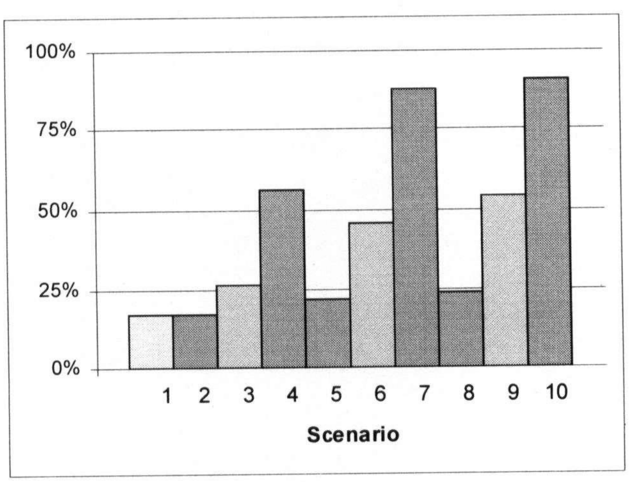
Decreased delay for commercial vehicles at the border crossing results in not only time saving benefits for carriers and their cargo, but also reduced energy consumption and air emissions. Reduced delay also provides for less mechanical wear and tear of vehicle components such as brakes, transmission, and other associated mechanical components. Less wear and tear results also in less particulate matter entering the environment and therefore mitigating impact on water bodies and local streams. For the purpose of estimating energy and environment benefit as a result of a DCBF implementation, two measures of effectiveness will be used:

- Average fuel consumption per truck, (millilitres), and
- Average CO_2 emission per truck, (grams).

Table 5.9 - Average percent of potential violators sent to secondary inspection

		Industry Participation			
		Base	10%	50%	100%
Agency Participation	Base	Sc.1			
		17.3%			
	Low		Sc.2	Sc.3	Sc.4
			17.3%	26.4%	55.8%
	Med		Sc.5	Sc.6	Sc.7
			22.0%	45.5%	87.6%
	High		Sc.8	Sc.9	Sc.10
			24.1%	53.8%	90.5%

Figure 5.9 - Average percent of potential violators sent to secondary inspection



Fuel Consumption

Average fuel consumption due to delay is estimated to drop dramatically from the Base Scenario, of which an average of 253 ml of diesel fuel is used per truck to pass through the primary inspection service, to an average of 47 ml per truck when there is 100% industry participation and high agency participation in the DCBF initiative (Table 5.10).

Figure 5.10 shows a similar pattern to the decreasing average fuel consumption with respect to increase agency and industry participation as with the other measures of effectiveness discuss previously. Again, the sensitivity towards industry participation (utilization of transponders) is greater than that of increased agency participation.

CO_2 Air Emission

As CO_2 emission rates of vehicles are proportional to the amount of fuel consumed, a similar pattern of decreasing CO_2 emissions is also estimated as agency and industry participation increases. As shown in Table and Figure 5.11, from a high of 669 grams of CO_2 emitted by the average commercial vehicle in the Base Scenario as a result of delay, the average CO_2 emission drops down to a low of 126 grams per vehicle for Scenario 10.

To put the results of this measure into perspective, with approximately 400,000 trucks entering Canada from the Pacific Highway crossing, the annual total CO_2 produced due to border delay alone would be approximately 267 tonnes in the Base Scenario. At the other extreme case with a full DCBF implementation (Scenario 10), the same 400,000 trucks would have produced 50 tonnes of CO_2, or 217 tonnes less than the Base Scenario.

Table 5.10 - Average diesel fuel consumption per truck (millilitres)

		Industry Participation			
		Base	10%	50%	100%
Agency Participation	Base	Sc.1			
		253			
	Low		Sc.2	Sc.3	Sc.4
			213	149	111
	Med		Sc.5	Sc.6	Sc.7
			187	99	58
	High		Sc.8	Sc.9	Sc.10
			177	83	47

Figure 5.10 - Average diesel fuel consumption per truck (Millilitres)

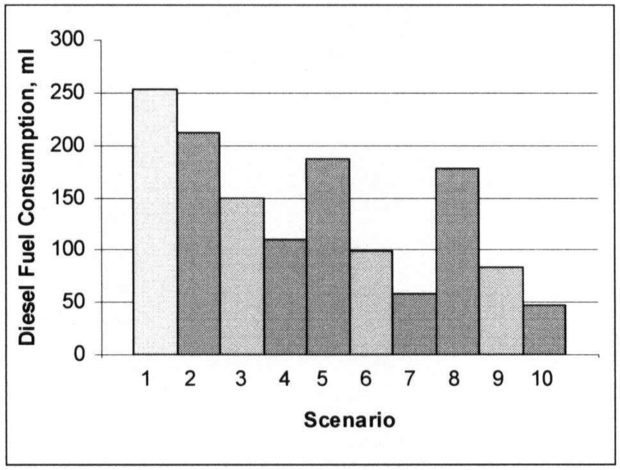
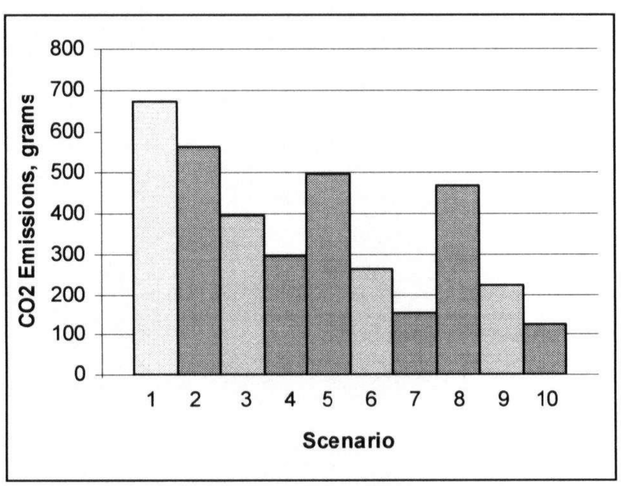


Table 5.11 - Average CO_2 emissions per truck (grams)

		Industry Participation			
		Base	10%	50%	100%
Agency Participation	Base	Sc.1 669			
	Low		Sc.2 564	Sc.3 396	Sc.4 293
	Med		Sc.5 496	Sc.6 262	Sc.7 153
	High		Sc.8 468	Sc.9 221	Sc.10 126

Figure 5.11 - Average CO_2 emissions per truck (grams)



5.9.4. OTHER BENEFITS

The benefits evaluated in the previous sections are by no means the complete list of possible benefits that a DCBF implementation could provide to border services agencies and their stakeholders and clients. The reduction of delay provides for a number of other savings that can be realized by various stakeholders. The availability of an automated and computerized pre-screening and rules-based DCBF system also provides for additional abilities of which provide additional benefits. Although beyond the scope of this research, other benefits could include:

- economic benefits from the spill-over effects of a more efficient and secure border;
- productivity benefits of border inspection services through reduced need for border staffing/resources, or alternatively, increased efficiency in the delivery of border services;
- effectiveness benefits by increasing the feasibility of just-in-time transport of highly time-sensitive cargo;
- safety benefits of knowing contents of cargo and their arrival times in advance to better prepare for sensitive or dangerous/hazardous cargo, as well as knowledge of the physical condition of trucks via on-board sensors in the future;
- positive multiplication effect of adapting technologies and standards that can benefit the commercial vehicle industry beyond the border (e.g. encouraging adoption and use of transponders can help in efficient weighing and safety inspections).

6. CONCLUSIONS AND CONTRIBUTIONS

This chapter provides a summary of the conclusions and contributions that derived from this research work. The work offers four separate initiatives that attempt to address problems with ITS/CVO evaluation studies. These initiatives are summarized as follows:

- Identify the benefits associated with Canadian ITS/CVO market Packages
- Identify major issues for ITS/CVO evaluation
- Develop a framework for evaluating the benefits of intelligent transportation systems for commercial vehicle operations
- Investigate the practicality of the framework through a case-study, a CVO Data Clearinghouse/brokerage facility

The conclusions associated with each initiative are summarized below, followed by the contributions that are made in support of advancing the knowledge with the ITS/CVO evaluation studies. The last section introduces further research that could be undertaken to advance the concepts and initiatives that have been presented in this thesis.

6.1. SUMMARY AND CONCLUSIONS FROM RESEARCH

6.1.1. BENEFITS ASSOCIATED WITH CANADIAN ITS/CVO MARKET PACKAGES

All Canadian ITS market packages for commercial vehicle operations were analyzed to identify the major benefits associated with their deployment. Table 6.1 presents a summary of the potential benefits associated with each market package. It is important to note that the benefits shown in the table should be used with certain care to avoid double counting of benefits, as some of the potential benefits of market packages are interrelated, especially with regard to efficiency, productivity, and mobility goal areas.

Table 6.1 – Potential benefits of Canadian ITS/CVO market packages

Canadian ITS/CVO Market Package	ITS Goal Area					
	Safety	Security	Efficiency	Productivity	Mobility	Energy and Environment
Fleet Administration		√√√	√	√√	√√	√
Freight Administration		√√√	√	√√	√√	√
Electronic Clearance	√	√√	√	√√√	√√	√√
Commercial Vehicle Administration Processes		√	√√	√√√	√√	√
International Border Crossing Clearance		√√	√	√√	√√	√
Weigh-in-Motion	√		√	√√√	√√	√√
Roadside CVO Safety	√√√	√	√√	√√√	√	√
On-Board Safety Monitoring	√√√	√	√√	√√√	√	√
CVO Fleet Maintenance	√√	√	√√	√√√	√	√
Hazardous Material Planning and Incident Response	√√√	√√√	√	√√	√√	√√
Freight In-Transit Monitoring		√√√	√	√√√	√√	√
Freight Terminal Management	√	√√	√	√√	√	√

Note: √√√ High Benefits; √√ Medium Benefits; √ Low Benefits

6.1.2. MAJOR ISSUES FOR ITS/CVO EVALUATION

A review of the currently available literature on ITS/CVO evaluation studies suggests that evaluation results and reported benefits suffer in either quantity and/or quality, due to the following issues:

- **Inconsistent Terminology:** Inconsistent terminology associated with the components of ITS taxonomy for commercial vehicle operations as well as with the reported benefits was found to be one of the major issues in ITS/CVO evaluation studies, which makes the interpretation of the results difficult and sometimes misleading. Especially with regard to the benefits, employing consistent terminology may assist evaluators to better understand interrelation between benefits and to mitigate the likelihood of double counting.

- **Public versus Private Benefits:** ITS/CVO technologies provide benefits to both public and private sectors. Therefore, an ITS/CVO evaluation study should identify and consider the interests of all customer groups affected by an ITS/CVO deployment from the early stages of the evaluation process. The result of an evaluation that has considered both public and private benefits can assist decision makers to asses the potential benefits of the ITS/CVO deployment to the public, while considering possibilities for public/private partnership.

- **Data Availability and Data Transferability:** Lack of widespread deployment of ITS/CVO technologies results in lack of before-and-after data for evaluation. Furthermore, the extent of deployment in many ITS/CVO technologies has not reached a level that can be evaluated or generate real-life benefit results. Therefore, availability of the required data for evaluation, and finding resources for data collection considering limited budget assigned for evaluation remain major issues in evaluation that require coordination among stakeholder agencies. Data transferability among regions and the interpretation of the impact data are also important issues as there might be differences in various exposure conditions between the study site and a region that is using data. To mitigate the problems associated with data collection for future deployments, it is recommended that any information about project initiatives for collecting, analyses, and archiving data be documented in final evaluation report.

- **Uncertainty about Using New Technologies:** ITS/CVO applications propose new concepts and technologies with high level of uncertainties about their cost-effectiveness of investments. The result may be great reluctance among decision makers to accept the new technology. A framework for evaluating ITS/CVO projects and reporting the benefits in a consistent manner to decision makers can highly mitigate the uncertainties about employing new ITS/CVO technologies. Furthermore, adopting the framework can minimize the risk of project failure through unrealistic objectives that cannot be met through the proposed ITS/CVO technology.

- **Institutional Issues:** Institutional issues are usually one of the major barriers in all ITS/CVO evaluation processes, as ITS/CVO technologies will be deployed in institutional environments that may or may not advocate their intended functions. Institutional issues involved in an ITS/CVO implementation program include both non-technical challenges for having participating agencies cooperated and technical challenges for integrating ITS/CVO components. The former focuses on "people" and organizational issues associated with ITS/CVO deployment and operation, such as participant responsibilities, role expectations, staffing levels, inter-jurisdictional coordination, and other inter-agency partnership issues. The latter deals with issues such as interoperability among systems, standards and protocol compliance, infrastructure readiness, integrating new ITS/CVO components with existing legacy systems, and cost and budget constraints. To mitigate the problems associated with institutional issues for future deployments, it is recommended that any information about project initiatives for overcoming and lessening institutional challenges be documented in the final report.

6.1.3. DEVELOPED EVALUATION FRAMEWORK

Evaluation is a tool to aid decision making that demonstrates the benefits and impacts of the project. A review of the literature on ITS/CVO evaluation studies suggests that there have been inconsistencies among evaluators in all stages of evaluation processes from initial stages to reporting the benefits that makes the interpretation of the results difficult and sometimes misleading. It is believed that a well-defined evaluation framework will assist evaluators to investigate the impacts of the proposed deployment and to better quantify the benefits. The outcome of the framework assists decision makers to make more confident future investment decisions on whether the deployment should be extended or dismantled. The different steps for the proposed ITS/CVO evaluation process are as follows (also illustrated in Figure 4.1):

- **Identify the Project Stakeholders:** One of the important issues in any evaluation process is to consider the interests of stakeholders or customers in the early stages of the planning process and therefore, identification of the "customer" groups affected by the deployment of ITS/CVO technology is the major task in this stage.

- **Form an Evaluation Team:** Evaluation should be conducted by an independent party without any vested interest or risk in the project; however, the independent evaluator should have a close interaction with evaluation team that consists of one member from each of the project partners and stakeholder.

- **Identify Goals, Objectives, and Measures of Effectiveness:** There should be an agreement among all participating parties on the goals, objectives, and expectations of both proposed ITS/CVO technology and associated evaluation study. The former is mainly about the expected impacts over the course of time, and the groups being impacted by the deployment. The latter focuses on the purpose of the evaluation and the limitation of the evaluation study. For consistency, ITS/CVO projects should be evaluated based on their impacts on the overall ITS goal areas, including safety, security, efficiency, productivity, mobility, energy and environment, and customer satisfaction. Based on the goals and objectives of both project and evaluation, the measures of effectiveness will be selected to address the needs of decision makers as well as goals of participating stakeholders and the public.

- **Prepare an Evaluation Plan:** The evaluation plan is a vital part of the evaluation process that identifies the expected outcome of the project, the methodology used for analysis, and the associated data requirements. Evaluation plan should also identify qualitative studies to account of any impacts that are not quantifiable and of any "costs and benefits" for which dollar values cannot be assigned.

- **Collect and Analyze Evaluation Data and Information:** Data collection practice requires careful cooperation between parties involved in the project. The evaluator should examine potential ways to reduce data collection expenses by integrating data collection efforts across various measures of effectiveness. The interpretation of analysis results is very important as observable benefits of an ITS/CVO deployment usually emerge after systems have been implemented for some time, and the results may change with time as users change their behaviour in response to system.

- **Prepare the Final Report:** Final report contains documentation of evaluation methodology, plans, results, conclusions, and recommendations. Final report should also include deployment/evaluation barriers and the strategies employed to overcome these barriers during different phases of the ITS/CVO project. The major issues that should be documented include data collection, funding/procurement, and institutional issues.

- **Test the Framework:** The final step in the evaluation process is to examine the evaluation framework and its viability. The framework could be modified, improved, and updated based on the outcomes from the evaluation tests.

6.1.4. CVO DATA CLEARINGHOUSE/BROKERAGE FACILITY

The practicality of the proposed evaluation framework was investigated through a case study, a commercial vehicle operations data clearinghouse/brokerage facility (DCBF) project. A DCBF is a technology that synergistically integrates current technologies such as stakeholder information systems, electronic seals (e-seals), automatic vehicle identification (AVI) and automated vehicle location (AVL) devices (MDA 2004). A DCBF provides various benefits to the transportation carrier, the shipper, the owner of the goods, and the customer. Furthermore, it will help federal, provincial and international agencies monitor freight movements more efficiently by identifying those elements of the system that require closer security and manual inspection, while allowing trustworthy elements to be processed electronically and more efficiently. The major potential benefits of a DCBF deployment were found to be:

- **Efficiency:** The major efficiency benefits include timesavings, improved resource utilization, and improved targeting of commercial vehicle inspections due to real-time access to timely and accurate data for targeting high-risk carriers, and more prescreening of commercial vehicles for violations. In border-crossing inspection processes, prearrival information results in faster processing time for participated commercial vehicles and direct release of participated commercial vehicles from primary line. In roadside inspection processes, prearrival information results in faster processing time for participated commercial vehicles and preclearance of participants (*i.e.*, participating commercial vehicles may bypass inspection sites at mainline speeds).

- **Security:** The security benefits of a DCBF include improved targeting of commercial vehicle inspections due to Real-time access to timely and accurate data for targeting high-risk carriers, more prescreening of commercial vehicles for violations, and enhanced compliance.

- **Safety:** The major safety benefits of a DCBF deployment is for roadside inspections that includes decreased number of crashes involving commercial vehicles, and improved targeting of commercial vehicle inspections due to real-time access to timely and accurate data for targeting high-risk carriers, more prescreening of commercial vehicles for violations, more out-of service orders for the same number of inspections, and enhanced compliance

- **Mobility:** The major mobility benefits of a DCBF include reduced time in transit for trucks and shipments due to preclearance of participated trucks in roadside inspections, and due to prearrival information in border-crossing processes, which reduces shipper or receiver inventory costs; and reduced highway delays to public due to fewer truck-related crashes in roadside inspections.

- **Energy and Environment:** Fuel savings and fewer emissions are major benefits in this category, as more commercial vehicles will be released directly from primary line and there is less need for stopping and queuing for inspection and consequently less idling of diesel engines at weigh and inspection stations. Reduced energy use from reduced accelerations and less wear and tear of brakes are among other benefits.

- **Other Benefits:** Other potential benefits of a DCBF may include cost reduction, revenue, economic benefits, and customer satisfaction; increased trade flows; DCBF customers value the incremental benefits they experience more highly than the incremental costs they bear; increased shipper or receiver satisfaction with carriers due to enhanced quality of service and less delays.

DCBF Benefits for Border-Crossing Inspections

Lack of data is the major problem in the evaluation process of all ITS applications, including DCBF. Therefore, the potential benefits of implementing a DCBF technology for border-crossing inspections were estimated through a simulation model using *Arena*, based on data from similar studies and some assumptions due to so many unique and undefined aspects of DCBF and the lack of "track record" of its operation. Ten simulation scenarios were developed to investigate the effectiveness of the DCBF technology for various industry and agency participation rates. It is worth noting that these conceptual scenarios were developed assuming hypothetical participation levels of a DCBF implementation. Their value is in playing the role of incrementally changing "test" environments that will provide indications as to how each of the measures of effectiveness in the evaluation framework will perform.

The potential benefits of a DCBF deployment for border-crossing inspections were identified as efficiency, security, and energy and environment. Average total time in system, average total delay time, and average and maximum number of trucks in queue per lane were chosen as the measures of effectiveness for quantifying safety benefits in the simulation model. The measures of effectiveness that has been considered to quantify the security benefit of DCBF implementation was average percent of potential violators sent to secondary inspection. For the purpose of estimating energy and environment benefit due to a DCBF implementation, two measures of effectiveness were used, including average fuel consumption, and average CO2 emission. The results of simulation showed that a DCBF deployment for border-crossing inspections would be promising; however, field data is required to measure actual benefits.

6.2. RESEARCH CONTRIBUTIONS

6.2.1. Benefits Associated with Canadian ITS/CVO Market Packages

ITS applications for commercial vehicle operations promise to enhance operational aspects of commercial vehicle and goods movement by streamlining communication between driver/vehicle/carrier and regulatory agencies. Market packages present the deployment-oriented aspect of the Canadian ITS Architecture in response to real-world transportation problems and needs. It is expected that through the deployment of market packages, various benefits accrue to a wide variety of users, non-users, and society as a whole. Therefore, all CVO market packages under the Canadian ITS Architecture were qualitatively analyzed to identify the potential benefits of their deployment. The potential benefits were grouped under six categories, including safety, security, efficiency, productivity, mobility, and energy and environment.

6.2.2. INCORPORATING SECURITY BENEFITS

The security of the freight transportation system can be improved by employing various ITS/CVO technologies; however, these systems are also subject to security threats like any other information technology system. This research suggests that security be considered as one of the major goal areas in any ITS/CVO evaluation process in order to provide new information about security benefits of the proposed technology to decision makers. Furthermore, there was an attempt to quantify security benefits through evaluating a data clearinghouse/brokerage facility (DCBF) concept.

6.2.3. DEVELOPMENT OF AN EVALUATION FRAMEWORK

Major issues associated with the deficiencies of existing ITS/CVO evaluation practices were identified that result in inconsistent procedure and consequently affect the quantity and/or quality of evaluation results and reported benefits. It is believed that lack of a framework for evaluation has further aggravated the problems associated with ITS/CVO evaluation studies. Therefore, based on thorough investigation into previous evaluation studies, a framework for evaluating the benefits of ITS technologies for commercial vehicle operations was developed that addresses the key issues identified.

6.2.4. CVO DATA CLEARINGHOUSE/BROKERAGE FACILITY

Based on the developed evaluation framework, a framework for evaluating and modelling a commercial vehicle operations data clearinghouse/brokerage facility (DCBF) was developed in order to:

- Investigate the practicality of the developed framework for evaluation; and

- Evaluate the benefits of a DCBF technology if employed for border-crossing inspection processes.

6.3. FURTHER RESEARCH

The research presented in this thesis opens the door for additional research activities that could be undertaken in the future to advance the concepts and initiatives aimed at capturing the benefits of intelligent transportation systems for commercial vehicle operations and consequently evaluating the potential ITS/CVO deployment. These activities may include:

- More research could be undertaken to measure actual benefits associated with ITS/CVO market packages through testing prototypes. The research can lead to the development of a structured database to support this framework by setting up the relationship between the Canadian ITS market packages and the associated benefits, while providing data for evaluating the benefits of future deployments.

- Research is required to mitigate the negative impacts of issues identified in this thesis with regard to evaluation practices. The focus could be on terminology consistency, most cost-effective data collection practices associated with different levels of ITS/CVO evaluation studies, and strategies to overcome institutional challenges.

- The framework could be examined and enhanced by being employed for evaluating ITS/CVO research projects. This includes identification of data availability as well as data requirements that should be generated through future infrastructure investments. Continuous usage of the framework can lead to consistency and coordination in ITS/CVO deployments and performance evaluations.

- Our knowledge about security and the methods to quantify security benefits is incipient. More research could be undertaken to identify the security benefits of ITS/CVO market packages as well as better methodologies for quantifying the security benefits and associated measures of effectiveness. Data availability is a big barrier for measuring security benefits, especially with regard to confidentiality associated with security issues. Furthermore, it is still ambiguous what the most cost-effective data for identifying high-risk drivers/vehicles/carriers is.

- The results of simulation for employing a data clearinghouse/brokerage facility in border crossing was promising; however, more research is required to determine the actual benefits of a DCBF technology through testing prototypes.

REFERENCES

Altiok, T., and B. Melamed. 2001. *Simulation modeling and analysis with Arena.* Cyber Research, Inc. and Enterprise Technology Solutions, Inc.

American Trucking Associations (ATA) Foundation. 1996. Assessment of intelligent transportation systems/commercial vehicle operations users services: ITS/CVO qualitative benefit/cost analysis. Executive Summary. Alexandria, VA: ATA Foundation.

Bapna, S., J. Zaveri, and Ż. A. Farkas. 1998. Benefit/cost assessment of the commercial vehicle information systems and networks in Maryland. EDL No. 9369. Baltimore, MD: Morgan State University National Transportation Center.

Battelle. 2002a. Evaluation of the commercial vehicle information systems and networks (CVISN) model deployment initiative. Vol. I, Final Report. EDL No. 13677. Prepared for U.S. Department of Transportation, ITS Joint Program Office. Columbus, OH: Battelle.

Battelle. 2002b. Evaluation of the I-95 commercial vehicle operations roadside safety and SAFER data mailbox field operational tests. Prepared for U.S. Department of Transportation, ITS Joint Program Office, HOIT-1. Columbus, OH: Battelle.

Battelle. 1998. CVISN model deployment initiative summary evaluation plan. Prepared for U.S. Department of Transportation, ITS Joint Program Office, HVH-1. Columbus, OH: Battelle.

Booz-Allen and Hamilton. 2000. Final evaluation report: Ambassador Bridge border crossing system (ABBCS) field operational test. EDL No. 13072. Prepared for ABBCS FOT Partners.

Brand, D. 1998. Applying benefit/cost analysis to identify and measure the benefits of intelligent transportation system. *Transportation Research Record* 1651: 23-29.

Brand, D. 1994. Criteria and methods for evaluating intelligent transportation system plans and operational tests. *Transportation Research Record* 1453: 1-15.

Brand, D., T. E. Parody, J. E. Orban, and V. J. Brown. 2002. Benefit-cost analysis of the commercial vehicle information systems and networks program. *Transportation Research Record* 1800: 35-43.

Canada Border Services Agency Web site (CBSA). 2004. Online, http://www.cbsa-asfc.gc.ca/menu-e.html (August 10, 2004 and November 26, 2004).

Chen, K., and J. C. Miles, eds. 1999. *ITS handbook 2000, Recommendations from the World Road Association (PIARC)*. Norwood, MA: Artech House.

Chowdhury, M. A., and A. Sadek. 2003. *Fundamentals of intelligent transportation systems planning.* Norwood, MA: Artech House.

Driving Force Web site, Online, http://www.drivingforcemag.com/ (July 7, 2004).

Federal Highway Administration, and Federal Transit Administration (FHWA/FTA). 2001. Intelligent transportation systems at international borders, A cross-cutting study. EDL No. 11490. Washington, DC: U.S. Department of Transportation.

Forkenbrock, D. J. 1999. External costs of intercity truck freight transportation. *Transportation Research Part A*, 33 (7-8): 505-526.

Fox, A. K., J. F. Francois, and P. Londoño-Kent. 2003. Measuring border crossing costs and their impact on trade flows: the United States-Mexican trucking case. Presented at the Sixth Annual Conference on Global Economic Analysis, The Hague, The Netherlands.

Greater Vancouver Transportation Authority (TransLink) Web site. Online, http://www.translink.bc.ca/

Haling, D., and H. Cohen. 1996. Residential noise damage costs caused by motor vehicles. *Transportation Research Record* 1559: 84-94.

Haralambides, H., and P. Londoño-Kent. 2002. Impediments to free trade: The case of trucking and NAFTA in the U.S.-Mexican border. Erasmus University, Rotterdam, The Netherlands.

Harbord, B. 1998. M25 controlled motorway – Results of the first two years. IEE Ninth Road Control International Conference, Publication no. 454, London. Quoted in K. Chen and J. C. Miles, eds., *ITS handbook 2000, Recommendations from the World Road Association (PIARC)* (Norwood, MA: Artech House, 1999).

IBI Group. 2000. Canadian architecture for intelligent transportation systems. Prepared for Transport Canada.

Intelligent Transportation Society of America (ITS America). 2002. *Homeland security and ITS - Using intelligent transportation systems to improve and support homeland security.* Washington, DC: Intelligent Transportation Society of America.

Intelligent Transportation Systems Joint Program Office (ITS/JPO). 2002. *ITS evaluation guidelines: ITS evaluation resource guide.* Washington, DC: U.S. Department of Transportation.

Intelligent Transportation Systems Joint Program Office (ITS/JPO). 2001. *ITS evaluation guidelines: ITS integration self-evaluation guidelines.* Washington, DC: U.S. Department of Transportation.

Kelton, W. D., R. P. Sadowski, and D. T. Sturrock. 2004. *Simulation with Arena.* 3rd ed. New York: McGraw-Hill.

Lantz, B. M. 2000. ISS-2: The integration of the motor carrier safety status measurement system (SafeStat) into the roadside inspection selection system (ISS) (final report). Fargo, ND: The Upper Great Plains Transportation Institute, North Dakota State University.

MacDonald, Dettwiler and Associates Ltd. (MDA). 2004. CVO DCBF conceptual architecture. Richmond, BC: MDA.

MacDonald, Dettwiler and Associates Ltd. (MDA). 2003. CVO data clearinghouse/ brokerage facility for transportation security and efficiency, Part A – technical and management proposal. Richmond, BC: MDA.

McCall, B., *et al.* 1997. Minutes of the I-75 evaluation task force meeting. Quoted in S. Bapna, J. Zaveri, and Z. A. Farkas, Benefit/cost assessment of the commercial vehicle information systems and networks in Maryland (Baltimore, MD: Morgan State University National Transportation Center, 1998).

McGurrin, M. and K. Wunderlich. 1999. Running at Capacity. *Traffic Technology International*, April/May. Quoted in Mitretek Systems, Intelligent transportation systems benefits and cost, 2003 update (Washington, DC: U.S. Department of Transportation, 2003).

McQueen, B., and J. McQueen. 1999. *Intelligent transportation systems architecture.* Norwood, MA: Artech House.

Meyer, M. D., and E. J. Miller. 2001. *Urban transportation planning.* 2nd ed. New York: McGraw-Hill.

Miller, H. J., and S. L. Shaw. 2001. *Geographic information systems for transportation.* New York: Oxford University Press.

Mitretek Systems. 2003. Intelligent transportation systems benefits and cost, 2003 update. Washington, DC: U.S. Department of Transportation.

Mitretek Systems. 1999. Simulation and analysis of North American Trade Automation Prototype (NATAP) operations at the Ambassador Bridge. Prepared for Federal Highway Administration.

Moses, L. N., and I. Savage. 1997. A cost-benefit analysis of US motor carrier safety programmes. *Journal of Transport Economics and Policy* XXXI (January): 51-67.

Nozick, L. K., G. F. List, M. A. Turnquist, and T. L. Wu. 1998. Potential effects of advanced technologies at commercial border crossings. *Transportation Research Record* 1613: 88-95.

Nozick, L. K., M. A. Turnquist, F. J. Wayno, G. F. List,T. L. Wu, and B. Menyuk. 1999. Evaluation of advanced information technology at the Peace Bridge. Prepared for the Buffalo and Fort Erie Public Bridge Authority, Buffalo, NY and Fort Erie, Ontario, by Cornell University and Rensselaer Polytechnic Institute.

Orban, J. E. 2000. Chapter 6: What have we learned about ITS for commercial vehicle operations? Status, challenges, and benefits of CVISN level 1 deployment. In *What have we learned from intelligent transportation systems?* Federal Highway Administration (FHWA), 108-126. Washington, DC: U.S. Department of Transportation.

Richeson, K. E. 2000. *Introductory guide to CVISN*. Laurel, MD: Johns Hopkins University Applied Physics Laboratory.

Sienicki, D. 1998. OMC program performance measures: Development and results. OMC Analysis Division. Quoted in S. Bapna, J. Zaveri, and Z. A. Farkas, Benefit/cost assessment of the commercial vehicle information systems and networks in Maryland (Baltimore, MD: Morgan State University National Transportation Center, 1998).

Sussman, J. 2000. *Introduction to transportation systems*. Norwood, MA: Artech House.

Titus, M. J. 1996. Benefits of electronic clearance for enforcement of motor carrier regulations. *Transportation Research Record* 1522: 64-68.

Transportation Research Board (TRB). 2000. *Highway Capacity Manual 2000*. Washington, DC: Transportation Research Board.

Transportation Research Board (TRB). 1996. *Special report 246: Paying our way: Estimating marginal social costs of freight transportation*. Washington, DC: National Academy Press.

Tri-global Solutions Group. 2003. Cost benefit study of electronic clearance and roadside inspection (ECRI) for Canada. Prepared for Transport Canada.

Underwood, S. E., and S. G. Gehring. 1994. Framework for evaluating intelligent vehicle-highway systems. *Transportation Research Record* 1453: 16-22.

University of Chicago Press. 2003. *The Chicago manual of style.* 15th ed. Chicago: University of Chicago Press.

U.S. Customs and Border Protection Web site (USCBP). 2004. Online, http://www.cbp.gov/ (November 26, 2004).

Virginia Tech Transportation Institute (VTTI). 2003. I-81 ITS program evaluation framework. Prepared for Virginia Department of Transportation.

Wolfe, M. (North River Consulting Group). 2002. Freight transportation security and productivity, Executive summary. Prepared for U.S. Department of Transportation, Federal Highway Administration. Long Beach, CA: Intermodal Freight Security and Technology Workshop.

Appendix I

(Safety Analysis)

Safety Analysis

One of the important benefits expected from the deployment of DCBF technology is a reduction in commercial vehicle related crashes through improved enforcement of motor carrier safety regulations. Tracking the history of commercial vehicles and drivers via the utilization of a DCBF will result in better identification of high-risk carriers that have had a history of out-of-service vehicles or drivers. Such carriers and drivers cause a majority of accidents, as well as a hazard to society. Therefore, those vehicles and drivers that are in violation of federal and provincial regulations may be placed out-of-service until the violation is corrected. This may lead to a reduction in accident rate caused by commercial vehicles, as carriers equipped with transponders can be identified for safety enforcement.

It is expected that utilization of DCBF technology will help enforcement staff focus inspection resources on high-risk carriers, which will result in more out-of-service orders for the same number of inspections. This leads to removing additional trucks and drivers from service that are most likely to cause crashes because of vehicle defects and driver violations of safety regulations. Further, the increased attention on high-risk carriers via DCBF will encourage motor carriers to enhance their compliance with safety regulations, which will indirectly reduce likely number of crashes in the future, that is, the number of crashes that would have been caused by violations in safety regulations, but are avoided because of enhanced compliance.

Safety benefit analyses addresses the impact of DCBF on the number of crashes, injuries and fatalities involving large commercial vehicles as well as on rates of driver and carrier compliance with the motor carrier safety regulations. It is also expected that the results of a safety analysis will help to determine the effectiveness of a DCBF in helping roadside safety enforcement officials to identify high-risk commercial vehicles and motor carriers, as well as out-of-service violators.

In the case of enhanced driver and vehicle identification at border crossings, safety benefit can be determined by the additional numbers of vehicles and drivers placed out-of-service, which will lead to an estimated accident rate reduction which can be quantitatively modelled. To do so, the benefits of placing vehicles or drivers out-of-service are first calculated in the existing inspection system. These figures are then used to estimate the benefits of DCBF to help in identifying high-risk carriers. The DCBF safety benefits analysis is performed using a probability model, as used by Orban *et al.* (2002), and predicts the number of crashes avoided under various scenarios. Each scenario is defined by specific assumptions concerning the future deployment of DCBF. The probability model relates the number of crashes avoided to several input parameters including the probability that a commercial vehicle has an out-of-service condition, the number of inspections performed, historical rates at which out-of-service orders were issued, national crash/injury/fatality rates involving large trucks, and probabilities that certain out-of-service conditions will contribute to a crash. Estimates of these inputs were obtained from the literature or from data collected in several special studies conducted in the United States that had previously deployed—or were in the process of deploying— *Commercial Vehicle Information Systems and Networks* (CVISN) safety information exchange and electronic screening technologies.

It is worth noting that the model used in this study has been derived from basic principles of probability and can be easily justified; however, the final results were estimated by using data from open literature on crashes and highway statistics in Canada and the United States, as well as other studies on CVISN deployment, all of which are subject to errors. Furthermore, DCBF technology is a quite new concept that has never been implemented and is somewhat different from other U.S. CVISN deployments. This means that additional data are needed to support these results; however, the safety analysis presented in this study helps to illustrate the impacts of a DCBF implementation on highway safety, and the analysis can be easily modified as new data become available.

Technical Approach

The safety improvement can be measured as the number of crashes, injuries, and fatalities avoided due to implementing the DCBF. The methodology to estimate the safety benefits of the DCBF utilizes a probability model (Orban *et al.* 2002) that relates the safety improvement to the number of out-of-service (OOS) orders issued and other safety parameters such as commercial vehicle crash rates, violation rates, and crash causation statistics. The safety evaluation examines the safety benefits through improvements in the enforcement of vehicle and driver compliance with safety regulations as well as the relationship between DCBF implementation and its impact on enforcement practices. The effect of DCBF on crashes, injuries, and fatalities is estimated via a statistical model. Data collected from published sources as well as assumptions provide input to the model.

It is expected that DCBF technology increases the effectiveness of roadside inspection operations by improving the inspectors' ability to select commercial vehicles for inspection in a more efficient manner. This will encourage carriers to spend resources to ensure that their vehicles stay in compliance. The likely safety impacts can be:

- the removal of unsafe drivers and vehicles from the highways (direct, but small impact); and
- the behaviour modification of drivers and carriers in response to the improved and more targeted inspections (indirect, but large impact).

The major assumption is that low-risk carriers (*i.e.*, carriers with good safety records) would expect to have a small probability of being inspected, while high-risk carriers will try to improve their safety rating to avoid increased inspections. A DCBF enables enforcement staff to focus on targeted inspections, by which additional drivers and vehicles operating with out-of-service conditions will be removed from the roadway for the same number of inspection performed. The elimination of out-of-service conditions that could be cause of likely crashes will result in preventing the occurrence of those crashes. The safety benefit of DCBF is determined by comparing the number of crashes avoided under the baseline scenario (*i.e.*, no DCBF) with the number of crashes avoided under each DCBF deployment scenario. The number of injuries and fatalities under each scenario is assumed to be proportional to the number of crashes avoided. The number of crashes avoided can be written as:

$$N_{CA} = N_{OOS} \cdot P(C, D | OOSC) \qquad [1]$$

where

N_{CA} is the number of crashes avoided;

N_{OOS} is the number of out-of-service orders issued; and

$P(C, D \mid OOSC)$ is the probability of occurrence of a crash (C) with a contributing defect or driver safety violation (D), given that a vehicle has the out-of-service condition ($OOSC$).

Equation [1] can also be written as:

$$N_{CA} = N_{OOS} \cdot P(C|OOSC) \cdot P(D|C, OOSC) \qquad [2]$$

where

$P(C \mid OOSC)$ is the probability of a crash given that a vehicle has an out-of-service condition; and

$P(D \mid C, OOSC)$ is the probability of a contributing defect given that a vehicle is involved in a crash and has an out-of-service condition.

The second and last terms in equation [2] can also be written as follows, using Bayes Theorem:

$$P(C|OOSC) = \frac{P(OOSC|C) \cdot P(C)}{P(OOSC)} \qquad [3]$$

$$P(D|C, OOSC) = \frac{P(D|C) \cdot P(OOSC|D, C)}{P(OOSC|C)} \qquad [4]$$

Where

$P(OOSC \mid C)$ is the probability that a vehicle has an out-of-service condition given it is in a crash;

$P(C)$ is the probability of a crash;

$P(OOSC)$ is the probability that a vehicle has an out-of-service condition;

$P(D \mid C)$ is the probability of a contributing defect given that there was a crash; and

$P(OOSC \mid D,C)$ is the probability that a vehicle has an out-of-service condition given it has a crash with a contributing defect that is equal to 1, as an out-of-service condition is assumed to be due to the vehicle defect or driver violation (D).

Combining equations [2], [3], and [4] will result in:

$$N_{CA} = \frac{N_{OOS} \cdot P(C) \cdot P(D|C)}{P(OOSC)} \qquad [5]$$

The major concerns in this analysis are crashes due to a defect or driver violation that can be prevented by an out-of-service order. If we assume that the probability of a crash is proportional to the number of vehicle-miles-travelled (VMT), the probability of a crash is estimated by the national crash rate for large trucks (λ) multiplied by the number of safe miles (SM) travelled as a result of fixing an out-of-order condition (Orban *et al.* 2002). Orban *et al.* (2002) used the values of SM as 15,000 miles for vehicle out-of-service orders and 10,000 miles for driver out-of-service orders. The authors stated that the expert panel reviewing the Safe-Mile program was not comfortable with these assumptions; however, they were not able to identify a better approach due to lack of data. Equation [5] can now be rewritten as:

$$N_{CA} = \frac{N_{OOS} \cdot \lambda \cdot SM \cdot P(D|C)}{P(OOSC)} \qquad [6]$$

Equation [6] is used to estimate the safety benefits associated with various DCBF deployment scenarios. In 1998, large trucks were involved in 412,000 crashes while travelling 196 billion vehicle miles in the United States, which resulted in 127,000 injuries and 5,374 fatalities (*i.e.*, an average of 0.308 injuries per crash and 0.013 fatalities per crash). Therefore, the U.S. national crash rate for trucks can be calculated as number of truck crashes divided by million vehicle miles travelled (VMT), or 2.1 crashes per million miles travelled. Based on the crash causation probability estimates used in the Safe-Mile program, $P(D \mid C)$ is determined to be equal to 0.046 for vehicle out-of-service conditions and 0.057 for driver out-of-service conditions (Orban *et al.* 2002). Further, as cited in Orban *et al.*

(2002), the percent of VMT with vehicle out-of-service condition was 29%, the percent of VMT with driver out-of-service condition was 5%, and the percent of VMT with vehicle and driver out-of-service condition was 32% in 1996. Therefore, *P(OOSC)* is determined to be equal to 0.29 and 0.05 for vehicle and driver out-of-service conditions, respectively. Further, it can be concluded that in 40 percent of the inspections where a driver was placed out-of-service, there was also a vehicle out-of-service order. The impact of placing a vehicle out-of service is relatively greater than placing a driver out-of-service; therefore, the total number of crashes avoided can be estimated by adding the number of crashes avoided due to vehicle out-of-service orders to the 60 percent of the crashes avoided due to driver out-of-service orders.

The potential scenarios are described as follows. It is notable that these are just examples to show how the DCBF safety analysis can be conducted.

Scenario 1 (Baseline Scenario): No DCBF

In 1998, there were 1,562,739 inspections on commercial vehicles and 2,089,846 driver inspections, among which 25.5% of vehicles and 8.1% of drivers were placed out-of-service (Orban *et al.* 2002). These figures show 398,498 vehicles and 169,278 drivers were placed out-of-service (*i.e.*, 0.255*1,562,739=398,498; 0.081*2,089,846=169,278), which can be used in equation [6] to estimate the number of crashes avoided due to vehicle and driver out-of-service orders, respectively. Number of crashes avoided due to vehicle out-of-service order is equal to:

$$\frac{398{,}498 \cdot 15{,}000 \cdot 2.1 \cdot 0.046}{0.29} = 1{,}991$$

Similarly, number of crashes avoided due to driver out-of-service order is equal to:

$$\frac{168{,}278 \cdot 10{,}000 \cdot 2.1 \cdot 0.057}{0.05} = 4{,}053$$

As discussed before, the estimated number of crashes avoided can be calculated by applying the 60 percent adjustment factor that is equal to 4,423 (*i.e.*, 1,991 + 0.6*4,053=4,423). By applying average rates of 0.308 for injuries and 0.013 for fatalities, the corresponding numbers of injuries and fatalities avoided can be estimated as 1,362 and 57, respectively.

Scenario 2: Semi-DCBF

The *inspection selection system* (ISS) was developed as part of the *Aspen* roadside inspection software system in the United States. The *Aspen* system supports functions as electronic transfer of inspection results, and electronic access to carrier safety performance data and commercial driver licence status data. The major objectives of the ISS were to help roadside inspections to identify commercial vehicles and drivers with poor prior safety performance (*e.g.*, inadequate safety compliance fitness rating, higher than average vehicle/driver out-of-service rates); and/or very few or no roadside inspections in recent years. The initial inspection selection algorithm, developed in 1995, was primarily based on a carrier's history of out-of-service (OOS) violations. The next-generation algorithm, ISS-2, was introduced in 1999. ISS-2 integrates the more comprehensive *safety status measurement system* (SafeStat) algorithm into the ISS (SafeStat was designed to prioritize carriers for monitoring and compliance reviews, while ISS was designed to prioritize carriers for roadside inspection) (Lantz *et al.* 1997; Lantz 2000).

It is expected that the DCBF will increase the efficiency of safety enforcement activities. Via DCBF, safety enforcement staff have access to updated databases and systems similar to the ISS, which can be used for selecting vehicles and drivers for inspection based on previous records. However, the major benefits of ISS will not be realized without integrating ISS into electronic screening algorithms due to difficulties in using ISS (*i.e.*, the time and logistics involved in stopping a vehicle, entering identification numbers into the computer, and reviewing the data). Review of literature shows that ISS has not been used extensively as a tool for inspection selection (Orban *et al.* 2002). Orban *et al.* (2002) conducted a study at the four Connecticut weigh stations to evaluate the impact of ISS on the inspection selection process. They found that "when ISS is used in combination with manual prescreening to select commercial vehicles for inspection, the number of out-of-service orders issued for a fixed number of inspections will increase by 1.9 percent compared to sites that do not use ISS and manual prescreening for inspection selection." The number of crashes, injuries, and fatalities avoided because of 1.9% increase in out-of-service orders, can be equal to 4,507 (*i.e.*, 1.019*4,423 = 4,507) or 84 more crashes avoided compared to the baseline scenario, which means 1,388 injuries and 59 fatalities avoided. It is clear that full DCBF (*e.g.*, integrating ISS with electronic screening) has much more benefits to what was calculated in this scenario.

Scenario 3: Full-DCBF

Making use of full capabilities of DCBF can be similar to integrating ISS with electronic screening, by which roadside enforcement officials will be able to enhance the efficiency of selecting high-risk commercial vehicles for inspection. Under this scenario, low-risk vehicles are allowed to bypass the inspection sites. This means that enforcement officials are able to give all their attention to inspecting medium- and high-risk carriers and carriers with insufficient safety data.

Orban *et al.* (2002) referred to a few states that use ISS or similar tools in combination with electronic screening. However, as carrier enrolment in electronic screening in these states was not sufficient to demonstrate any impacts on the inspection selection process, they conducted a study on the *Connecticut Screening Assessment Study* and found that the number of out-of-service orders would increase by 11.2 percent compared to the average number that would be achieved under scenario 2. This makes the calculation of the numbers of crashes, injuries, and fatalities avoided under scenario 3 possible. With an 11.2 percent increase in the number of out-of-service orders, the number of crashes that can be avoided under this scenario will be 5,012 (*i.e.*, 1.112*4,507=5,012) that show an increase of 589 crashes avoided compared to the baseline scenario. This means 1,544 injuries and 85 fatalities avoided.

Scenario 4: Full-DCBF and a 10% Reduction in Out-of-Service Conditions

As mentioned earlier, the implementation of DCBF will also have some indirect benefits that can be referred to deterrent benefit. This means that DCBF will result in increased compliance with safety regulations as well as fewer unsafe trucks in the road, which will also reduce the numbers of truck-related crashes and associated injuries and fatalities. By reviewing the literature (*i.e.*, Bapna *et al.* 1998; Moses and Savage 1997; Orban *et al.* 2002) it was found that a 10 percent reduction in violation rates of motor carrier safety regulations could be a good estimate, which occurs uniformly across all types of driver and vehicle violations, including those that are likely to cause crashes. If we assume that implementing DCBF and targeted enforcement will result in 10 percent fewer violation rates of motor carrier safety regulations, the calculation of the number of crashes avoided under scenario 4 is divided into two parts: determining direct and indirect impacts. The indirect impact includes the number of crashes avoided because there would be 10 percent fewer trucks and drivers with safety violations on the road. The direct impact includes the changes on inspection selection efficiency because there are fewer out-of-service violators to select for inspection.

It is assumed that the number of crashes avoided would be equal to 10 percent of the number of crashes caused by vehicle defects and driver violations before safety compliance was improved. Further, based on the results of Safe-Mile model, it can be estimated that 4.6 percent of truck-related crashes are because of driver violations, and 5.7 percent of truck-related crashes are caused by vehicle defects. The number of crashes caused by out-of-service conditions can be calculated as 42,436 (*i.e.*, 412,000 *(0.046 +0.057) = 42,436). As discussed earlier, 10 percent of these crashes (*i.e.*, 4244 crashes) would be prevented because of the indirect impact of improved roadside enforcement.

To calculate the direct impacts, it is assumed that a 10 percent reduction in violation rates will result in 10 percent reduction in (a) out-of-service orders issued; (b) probability that a vehicle has an out-of-service condition (*i.e.*, *P(OOSC)*); and (c) percent of crashes caused by defects or driver violations (*i.e.*, *P(D | C)*, because it is expected there will be fewer commercial vehicles in violation, including those involved in crashes). It is notable that these assumptions are all from pervious studies (*e.g.*, Orban *et al.* 2002) that all lack necessary data.

There might be more data available in the future from specific studies such as *Large Truck Crash Causation Study* conducted by the U.S. *Federal Motor Carrier Safety Administration* (FMCSA).

Based on the results of pervious scenario (*i.e.*, scenario 3), there will be 4,511 crashes avoided through roadside enforcement with fully implementing DCBF (*i.e.*, (1-0.10)*5,012=4,511), which should be added to indirect impact. The total number of crashes avoided will then be 8,755 that show an increase of 4,332 compared to the baseline scenario. The corresponding number of injuries and fatalities avoided are 2,697 and 114, respectively.

References:

1) Bapna, S., J. Zaveri, and Z. A. Farkas. 1998. Benefit/cost assessment of the commercial vehicle information systems and networks in Maryland. EDL No. 9369. Baltimore, MD: Morgan State University National Transportation Center.

2) Lantz, B. M. 2000. ISS-2: The integration of the motor carrier safety status measurement system (SafeStat) into the roadside inspection selection system (ISS) (final report). Fargo, ND: The Upper Great Plains Transportation Institute, North Dakota State University.

3) Lantz, B. M., M. W. Blevins, and T. J. Hillegass. 1997. The roadside inspection selection system (ISS) for commercial vehicles. Prepared for Federal Highway Administration, Office of Motor Carriers.

4) Moses, L. N., and I. Savage. 1997. A cost-benefit analysis of US motor carrier safety programmes. *Journal of Transport Economics and Policy* XXXI (January): 51-67.

5) Orban, J. E., V. J. Brown, S. J. Naber, D. Brand, and M. A. Kemp. 2002. Evaluation of the commercial vehicle information systems and networks (CVISN) model deployment initiative. Vol. I, Final Report. EDL No. 13677. Prepared for U.S. Department of Transportation, ITS Joint Program Office.

Appendix II

(Energy and Environment Benefits)

Environmental Benefits

DCBF will help inspection staff to identify and allow safe and legal trucks to bypass a scale without pulling in for inspection. The pre-screening of more commercial vehicles at mainline speeds results in environmental benefits. There will be less idling of diesel engines at weigh and inspection stations as a DCBF allows more commercial vehicles to be pre-cleared, which means less need for stopping and queuing for inspections. This will result in fuel savings and fewer emissions.

Less commercial vehicles accelerating and decelerating for inspections result in additional fuel savings and reduced emissions and particulars from exhaust as well as less wear and tear of brakes and other associated motor vehicle components. Bapna *et al.* (1998) reported fuel savings of pre-screening systems between 0.05 and 0.18 gallons per avoided stop for commercial vehicles, not including fuel savings from reduced queues. Pre-screening of vehicles at mainline speeds will also decrease noise pollution at inspection stations.

It is worth noting that, at least in short run, similar numbers of commercial vehicles will be inspected as before implementing DCBF (but the highest risky ones), which means that we cannot expect major environmental benefit resulting from DCBF-enhanced roadside inspection. The engines of commercial vehicles will still idle during some part of the inspection process. However, there may be some environmental benefits due to targeting high-risk carriers and allowing freer flow of safe carriers. The DCBF-enhanced roadside inspection may encourage high-risk carriers to improve the maintenance of the entire vehicle, including engine operation (*i.e.*, the deterrence impact of DCBF).

Orban *et al.* (2002) described that the amount of air pollutant emissions from a truck is dependent on various factors such as engine size and design, vehicle condition, speed, temperature, frequency of acceleration and deceleration, *etc.* The monetary values for unit amounts of air pollution can be expressed as function of vehicle miles travelled or weight times distance travelled. Table II.1 shows the rates of pollutant emissions of various types of air pollutants for a diesel heavy truck. For heavy-duty diesel trucks that are idling and waiting for inspection, the rates of PM10, NO_x, CO, and VOC can be estimated as 2.57, 55.8, 94.3, and 2.36 grams per hour, respectively, while fuel consumption for a typical truck that is idling can be estimated as 0.5 gallons per hour.

Some researchers did not view carbon dioxide (CO_2) as air pollution; therefore, they add it in a separate category, namely *greenhouse gas emissions* (GHG). For instance, Forkenbrock (1999) described the uncertainty about the likely climate changes due to greenhouse gases and estimated the value of a GHG (only) emissions from truck operations as 0.15 cents per ton-mile based on 22.8 pounds CO_2 of released from each gallon of diesel fuel used, a fuel efficiency of 5.2 miles per gallon, an average payload of 14.80 tons per vehicle-mile, and the GHG value of CO_2 ($10 per ton). Further, Haling and Cohen (1996) estimated the costs of air pollutants (*i.e.*, NO_x, SO_x, PM_{10}, and VOC) for 2233 rural counties in 1994 dollars as shown in Table II.2.

Table II.1 – Rates of pollutant emissions for heavy diesel trucks (grams/mile) (TRB 1996; Orban *et al.* 2002)

Truck Speed (mph)	PM10	NO_x	CO	VOC	SO_x
10	1.43	18.96	22.26	2.36	0.58
20	1.43	14.52	12.13	2.36	0.58
30	1.43	12.81	7.93	2.36	0.58
40	1.43	13.03	6.22	2.36	0.58
50	1.43	15.28	5.85	2.36	0.58
60	1.43	20.64	6.61	2.36	0.58

PM10: Particular matter less than 10 microns in diameter

NO_x: Nitrogen oxides

CO: Hydrocarbons/carbon monoxide

VOC: Volatile organic compounds

SO_x: Sulfur oxides

Table II.2 – Average costs of air pollutants for 2233 rural counties (1994 dollars) (Haling and Cohen 1996)

Emission Type	Cost per ton
NO_x	$213
SO_x	$263
PM_{10}	$3943
VOC	$385

Tri-global Solutions Group (2003) estimated the fuel consumption for three cases including stopping at a static scale, an in-scale bypass and a mainline bypass. The authors assumed a 5-axle tractor / semi-trailer combination loaded to 27,000 kg GVW travelling 3.0 km. The assumed speeds for mainline and in-scale bypasses were 80 km/hr and 50 km/hr, respectively. Scale traffic was assumed to stop and move up several times depending on whether it is peak or off-peak period. Tri-global Solutions Group (2003) assumed that all bypasses are mainline bypasses and that there were no in-scale bypasses. The authors found fuel saving to a mainline bypass truck was about 0.4 Litres/bypass. The proportion of daily truck traffic for base case, in-scale bypasses, and mainline bypasses were assumed to be 20%, 60%, and 20% for peak, shoulder, and low conditions, respectively. Average stopped time for vehicles using static scale was assumed equal to 10 sec/veh. Travel times for stopping traffic were determined to be 192.1 sec/truck for non-OBU equipped trucks, and 182.1 sec/truck for OBU-equipped trucks (*i.e.*, both in-scale and mainline bypasses). Travel times were 144 sec/truck for in-scale bypass traffic and 131.9 for mainline bypass traffic. Travel times were then determined based on the vehicle distribution that resulted in 192.1, 144, and 134.5 sec/truck for non-OBU-equipped trucks, in-scale bypasses, and mainline bypasses, respectively, that showed savings equal to 48.112 and 57.641 sec/truck, for in-scale bypasses and mainline bypasses, respectively. Table II.3 shows fuel consumption, bulk diesel price, and fuel cost saving as cited in Tri-global Solutions Group (2003).

Table II.3 – General assumption for fuel consumption, bulk diesel price and fuel cost saving (Tri-global Solutions Group 2003)

	Non-OBU equipped trucks	In-scale Bypasses	Mainline Bypasses
Fuel Consumption (L/truck)			
for stopping Traffic	1.5354	1.4394	1.4394
For in-scale bypass traffic	1.2274	1.2274	1.2274
For mainline bypass traffic	1.1047	1.1047	1.1047
Weighted Average for selected vehicle distribution (L/truck)	1.5354	1.2274	1.1214
Saving (L/truck)		0.308	0.414
Bulk Diesel Price			
Taxes (% of total price)		45%	45%
Taxes ($/L)		$0.27	$0.27
Net Cost ($/L)		$0.33	$0.33
Total ($/L)		$0.60	$0.60
Fuel Cost Saving ($/truck)			
Taxes		$0.083	$0.112
Net Cost		$0.102	$0.137
Total		$0.185	$0.248

Transportation is a major cause of noise pollution whose value is significantly affected by factors such as traffic characteristics, vehicle type, roadway geometry, speed, land use and density. Differences between trucks and automobiles (*e.g.*, engine size, vehicle weight, number of axles) result in different noise patterns (Orban *et al.* 2002). Haling and Cohen (1996) found that noise damage costs could vary from 0 to 11.48 cents per mile (1993 dollars) for different truck configuration, operating weights, and land use conditions, while Forkenbrock (1999) estimated a value of 0.045 cents per ton-mile (1994 dollars) for truck noise damage costs.

Orban *et al.* (2002) utilized the values of $64,985 per incident for truck crash (total), $80 per hour for truck value of time (total), $2.33 per hour for air and greenhouse gas (in motion), $0.099 per hour for air and greenhouse gas (idling), and $0.00045 per ton-mile for noise pollution. Table II.4 shows times and costs of various truck inspection activities as assumed by Orban *et al.* (2002). For instance, it can be seen that the time associated with avoiding a weigh-in-motion station is assumed to be 1.23 minutes, which results in $1.64 time savings per station bypassed (WIM) (*i.e.*, 80*1.23/60=$1.64). Similarly, the values of the air and noise pollution avoided by bypassing a weigh-in-motion station can be estimated to be $0.048 and $0.007, respectively (*i.e.*, 2.33*1.23/60=$0.048, and 0.00045* 14.8*50*1.23/60=$0.007 assuming that a truck travels at an average of 50 mph and carried 14.80 tons), that leads to $1.69 value of cost saving (time, air, noise) per station bypassed (WIM) (*i.e.*, $1.64+$0.048+ $0.007=$1.69).

Table II.4 – Times and Costs Associated With Various Truck Inspection Activities (1999 dollar) (Orban *et al.* 2002)

Factor (Item)	Natural Unit	Value ($1999)
Roadside inspection time	31.5 min	$42.05
Safety review time	2-3 hrs	N/A
Roadside safety inspection	40 min	$53.40
Compliance review time	28 hrs	N/A
Roadside size/weight inspection	22 min	$29.37
Level I inspection	34 min	$45.39
Level II inspection	29 min	$38.71
Level III inspection	20 min	$26.70
Time savings per station bypassed (Static)	2.81 min	$3.75
Total cost savings (time, air, noise) per station bypassed (Static)	2.81 min	$3.87
Time savings per station bypassed (WIM)	1.23 min	$1.64
Total cost savings (time, air, noise) per station bypassed (WIM)	1.23 min	$1.69
Vehicle OOS time	1.5 hrs	$120
Driver OOS time	4 hrs	$320

References:

1. Bapna, S., J. Zaveri, and Z. A. Farkas. 1998. Benefit/cost assessment of the commercial vehicle information systems and networks in Maryland. EDL No. 9369. Baltimore, MD: Morgan State University National Transportation Center.

2. Forkenbrock, D. J. 1999. External costs of intercity truck freight transportation. *Transportation Research Part A*, 33 (7-8): 505-526.

3. Haling, D., and H. Cohen. 1996. Residential noise damage costs caused by motor vehicles. *Transportation Research Record* 1559: 84-94.

4. Orban, J. E., V. J. Brown, S. J. Naber, D. Brand, and M. A. Kemp. 2002. Evaluation of the commercial vehicle information systems and networks (CVISN) model deployment initiative. Vol. I, Final Report. EDL No. 13677. Prepared for U.S. Department of Transportation, ITS Joint Program Office.

5. Transportation Research Board (TRB). 1996. *Special report 246: Paying our way: Estimating marginal social costs of freight transportation.* Washington, DC: National Academy Press.

6. Tri-global Solutions Group. 2003. Cost benefit study of electronic clearance and roadside inspection (ECRI) for Canada. Prepared for Transport Canada.

Appendix III

(Simulation Model)

Simulation Model Experimental Design

This appendix contains modelling information used to support the benefits outlined in Chapter 5.

Inputs and Assumptions

Truck Arrival Rates

Hourly border truck traffic arrival data for a 24hour period to the Pacific Highway Crossing was provided by CCRA[1] and the profile is shown in Figure III.1. This data was from the site model simulation done in 2002 and was sufficient as input to the generation of arrival rates for trucks in the simulation model.

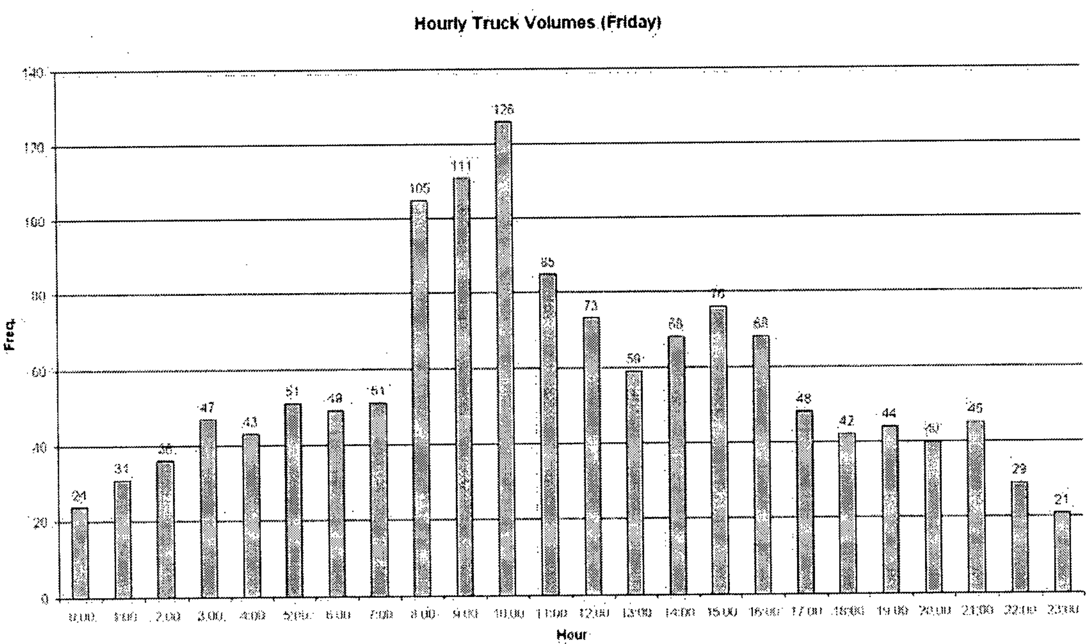


Figure III.1 - Truck hourly arrival rates (24hr Period)

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[1] Provided by Ms. Janice Baird, Senior Project Advisor, Strategy and Co-ordination Branch, CCRA, Nov. 15, 2004.

Assignment of Truck Attributes

For every truck transaction generated, attributes were assigned that were used during the simulation modelling process. The following attributes were assigned to each transaction and a description of their use and possible values:

Table III.1 - Truck hourly arrival rates (24hr Period)

Attribute	Description	Possible Value (in brackets) and Probability Distribution (in %)
Truck Type	Average primary inspection times were a function of truck type (information provided by CCRA)	Driver completes own documentation - avg. (72.5 sec); 7.0% Empty - avg. (48.2 sec); 46.0% Cargo-referred for inspection or documentation - avg. (77.4 sec); 17.1% Cargo-released - avg.(80.9 sec); 24.2% Cargo-in-transit - avg. (69.8 sec); 1.2% Cargo- in bond - avg. (57.4 sec); 4.5%
Transponder Utilization	A scenario control parameter that determines the probability of trucks utilizing transponders (industry participation rate)	Value: (1) if true; (0) if false 0%, 10%; 50%; or 100%, depending on Scenario
*Driver	DCBF rule variable	OK (5): 60%

* The values and probability distributions for these attributes were not provided and therefore assumed. These attributes influence the primary inspection process for a given truck only when a transponder is available.

Attribute	Description	Possible Value (in brackets) and Probability Distribution (in %)
	describing driver history	Questionable (4): 25% 1 Violation Record (3): 8% Multiple Records (2): 5% Different Driver (1): 2%
*Cargo	DCBF rule variable describing cargo status	Correct Cargo (2): 95% Wrong Cargo (1): 5%
*Schedule Adherence	DCBF rule variable describing truck adherence to schedule status	On Time (3): 85% Small differential (2): 10% Large differential (1): 5%
*E-Seal Utilization	DCBF rule variable describing E-Seal utilization	No E-Seal (0): 90% Have E-Seal: (1) 10%
*E-Seal Status	DCBF rule variable describing E-Seal status	OK (2): 95% Broken (1): 5%

Other than the Transponder Utilization attribute, all of the attributes were subject to the same probability distribution for each of the 10 scenarios. This allows a controlled environment to test only the changes in each of the simulation scenarios, of which were changes to the combination of agency participation rate (a function of information or attributes available to the DCBF for rules checking) and industry participation rate (a function of the utilization of transponders by commercial vehicles). In this regard, the issue of the accuracy of the hypothetical attribute values and corresponding distributions is not as significant. Given also the fact that such information was either unobtainable (highly classified information) or unavailable, assumptions as to the values and distributions for the attributes were required and the output of the simulation model runs should be interpreted in light of these assumptions.

Estimation of Primary Inspection Delays

Delays experienced by each truck transaction at the primary inspection booth were a function of not only the attributes as described in the previous section, but also a function of agency participation rates. The model considered the influence of agency participation rates to the delay by utilizing separate delay equations for each of following the agency participation rates:

No Agency Participation (Base Scenario 1)

$$Delay_{Base} = 17 + 20 + tria(AvgPrimaryServiceTime) \quad (1)$$

Low Agency Participation (Scenarios 2, 3 & 4)

$$Delay_{Base} = (17 + 20 + tria(AvgPrimaryServiceTime)) - Transponder * (Driver * 2) \quad (2)$$

Medium Agency Participation (Scenarios 5, 6, & 7)

$$Delay_{Base} = (17 + 20 + tria(AvgPrimaryServiceTime)) - Transponder * ((Driver * 2) + (Cargo * 3) + (HaveESeal * ESeal * 3)) \quad (3)$$

High Agency Participation (Scenarios 8, 9, & 10)

$$Delay_{Base} = (17 + 20 + tria(AvgPrimaryServiceTime)) - Transponder * ((Driver * 2) + (Cargo * 3) + (HaveESeal * ESeal * 3) + (Schedule * 2)) \quad (4)$$

where:

tria(AvgPrimaryServiceTime) represents a triangular distribution of additive primary inspection service times with an average time determined by the truck type, and min. and max. times defined by factors of 0.7 and 2.0 of this average time, respectively.

The constant term of 20 seconds represents a minimum primary inspection service time for all transactions, regardless of type. The constant term of 17 seconds represents the time for commercial vehicles to pull-up from first-in-queue to a complete stop at a primary inspection booth[2]. The total primary inspection service time is therefore the sum of the pull-up time (i.e., 17 seconds), minimum inspection service time (i.e., 20 seconds), and the additive triangular distribution of average primary inspection times as previously described.

The influence of transponder utilization is a reduction in service times due to the benefit of providing information in advance of primary inspection, allowing the DCBF system to assist in the assessment of transponder-equipped trucks. Generally, the higher the agency participation, the more information is provided to the DCBF system, resulting in a greater reduction in time required for primary inspection.

Determination of DCBF Rule Violations and Probability of Secondary Inspection

The purpose of a truck border inspection service is to ensure commercial vehicles and their cargo comply with customs regulations. This assumes that there are vehicles crossing the border that may not comply with regulations, and therefore the goal is to identify these "violators" and respond accordingly.

The benefit of a simulation modelling environment is the ability to assign transactions with a "mark", giving transactions special status, and testing how the simulated environment handles these "marked" transactions. In the case of a truck border crossing environment, commercial vehicles can be created and marked as either "violators" or "non-violators" to test how the simulated border crossing services responds to these transactions.

Within the simulation model developed to test DCBF implementations, simulated trucks were determined to be "actual violators" if the following rules were broken:

- The driver is different (Driver = 1) OR
- The cargo is different (Cargo = 1) OR

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[2] Nozick, Linda K., M. A. Turnquist, F. J. Wayno, G. F. List, T. L. Wu and B. Menyuk. 1999. *Evaluation of advanced information technology at the Peace Bridge*. Prepared for the Buffalo and Fort Erie Public Bridge Authority, Buffalo, NY, and Fort Erie, ON.

- The truck is way off schedule (Schedule = 1) OR
- The E-Seal is broken (ESeal = 1) OR
- The driver has multiple infraction records AND is driving somewhat behind schedule (Driver = 2 AND Schedule =2)

Recalling that the range of values of these truck attributes are as follows:

- Driver: 1, 2, 3, 4, 5
- Cargo: 1,2
- Schedule: 1,2,3
- E-Seal: 1,2

The "actual violators" can also be identified if the value resulting from the following equation is greater than 0:

$$(1/driver+1/cargo+1/schedule+1/eseal-1.99) > 0 \quad (5)$$

Note that the probability of a given transaction to be identified as an "actual violator" is the same in all scenarios and assumed independent of agency or industry participation in DCBF implementations.

With each of the truck transactions identified as an "actual violator" or not, the transactions are passed through the simulated primary inspection process equipped with varying degrees of DCBF implementations, as per scenario definitions. The probability of a truck transaction sent for secondary inspection can then be represented by the following equation, where transactions with resulting values greater than 0 are sent to secondary inspection:

(DISC(0.15,10,1,0)*(1-transponder))+

((transponder)*(DriverOn*1/driver+CargoOn*1/cargo+

ScheduleOn*1/schedule+ESealOn*1/eseal-VCoef))+
((transponder)*(DISC(SecondaryRate,10,1.0,0))) >0 (6)

where:

DISC(p1,v1,p2,v2) represents a discrete probability distribution with values of v1 having a probably of p1 and values of v2 having a probability of p2-p1.

transponder = 1 if equipped or 0 if unequipped

DriverOn = 1 for Low, Med. and High agency participation rates, else 0

CargoON = 1 for Med. and High agency participation rates, else 0

ESealON = 1 for Med. and High agency participation rates, else 0

ScheduleON = 1 for High agency participation rates, else 0

VCoef = 0, 0.99, 1.51, and 1.99 for No, Low, Med. and High agency participation rates, respectively

SecondaryRate = 0.15, 0.10, 0.05, 0.02 for No, Low, Med. and High industry participation rates, respectively

The security effectiveness of the truck border crossing services can measured by the percent of "actual violators" that are sent to secondary inspection from the primary inspection process. Equation (6) essentially models the effectiveness of DCBF implementations with varying degrees of agency and industry participation rates, measuring the ability for the DCBF implementation to assist in the identification of "actual violators".

Modelling Flowcharts and Coding

General Modelling Process

With the simulation model inputs and assumptions, the general modelling process is illustrated in Figure III.2.

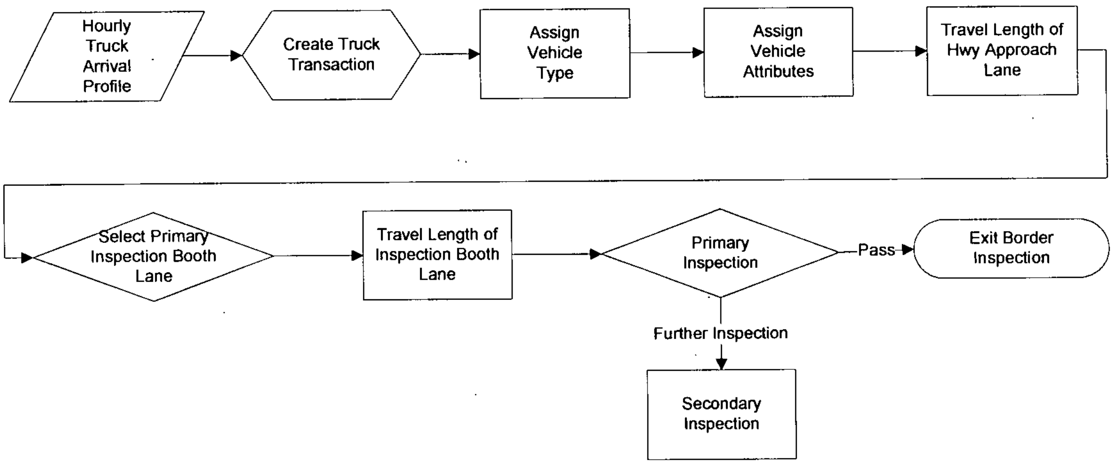

Figure III.2 - General simulation modelling process

Detailed simulation Model Flowchart

The simulation model was developed and run in Arena, a discrete-even simulation software package developed by Rockwell Software Inc. The following Figures III.3-III.5 illustrate the simulation model flowchart developed to perform the 200 simulation runs in the evaluation of the 10 DCBF implementation scenarios.

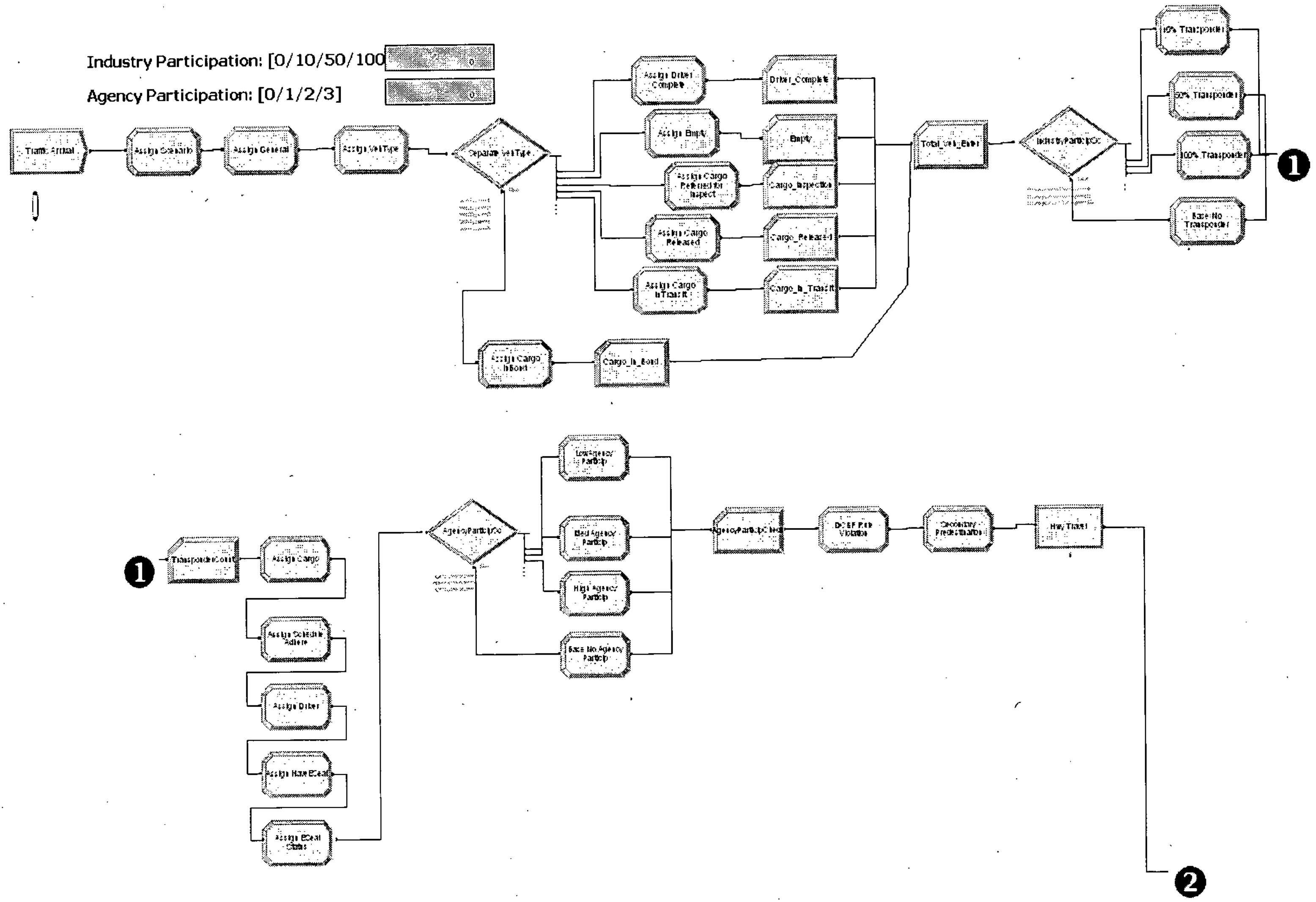

Figure III.3 - Creation of transactions and assignment of attributes

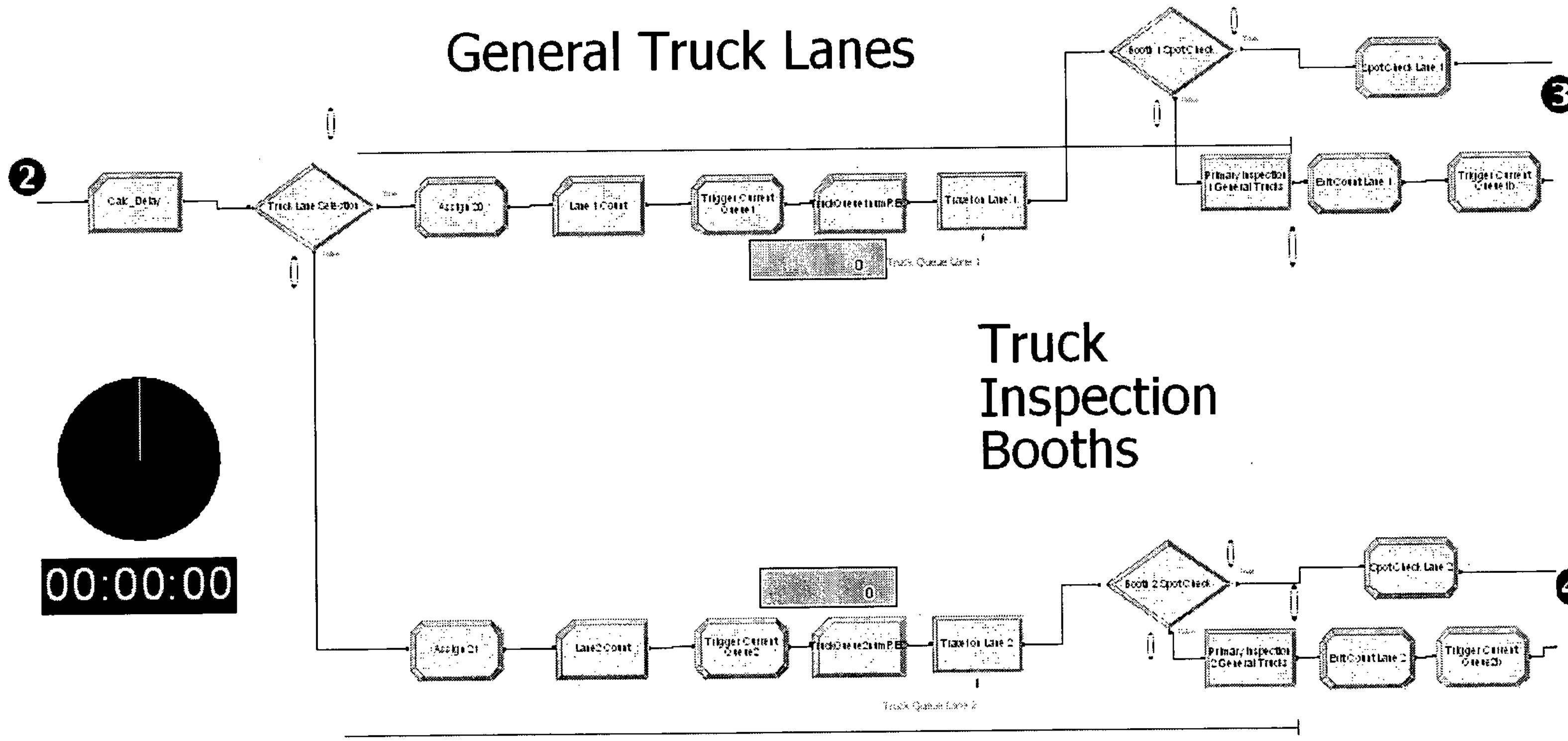

Figure III.4 - Primary inspection booth lane selection and inspection logic (1)

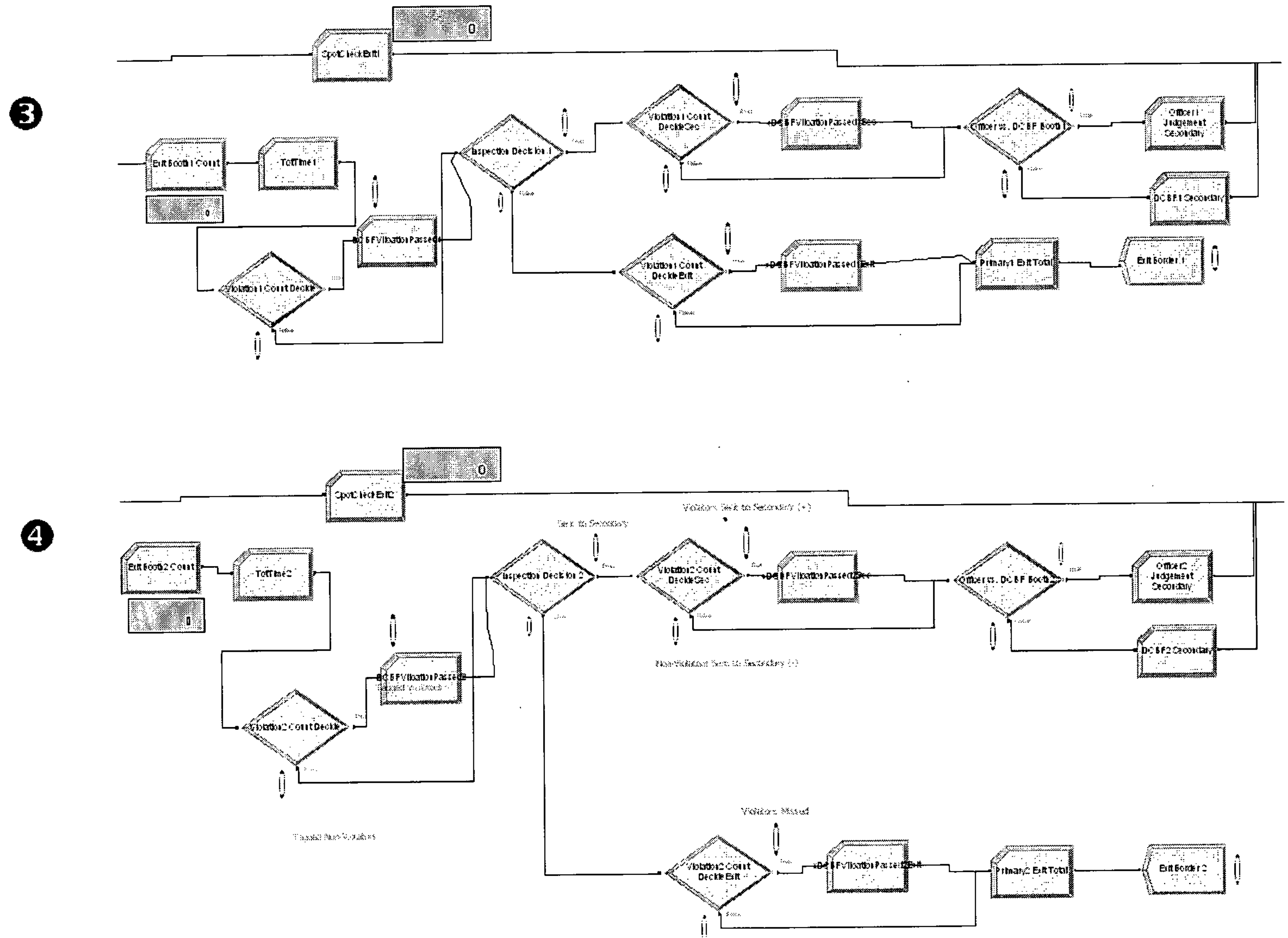

Figure III.5 - Primary inspection process logic (2)

Simulation Model Code

```
;    Model statements for module:  Create 2
;
95$        CREATE,       1,NSEXPO(TruckSchedule),Entity 1:NSEXPO(TruckSchedule);
96$        ASSIGN:       Traffic Arrival.NumberOut=Traffic Arrival.NumberOut + 1:NEXT(62$);
;
;    Model statements for module:  Assign 37
;
62$        ASSIGN:       TransponderParticip=100:
                    AgencyParticip=3:NEXT(17$);
;
;    Model statements for module:  Assign 9
;
17$        ASSIGN:       ArriveTime=TNOW:
                    TruckCondition=DISC(0.7,1,0.9,2,1.0,3):
                    Picture=Picture.Truck:NEXT(45$);
;
;    Model statements for module:  Assign 28
;
45$        ASSIGN:       VehType=DISC(0.07,1,0.53,2,0.701,3,0.943,4,0.955,5,1.0,6):NEXT(46$);
;
;    Model statements for module:  Decide 30
;
46$        BRANCH,       1:
                    If,VehType==1,48$,Yes:
                    If,VehType==2,49$,Yes:
                    If,VehType==3,50$,Yes:
                    If,VehType==4,51$,Yes:
                    If,VehType==5,52$,Yes:
                    Else,47$,Yes;
;
;    Model statements for module:  Assign 29
;
47$        ASSIGN:       AvgPrimaryServiceTime=20.4:NEXT(58$);
;
;    Model statements for module:  Record 19
;
58$        COUNT:        Cargo_In_Bond,1:NEXT(27$);
;
;    Model statements for module:  Record 4
;
27$        COUNT:        Total_Veh_Enter,1:NEXT(59$);
;
;    Model statements for module:  Decide 31
;
59$        BRANCH,       1:
                    If,TransponderParticip==10,68$,Yes:
                    If,TransponderParticip==50,16$,Yes:
                    If,TransponderParticip==100,60$,Yes:
                    Else,61$,Yes;
;
;    Model statements for module:  Assign 36
;
61$        ASSIGN:       SecondaryRate=.15:
                    Transponder=0:NEXT(63$);
;
;    Model statements for module:  Record 20
;
63$        TALLY:        TransponderCount,Transponder,1:NEXT(18$);
;
;    Model statements for module:  Assign 10
;
18$        ASSIGN:       Cargo=DISC(0.95,2,1.0,1):NEXT(19$);
;
;    Model statements for module:  Assign 11
;
19$        ASSIGN:       Schedule=DISC(0.85,3,0.95,2,1.0,1):NEXT(20$);
;
;    Model statements for module:  Assign 12
```

```
;
20$        ASSIGN:      Driver=DISC(0.6,5,0.85,4,0.93,3,0.98,2,1.0,1):NEXT(21$);
;
;   Model statements for module:  Assign 13
;
21$        ASSIGN:      HaveESeal=DISC(0.9,1,1.0,0):NEXT(22$);
;
;   Model statements for module:  Assign 14
;
22$        ASSIGN:      ESeal=DISC(0.95,2,1.0,1):NEXT(65$);
;
;   Model statements for module:  Decide 32
;
65$        BRANCH,      1:
                 If,AgencyParticip==1,69$,Yes:
                 If,AgencyParticip==2,64$,Yes:
                 If,AgencyParticip==3,66$,Yes:
                 Else,67$,Yes;
;
;   Model statements for module:  Assign 40
;
67$        ASSIGN:      DriverOn=0:
                 CargoOn=0:
                 ESealOn=0:
                 ScheduleOn=0:
                 CalcDelay=(17+20+tria(AvgPrimaryServiceTime*0.7,AvgPrimaryServiceTime,AvgPrimaryServiceTime*2))
                 :NEXT(70$);
;
;   Model statements for module:  Record 21
;
70$        TALLY:       AgencyParticipCheck,AgencyParticip,1:NEXT(80$);
;
;   Model statements for module:  Assign 44
;
80$        ASSIGN:      DCBFViolation=(1/driver+1/cargo+1/schedule+1/eseal-1.99):NEXT(71$);
;
;   Model statements for module:  Assign 43
;
71$        ASSIGN:      Secondary=
                 (DISC(0.15,10,1,0)*(1-
transponder))+((transponder)*(DriverOn*1/driver+CargoOn*1/cargo+ScheduleOn*1/schedule+ESealOn*1/eseal-
VCoef))+((transponder)*(DISC(SecondaryRate,10,1.0,0)))
                 :NEXT(15$);
;
;   Model statements for module:  Process 57
;
15$        ASSIGN:      Hwy Travel.NumberIn=Hwy Travel.NumberIn + 1:
                 Hwy Travel.WIP=Hwy Travel.WIP+1;
134$       STACK,       1:Save:NEXT(106$);

106$       DELAY:       0.500000000000000,,NVA:NEXT(115$);

115$       TALLY:       Hwy Travel.TotalTimePerEntity,Diff.StartTime,1;
139$       ASSIGN:      Hwy Travel.NVATime=Hwy Travel.NVATime + Diff.NVATime;
140$       TALLY:       Hwy Travel.NVATimePerEntity,Diff.NVATime,1;
154$       STACK,       1:Destroy:NEXT(153$);

153$       ASSIGN:      Hwy Travel.NumberOut=Hwy Travel.NumberOut + 1:
                 Hwy Travel.WIP=Hwy Travel.WIP-1:NEXT(28$);
;
;   Model statements for module:  Record 5
;
28$        TALLY:       Calc_Delay,CalcDelay,1:NEXT(5$);
;
;   Model statements for module:  Decide 21
;
5$         BRANCH,      1:
                 If,TruckQueue1Num<=TruckQueue2Num,156$,Yes:
                 Else,157$,Yes;
156$       ASSIGN:      Truck Lane Selection.NumberOut True=Truck Lane Selection.NumberOut True + 1:NEXT(29$);

157$       ASSIGN:      Truck Lane Selection.NumberOut False=Truck Lane Selection.NumberOut False + 1:NEXT(31$);
```

```
;
;    Model statements for module:  Assign 20
;
29$          ASSIGN:        TruckQueue1=TruckQueue1+1:NEXT(30$);
;
;    Model statements for module:  Record 6
;
30$          TALLY:         Lane 1 Count,TruckQueue1,1:NEXT(37$);
;
;    Model statements for module:  Assign 24
;
37$          ASSIGN:        TruckQueue1Num=TruckQueue1-TruckQueue1b-TruckQueue1c:NEXT(39$);
;
;    Model statements for module:  Record 10
;
39$          TALLY:         TruckQueue1numREC,TruckQueue1num,1:NEXT(6$);
;
;    Model statements for module:  Process 47
;
6$           ASSIGN:        Travel on Lane 1.NumberIn=Travel on Lane 1.NumberIn + 1:
                       Travel on Lane 1.WIP=Travel on Lane 1.WIP+1;
187$         STACK,         1:Save:NEXT(159$);

159$         DELAY:         0.083333333333333,,VA:NEXT(168$);

168$         TALLY:         Travel on Lane 1.TotalTimePerEntity,Diff.StartTime,1;
192$         ASSIGN:        Travel on Lane 1.VATime=Travel on Lane 1.VATime + Diff.VATime;
193$         TALLY:         Travel on Lane 1.VATimePerEntity,Diff.VATime,1;
207$         STACK,         1:Destroy:NEXT(206$);

206$         ASSIGN:        Travel on Lane 1.NumberOut=Travel on Lane 1.NumberOut + 1:
                       Travel on Lane 1.WIP=Travel on Lane 1.WIP-1:NEXT(23$);
;
;    Model statements for module:  Decide 28
;
23$          BRANCH,        1:
                       With,(2)/100,209$,Yes:
                       Else,210$,Yes;
209$         ASSIGN:        Booth 1 Spot Check.NumberOut True=Booth 1 Spot Check.NumberOut True + 1:NEXT(41$);

210$         ASSIGN:        Booth 1 Spot Check.NumberOut False=Booth 1 Spot Check.NumberOut False + 1:NEXT(0$);
;
;    Model statements for module:  Assign 26
;
41$          ASSIGN:        TruckQueue1c=TruckQueue1c+1:NEXT(42$);
;
;    Model statements for module:  Record 12
;
42$          TALLY:         SpotCheckExit1,TruckQueue1c,1:NEXT(3$);
;
;    Model statements for module:  Process 34
;
3$           ASSIGN:        Drive to Secondary Inspection General 1.NumberIn=
                       Drive to Secondary Inspection General 1.NumberIn + 1:
                       Drive to Secondary Inspection General 1.WIP=Drive to Secondary Inspection General 1.WIP+1;
240$         STACK,         1:Save:NEXT(212$);

212$         DELAY:         0.083333333333333,,VA:NEXT(221$);

221$         TALLY:         Drive to Secondary Inspection General 1.TotalTimePerEntity,Diff.StartTime,1;
245$         ASSIGN:        Drive to Secondary Inspection General 1.VATime=
                       Drive to Secondary Inspection General 1.VATime + Diff.VATime;
246$         TALLY:         Drive to Secondary Inspection General 1.VATimePerEntity,Diff.VATime,1;
260$         STACK,         1:Destroy:NEXT(259$);

259$         ASSIGN:        Drive to Secondary Inspection General 1.NumberOut=
                       Drive to Secondary Inspection General 1.NumberOut + 1:
                       Drive to Secondary Inspection General 1.WIP=Drive to Secondary Inspection General 1.WIP-1:NEXT(8$);
;
;    Model statements for module:  Process 51
;
8$           ASSIGN:        Secondary Truck Inspection General 1.NumberIn=Secondary Truck Inspection General 1.NumberIn + 1:
```

```
                Secondary Truck Inspection General 1.WIP=Secondary Truck Inspection General 1.WIP+1;
291$      STACK,        1:Save:NEXT(265$);

265$      QUEUE,        Secondary Truck Inspection General 1.Queue;
264$      SEIZE,        2,VA:
                Secondary Truck Inspector,1:NEXT(263$);

263$      DELAY:        Triangular(5,15,60),,VA:NEXT(306$);

306$      ASSIGN:       Secondary Truck Inspection General 1.WaitTime=
                Secondary Truck Inspection General 1.WaitTime + Diff.WaitTime;
270$      TALLY:        Secondary Truck Inspection General 1.WaitTimePerEntity,Diff.WaitTime,1;
272$      TALLY:        Secondary Truck Inspection General 1.TotalTimePerEntity,Diff.StartTime,1;
296$      ASSIGN:       Secondary Truck Inspection General 1.VATime=
                Secondary Truck Inspection General 1.VATime + Diff.VATime;
297$      TALLY:        Secondary Truck Inspection General 1.VATimePerEntity,Diff.VATime,1;
262$      RELEASE:      Secondary Truck Inspector,1;
311$      STACK,        1:Destroy:NEXT(310$);

310$      ASSIGN:       Secondary Truck Inspection General 1.NumberOut=Secondary Truck Inspection General 1.NumberOut + 1:
                Secondary Truck Inspection General 1.WIP=Secondary Truck Inspection General 1.WIP-1:NEXT(4$);
;
;   Model statements for module: Dispose 18
;
4$        ASSIGN:       Dispose 18.NumberOut=Dispose 18.NumberOut + 1;
313$      DISPOSE:      Yes;
;
;   Model statements for module: Process 6
;
0$        ASSIGN:       Primary Inspection 1 General Trucks.NumberIn=Primary Inspection 1 General Trucks.NumberIn + 1:
                Primary Inspection 1 General Trucks.WIP=Primary Inspection 1 General Trucks.WIP+1;
343$      STACK,        1:Save:NEXT(317$);

317$      QUEUE,        Primary Inspection 1 General Trucks.Queue;
316$      SEIZE,        2,VA:
                Primary 1,1:NEXT(315$);

315$      DELAY:        SecondsToBaseTime(CalcDelay),,VA:NEXT(358$);

358$      ASSIGN:       Primary Inspection 1 General Trucks.WaitTime=
                Primary Inspection 1 General Trucks.WaitTime + Diff.WaitTime;
322$      TALLY:        Primary Inspection 1 General Trucks.WaitTimePerEntity,Diff.WaitTime,1;
324$      TALLY:        Primary Inspection 1 General Trucks.TotalTimePerEntity,Diff.StartTime,1;
348$      ASSIGN:       Primary Inspection 1 General Trucks.VATime=Primary Inspection 1 General Trucks.VATime +
Diff.VATime;
349$      TALLY:        Primary Inspection 1 General Trucks.VATimePerEntity,Diff.VATime,1;
314$      RELEASE:      Primary 1,1;
363$      STACK,        1:Destroy:NEXT(362$);

362$      ASSIGN:       Primary Inspection 1 General Trucks.NumberOut=Primary Inspection 1 General Trucks.NumberOut + 1:
                Primary Inspection 1 General Trucks.WIP=Primary Inspection 1 General Trucks.WIP-1:NEXT(35$);
;
;   Model statements for module: Assign 23
;
35$       ASSIGN:       TruckQueue1b=TruckQueue1b+1:NEXT(93$);
;
;   Model statements for module: Assign 45
;
93$       ASSIGN:       TruckQueue1Num=TruckQueue1-TruckQueue1b-TruckQueue1c:NEXT(36$);
;
;   Model statements for module: Record 9
;
36$       TALLY:        Exit Booth1 Count,TruckQueue1b,1:NEXT(26$);
;
;   Model statements for module: Record 3
;
26$       TALLY:        TotTime1,INT(ArriveTime),1:NEXT(83$);
;
;   Model statements for module: Decide 36
;
83$       BRANCH,       1:
                If,DCBFViolation>0,365$,Yes:
```

```
                Else,366$,Yes;
365$      ASSIGN:      Violation1 Count Decide.NumberOut True=Violation1 Count Decide.NumberOut True + 1:NEXT(84$);

366$      ASSIGN:      Violation1 Count Decide.NumberOut False=Violation1 Count Decide.NumberOut False + 1:NEXT(2$);
;
;   Model statements for module:  Record 30
;
84$       COUNT:       DCBFViloationPassed1,1:NEXT(2$);
;
;   Model statements for module:  Decide 5
;
2$        BRANCH,      1:
                If,Secondary>0,367$,Yes:
                Else,368$,Yes;
367$      ASSIGN:      Inspection Decision 1.NumberOut True=Inspection Decision 1.NumberOut True + 1:NEXT(91$);

368$      ASSIGN:      Inspection Decision 1.NumberOut False=Inspection Decision 1.NumberOut False + 1:NEXT(89$);
;
;   Model statements for module:  Decide 40
;
91$       BRANCH,      1:
                If,DCBFViolation>0,369$,Yes:
                Else,370$,Yes;
369$      ASSIGN:      Violation1 Count DecideSec.NumberOut True=Violation1 Count DecideSec.NumberOut True +
1:NEXT(92$);

370$      ASSIGN:      Violation1 Count DecideSec.NumberOut False=Violation1 Count DecideSec.NumberOut False +
1:NEXT(72$);
;
;   Model statements for module:  Record 34
;
92$       COUNT:       xDCBFViloationPassed1Sec,1:NEXT(72$);
;
;   Model statements for module:  Decide 33
;
72$       BRANCH,      1:
                If,Secondary>5,371$,Yes:
                Else,372$,Yes;
371$      ASSIGN:      Officer vs. DCBF Booth1.NumberOut True=Officer vs. DCBF Booth1.NumberOut True + 1:NEXT(73$);

372$      ASSIGN:      Officer vs. DCBF Booth1.NumberOut False=Officer vs. DCBF Booth1.NumberOut False + 1:NEXT(74$);
;
;   Model statements for module:  Record 22
;
73$       COUNT:       Officer1 Judgement Secondary,1:NEXT(3$);
;
;   Model statements for module:  Record 23
;
74$       COUNT:       DCBF1 Secondary,1:NEXT(3$);
;
;   Model statements for module:  Decide 39
;
89$       BRANCH,      1:
                If,DCBFViolation>0,373$,Yes:
                Else,374$,Yes;
373$      ASSIGN:      Violation1 Count DecideExit.NumberOut True=Violation1 Count DecideExit.NumberOut True +
1:NEXT(90$);

374$      ASSIGN:      Violation1 Count DecideExit.NumberOut False=Violation1 Count DecideExit.NumberOut False + 1
                :NEXT(82$);
;
;   Model statements for module:  Record 33
;
90$       COUNT:       xDCBFViloationPassed1Exit,1:NEXT(82$);
;
;   Model statements for module:  Record 29
;
82$       COUNT:       Primary1 Exit Total,1:NEXT(1$);
;
;   Model statements for module:  Dispose 3
;
1$        ASSIGN:      Exit Border 1.NumberOut=Exit Border 1.NumberOut + 1;
```

```
375$      DISPOSE:      Yes;
;
;   Model statements for module:  Assign 21
;
31$       ASSIGN:       TruckQueue2=TruckQueue2+1:NEXT(32$);
;
;   Model statements for module:  Record 7
;
32$       TALLY:        Lane2 Count,TruckQueue2,1:NEXT(38$);
;
;   Model statements for module:  Assign 25
;
38$       ASSIGN:       TruckQueue2Num=TruckQueue2-TruckQueue2b-TruckQueue2c:NEXT(40$);
;
;   Model statements for module:  Record 11
;
40$       TALLY:        TruckQueue2numREC,TruckQueue2num,1:NEXT(7$);
;
;   Model statements for module:  Process 48
;
7$        ASSIGN:       Travel on Lane 2.NumberIn=Travel on Lane 2.NumberIn + 1:
                  Travel on Lane 2.WIP=Travel on Lane 2.WIP+1;
405$      STACK,        1:Save:NEXT(377$);

377$      DELAY:        0.0833333333333333,,VA:NEXT(386$);

386$      TALLY:        Travel on Lane 2.TotalTimePerEntity,Diff.StartTime,1;
410$      ASSIGN:       Travel on Lane 2.VATime=Travel on Lane 2.VATime + Diff.VATime;
411$      TALLY:        Travel on Lane 2.VATimePerEntity,Diff.VATime,1;
425$      STACK,        1:Destroy:NEXT(424$);

424$      ASSIGN:       Travel on Lane 2.NumberOut=Travel on Lane 2.NumberOut + 1:
                  Travel on Lane 2.WIP=Travel on Lane 2.WIP-1:NEXT(24$);
;
;   Model statements for module:  Decide 29
;
24$       BRANCH,       1:
                  With,(2)/100,427$,Yes:
                  Else,428$,Yes;
427$      ASSIGN:       Booth 2 Spot Check.NumberOut True=Booth 2 Spot Check.NumberOut True + 1:NEXT(43$);

428$      ASSIGN:       Booth 2 Spot Check.NumberOut False=Booth 2 Spot Check.NumberOut False + 1:NEXT(9$);
;
;   Model statements for module:  Assign 27
;
43$       ASSIGN:       TruckQueue2c=TruckQueue2c+1:NEXT(44$);
;
;   Model statements for module:  Record 13
;
44$       TALLY:        SpotCheckExit2,TruckQueue2c,1:NEXT(11$);
;
;   Model statements for module:  Process 55
;
11$       ASSIGN:       Drive to Secondary Inspection Transponder.NumberIn=
                  Drive to Secondary Inspection Transponder.NumberIn + 1:
                  Drive to Secondary Inspection Transponder.WIP=Drive to Secondary Inspection Transponder.WIP+1;
458$      STACK,        1:Save:NEXT(430$);

430$      DELAY:        0.0833333333333333,,VA:NEXT(439$);

439$      TALLY:        Drive to Secondary Inspection Transponder.TotalTimePerEntity,Diff.StartTime,1;
463$      ASSIGN:       Drive to Secondary Inspection Transponder.VATime=
                  Drive to Secondary Inspection Transponder.VATime + Diff.VATime;
464$      TALLY:        Drive to Secondary Inspection Transponder.VATimePerEntity,Diff.VATime,1;
478$      STACK,        1:Destroy:NEXT(477$);

477$      ASSIGN:       Drive to Secondary Inspection Transponder.NumberOut=
                  Drive to Secondary Inspection Transponder.NumberOut + 1:
                  Drive to Secondary Inspection Transponder.WIP=Drive to Secondary Inspection Transponder.WIP-1
                  :NEXT(12$);
;
;   Model statements for module:  Process 56
```

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;
12$      ASSIGN:     Secondary Truck InspectionTransponder.NumberIn=Secondary Truck InspectionTransponder.NumberIn + 1:
              Secondary Truck InspectionTransponder.WIP=Secondary Truck InspectionTransponder.WIP+1;
509$     STACK,      1:Save:NEXT(483$);

483$     QUEUE,      Secondary Truck InspectionTransponder.Queue;
482$     SEIZE,      2,VA:
              Secondary Truck Inspector,1:NEXT(481$);

481$     DELAY:      Triangular(5,15,60),,VA:NEXT(524$);

524$     ASSIGN:     Secondary Truck InspectionTransponder.WaitTime=
              Secondary Truck InspectionTransponder.WaitTime + Diff.WaitTime;
488$     TALLY:      Secondary Truck InspectionTransponder.WaitTimePerEntity,Diff.WaitTime,1;
490$     TALLY:      Secondary Truck InspectionTransponder.TotalTimePerEntity,Diff.StartTime,1;
514$     ASSIGN:     Secondary Truck InspectionTransponder.VATime=
              Secondary Truck InspectionTransponder.VATime + Diff.VATime;
515$     TALLY:      Secondary Truck InspectionTransponder.VATimePerEntity,Diff.VATime,1;
480$     RELEASE:    Secondary Truck Inspector,1;
529$     STACK,      1:Destroy:NEXT(528$);

528$     ASSIGN:     Secondary Truck InspectionTransponder.NumberOut=Secondary Truck InspectionTransponder.NumberOut
+ 1:
              Secondary Truck InspectionTransponder.WIP=Secondary Truck InspectionTransponder.WIP-1:NEXT(13$);
;
;   Model statements for module:  Dispose 29
;
13$      ASSIGN:     Dispose 29.NumberOut=Dispose 29.NumberOut + 1;
531$     DISPOSE:    Yes;
;
;   Model statements for module:  Process 52
;
9$       ASSIGN:     Primary Inspection 2 General Trucks.NumberIn=Primary Inspection 2 General Trucks.NumberIn + 1:
              Primary Inspection 2 General Trucks.WIP=Primary Inspection 2 General Trucks.WIP+1;
561$     STACK,      1:Save:NEXT(535$);

535$     QUEUE,      Primary Inspection 2 General Trucks.Queue;
534$     SEIZE,      2,VA:
              Primary 2,1:NEXT(533$);

533$     DELAY:      SecondsToBaseTime(CalcDelay),,VA:NEXT(576$);

576$     ASSIGN:     Primary Inspection 2 General Trucks.WaitTime=
              Primary Inspection 2 General Trucks.WaitTime + Diff.WaitTime;
540$     TALLY:      Primary Inspection 2 General Trucks.WaitTimePerEntity,Diff.WaitTime,1;
542$     TALLY:      Primary Inspection 2 General Trucks.TotalTimePerEntity,Diff.StartTime,1;
566$     ASSIGN:     Primary Inspection 2 General Trucks.VATime=Primary Inspection 2 General Trucks.VATime +
Diff.VATime;
567$     TALLY:      Primary Inspection 2 General Trucks.VATimePerEntity,Diff.VATime,1;
532$     RELEASE:    Primary 2,1;
581$     STACK,      1:Destroy:NEXT(580$);

580$     ASSIGN:     Primary Inspection 2 General Trucks.NumberOut=Primary Inspection 2 General Trucks.NumberOut + 1:
              Primary Inspection 2 General Trucks.WIP=Primary Inspection 2 General Trucks.WIP-1:NEXT(33$);

;
;   Model statements for module:  Assign 22
;
33$      ASSIGN:     TruckQueue2b=TruckQueue2b+1:NEXT(94$);
;
;   Model statements for module:  Assign 46
;
94$      ASSIGN:     TruckQueue2Num=TruckQueue2-TruckQueue2b-TruckQueue2c:NEXT(34$);
;
;   Model statements for module:  Record 8
;
34$      TALLY:      Exit Booth2 Count,TruckQueue2b,1:NEXT(25$);
;
;   Model statements for module:  Record 2
;
25$      TALLY:      TotTime2,INT(ArriveTime),1:NEXT(78$);
;
;   Model statements for module:  Decide 35
```

```
;
78$       BRANCH,     1:
                 If,DCBFViolation>0,583$,Yes:
                 Else,584$,Yes;
583$      ASSIGN:     Violation2 Count Decide.NumberOut True=Violation2 Count Decide.NumberOut True + 1:NEXT(79$);

584$      ASSIGN:     Violation2 Count Decide.NumberOut False=Violation2 Count Decide.NumberOut False + 1:NEXT(14$);
;
;   Model statements for module:  Record 27
;
79$       COUNT:      DCBFViloationPassed2,1:NEXT(14$);
;
;   Model statements for module:  Decide 27
;
14$       BRANCH,     1:
                 If,Secondary>0,585$,Yes:
                 Else,586$,Yes;
585$      ASSIGN:     Inspection Decision 2.NumberOut True=Inspection Decision 2.NumberOut True + 1:NEXT(87$);

586$      ASSIGN:     Inspection Decision 2.NumberOut False=Inspection Decision 2.NumberOut False + 1:NEXT(85$);
;
;   Model statements for module:  Decide 38
;
87$       BRANCH,     1:
                 If,DCBFViolation>0,587$,Yes:
                 Else,588$,Yes;
587$      ASSIGN:     Violation2 Count DecideSec.NumberOut True=Violation2 Count DecideSec.NumberOut True +
1:NEXT(88$);

588$      ASSIGN:     Violation2 Count DecideSec.NumberOut False=Violation2 Count DecideSec.NumberOut False +
1:NEXT(75$);
;
;   Model statements for module:  Record 32
;
88$       COUNT:      xDCBFViloationPassed2Sec,1:NEXT(75$);
;
;   Model statements for module:  Decide 34
;
75$       BRANCH,     1:
                 If,Secondary>5,589$,Yes:
                 Else,590$,Yes;
589$      ASSIGN:     Officer vs. DCBF Booth2.NumberOut True=Officer vs. DCBF Booth2.NumberOut True + 1:NEXT(76$);

590$      ASSIGN:     Officer vs. DCBF Booth2.NumberOut False=Officer vs. DCBF Booth2.NumberOut False + 1:NEXT(77$);
;
;   Model statements for module:  Record 24
;
76$       COUNT:      Officer2 Judgement Secondary,1:NEXT(11$);
;
;   Model statements for module:  Record 25
;
77$       COUNT:      DCBF2 Secondary,1:NEXT(11$);
;
;   Model statements for module:  Decide 37
;
85$       BRANCH,     1:
                 If,DCBFViolation>0,591$,Yes:
                 Else,592$,Yes;
591$      ASSIGN:     Violation2 Count DecideExit.NumberOut True=Violation2 Count DecideExit.NumberOut True +
1:NEXT(86$);

592$      ASSIGN:     Violation2 Count DecideExit.NumberOut False=Violation2 Count DecideExit.NumberOut False + 1
                 :NEXT(81$);
;
;   Model statements for module:  Record 31
;
86$       COUNT:      xDCBFViloationPassed2Exit,1:NEXT(81$);
;
;   Model statements for module:  Record 28
;
81$       COUNT:      Primary2 Exit Total,1:NEXT(10$);
;
```

```
;   Model statements for module:  Dispose 28
;
10$        ASSIGN:     Exit Border 2.NumberOut=Exit Border 2.NumberOut + 1;
593$       DISPOSE:    Yes;

;
;   Model statements for module:  Assign 42
;
69$        ASSIGN:     VCoef=.99:
                DriverOn=1:
                CargoOn=0:
                ESealOn=0:
                ScheduleOn=0:
                CalcDelay=
                (17+20+tria(AvgPrimaryServiceTime*0.7,AvgPrimaryServiceTime,AvgPrimaryServiceTime*2))-
(transponder)*(Driver*2)
                :NEXT(70$);

;
;   Model statements for module:  Assign 38
;
64$        ASSIGN:     VCoef=1.51:
                DriverOn=1:
                CargoOn=1:
                ESealOn=1:
                ScheduleOn=0:
                CalcDelay=
                (17+20+tria(AvgPrimaryServiceTime*0.7,AvgPrimaryServiceTime,AvgPrimaryServiceTime*2))-
(transponder)*((Driver*2)+(Cargo*3)+(HaveESeal*ESeal*3))
                :NEXT(70$);

;
;   Model statements for module:  Assign 39
;
66$        ASSIGN:     VCoef=1.99:
                DriverOn=1:
                CargoOn=1:
                ESealOn=1:
                ScheduleOn=1:
                CalcDelay=
                (17+20+tria(AvgPrimaryServiceTime*0.7,AvgPrimaryServiceTime,AvgPrimaryServiceTime*2))-
(transponder)*((Driver*2)+(Cargo*3)+(HaveESeal*ESeal*3)+(Schedule*2))
                :NEXT(70$);

;
;   Model statements for module:  Assign 41
;
68$        ASSIGN:     SecondaryRate=.10:
                Transponder=DISC(0.9,0,1.0,1):NEXT(63$);

;
;   Model statements for module:  Assign 8
;
16$        ASSIGN:     SecondaryRate=.05:
                Transponder=DISC(0.5,0,1.0,1):NEXT(63$);

;
;   Model statements for module:  Assign 35
;
60$        ASSIGN:     SecondaryRate=.02:
                Transponder=1:NEXT(63$);

;
;   Model statements for module:  Assign 30
;
48$        ASSIGN:     AvgPrimaryServiceTime=35.5:NEXT(53$);

;
;   Model statements for module:  Record 14
;
53$        COUNT:      Driver_Complete,1:NEXT(27$);

;
;   Model statements for module:  Assign 31
;
49$        ASSIGN:     AvgPrimaryServiceTime=11.2:NEXT(54$);

;
;   Model statements for module:  Record 15
;
54$        COUNT:      Empty,1:NEXT(27$);

;
```

```
;    Model statements for module:  Assign 32
;
50$        ASSIGN:     AvgPrimaryServiceTime=40.4:NEXT(55$);
;
;    Model statements for module:  Record 16
;
55$        COUNT:      Cargo_Inspection,1:NEXT(27$);
;
;    Model statements for module:  Assign 33
;
51$        ASSIGN:     AvgPrimaryServiceTime=43.9:NEXT(56$);
;
;    Model statements for module:  Record 17
;
56$        COUNT:      Cargo_Released,1:NEXT(27$);

;
;    Model statements for module:  Assign 34
;
52$        ASSIGN:     AvgPrimaryServiceTime=32.8:NEXT(57$);
;
;    Model statements for module:  Record 18
;
57$        COUNT:      Cargo_In_Transit,1:NEXT(27$);
```