Final Report

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

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Executive Summary

Introduction

In 1993, the North American Free Trade Agreement (NAFTA) committed the United States,. Canada and Mexico to facilitate movements of people and goods among the three member countries. In a subsequent agreement in February, 1995, Canada and the United States agreed to establish the Accord on Our Shared Border. The Accord commits both governments to promoting international trade by permitting commercial goods to flow easily between the two countries and to facilitating the movement of people by eliminating unnecessary impediments to cross-border travel. Several projects, including the North American Trade Automation Prototype (NATAP) program, have focused on developing improved technology for sensing, inspection, and communication that could reduce delays to commercial traffic (trucks and trains) crossing the U.S.-Mexican and U.S.-Canadian borders.

One of the NATAP pilot studies was conducted at the Peace Bridge, a major border crossing facility joining Buffalo, New York and Fort Erie, Ontario. The project at the Peace Bridge is often referred to as the Intelligent Transportation Border Crossing System (ITBCS) project, and that nomenclature is used extensively in this report. The ITBCS technology is a transponder (tag) based system. The transponders identify load-driver-vehicle combinations moving across the bridge and are intended to help expedite both customs and immigration processing.

The results presented here are derived from a study that focused heavily on simulation of operations at the Peace Bridge border crossing. Using simulation, we evaluated the impacts that might occur if the ITBCS technology were deployed permanently and on a pervasive basis. We also conducted an investigation of the institutional issues that arose during the pilot study and those that would have to be overcome to achieve permanent deployment.

The project report contains 10 chapters plus an appendix. Chapters 2-5 deal with the impact assessment for the facilities on the U.S. side of bridge while Chapters 6-8 examine the Canadian facilities. Chapter 9 addresses the institutional issues and findings. Chapter 10 presents a summary of the most important findings and conclusions from the study. The appendix presents details of the analysis of data recorded by the tag readers during the ITBCS prototype experiment.

Methodology

The simulation models focus on how trucks and automobiles are and would be processed through the various customs and toll activities. Since buses are a very small percentage of the total traffic, we did not model their operation. Performance indicators generated by the models include: overall time in system (from first arrival to final departure), processing time in primary and secondary inspection, the percentage of vehicles sent to secondary inspection, and the utilization of system resources, such as vehicle parking space in secondary inspection.

The U.S. and Canadian models were developed in a similar way. Site visits and interviews provided information about the processing logic and physical layout. Data collection across 1998 allowed development of all model parameters, especially the service time distributions for all major activities. Of special interest were processing times for primary and secondary inspection, as well as toll collection, broken down by appropriate vehicle classifications. The resulting model was checked for validity (processing logic) and then calibrated for operating conditions extant in 1997. Three days, June 26, August 19, and August 28, 1997 were used for analysis purposes because they typified moderate to heavy traffic conditions for both trucks and autos.

Following calibration and validation, adjustments were made to the models to create various ITBCS scenarios so the range of impacts that might result could be investigated. Trends among these scenarios were compared and contrasted to gain a sense of the impacts to be expected.

U.S. Operations Evaluation

Figure ES-l shows the facility layout, as it is represented in the simulation model. North is at the bottom of the diagram and East is at the left.

Vehicles coming from Canada enter at bottom right, as they depart the bridge. Trucks use the rightmost lanes and enter one of the three rightmost processing lanes, adjacent to the administrative offices. There they pay a toll (the first set of blocks) and pass through primary inspection (the second set of blocks). Autos use the remaining lanes up to the left-hand end of the inspection booths, near the middle of the diagram.

Autos sent to secondary inspection move to the parking area adjacent to the southern (topmost) end of the administrative building on the right. Trucks turn left into the secondary inspection area adjacent to the Customs Warehouse in the middle of the top portion of the picture. Once a vehicle has been cleared for entry, either from primary or secondary inspection, it either exits to I-190 via the ramp at the top right-hand comer of the picture, or threads its way through the truck parking area to Baird Drive, passing through the traffic signal at upper left in the picture. Vehicles leaving the U.S. arrive either on the exit ramp from I-190, which runs right-to-left along the top of the picture, or via Baird Drive, which is located in the upper left-hand comer. In both cases, the vehicles pass through the signalized intersection in the top left-hand portion of the diagram.

Vehicles are categorized based on customs processing and toll collection. For trucks, the customs categories *are Line Release, Monthly, In-Transit, Empty, ITBCS,* and *General* and the toll categories *are Electronic Toll Collection (ETC), Charge* and *Cash.* Data collected both through videotaping and on-site manual recording allowed us to estimate service time distributions for the various truck categories, both for toll collection and customs processing. Autos fall into three customs categories *(AutoPass, Designated Commuter Lane (DCL)* and *Other)* and three toll categories *(Electronic Toll Collection, Coin/Token and Cash).* Data collection for estimating auto processing times was done primarily through videotaping.

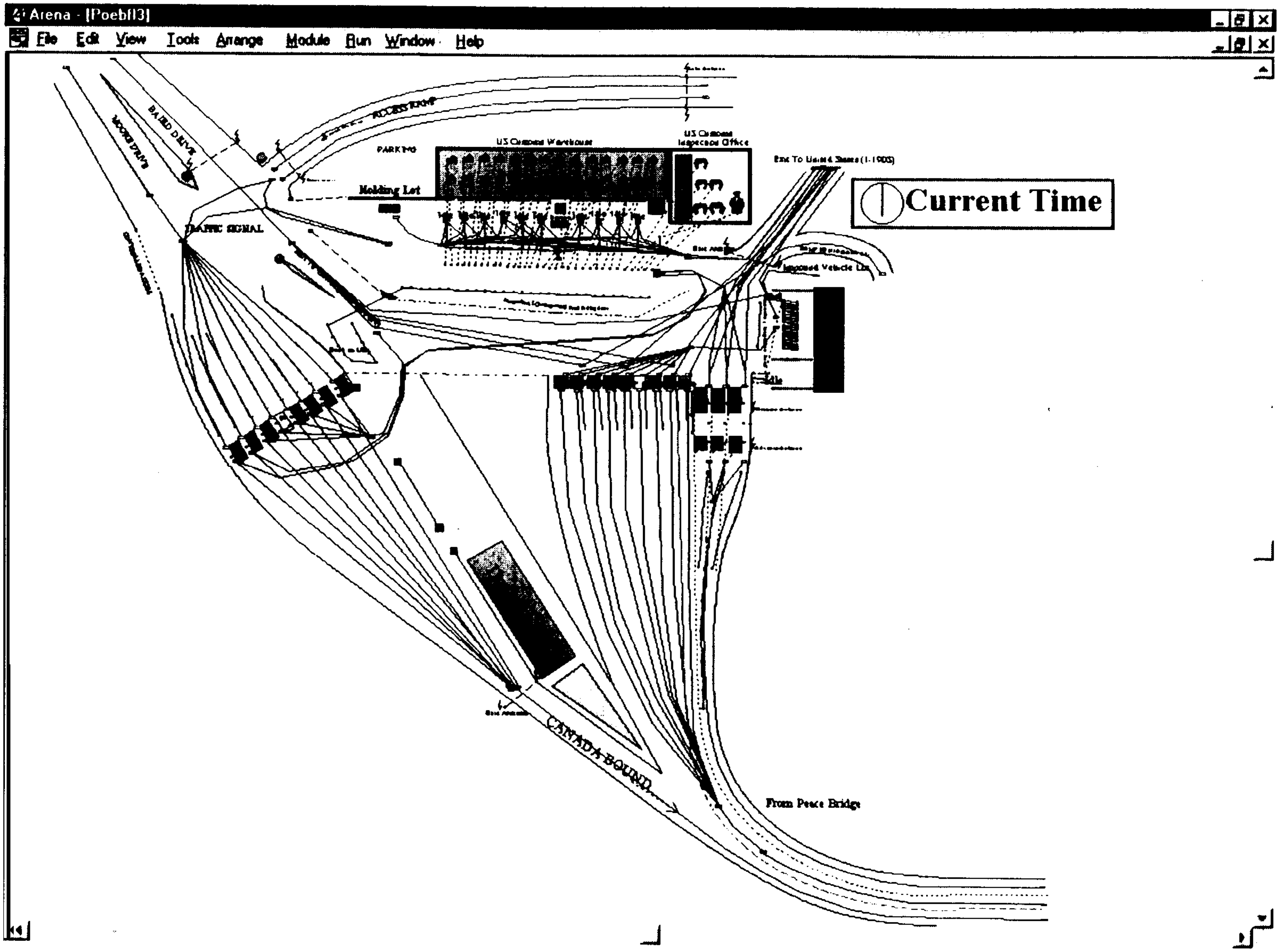

Figure ES-I. Model layout, U.S. side.

Two types of investigations were conducted with the U.S. side model. The first looks at impacts as a function of ITBCS performance, such as the reliability of the antennas (tag readers). The second looks at trends in impacts as a function of participation levels among cars and trucks.

The U.S. side performance investigation was based on making plausible, conservative assumptions to define “high” and “low” performance systems. The high performance system is assumed to have a faster turn-around time from the remote Customs computer. A 10% failure rate is assumed for the advance antenna and 1% for the decision antenna. These failure rates are quite high compared with typical installations, and produce conservative estimates of the impacts. It is assumed that the inspector takes 5-15 seconds to process the truck, that 2% of the trucks for which information is displayed (decision antenna worked) are sent to secondary inspection and 100% of those for which no information is displayed (decision antenna failed).

The results from these simulation experiments showed that the improvement from the base case to the low performance system is very substantial. The further improvement to the high performance system is smaller, but still notable, and is most significant for the 90th percentile measures (performance in the “tail” of the distribution). Thus, even under relatively high failure rates in the equipment, the ITBCS system has considerable potential to improve the level of service to both people and freight crossing from Canada into the U.S.

The second U.S. side investigation explored the impacts of different ITBCS penetration levels. Table ES- 1indicates the scenarios considered.

Table ES-l. U.S. side scenario definitions for entering traffic.

US-EASTBOUND

Scenario	Trucks	Autos
S1	0% ITBCS 1st & 2nd lanes in constant use, 3rd lane use depends on demand	20% AutoPass use 1 designated AutoPass lane 5 regular lanes
S21	20% ITBCS participation, proportionally drawn from all truck types; 1st & 2nd lanes, mixed use; 3rd lane, no ITBCS	35% ITBCS participation 1 designated ITBCS lane 5 regular lanes
S22	20% ITBCS participation, proportionally drawn from all truck types; 1st & 2nd lanes, mixed use; 3rd lane, no ITBCS	35% ITBCS participation 2 designated ITBCS lanes 5 regular lanes
S3 1 , S32	50% ITBCS participation, proportionally drawn from all truck types; 1st & 2nd lanes, mixed use; 3rd lane, no ITBCS	50% ITBCS participation 2 designated ITBCS lanes 5 regular lanes

Simulation experiments indicate that increased participation in the ITBCS program can have quite dramatic effects for trucks entering the U.S. From scenario S1 to S32 we see a 66% decrease in the average time, and a 78% decrease in the 90th percentile time.

In part, this is due to major changes in secondary inspection. The number of trucks sent to secondary inspection drops 64%, and the times in secondary inspection fall similarly. The average time in secondary drops 34%, and the 90th percentile time drops 31%.

Primary processing times also fall dramatically. The average time in primary inspection drops 64%, from 225 seconds to 81, and the 90th percentile time falls 68%, from 407 seconds to 129.

The change in system performance for eastbound autos is also dramatic, as summarized in Table ES-2. From Scenario S1 to S32, average time in system drops 35%, from 166 seconds to 108. The 90th percentile time drops even more, 48% from 295 seconds to 155. Again, the ITBCS technology produces significant benefits. Moreover, there are significant differences between S21 and S22. In S21, there is one designated ITBCS lane, while in S22 there are two. That extra lane produces a 21% drop in average time in system, and a 28% decline in the 90th percentile time in system. Considering that this benefit accrues to all system users, primarily due to a decrease in time in queue waiting to reach primary inspection, the benefits should be carefully weighed against the costs of providing the second ITBCS booth.

Table ES-2. Eastbound Auto Time in System

Scenario	Avg	90%
S1	166	295
S21	152	263
S22	120	190
S31	108	155
S32	108	155

Canadian Operations Evaluation

The Canadian side investigation focuses on impact trends due to participation rates among both autos and cars. Trucks and autos are classified on the basis of their treatment by Canadian Customs. For trucks, there are three categories, Y-28, *ITBCS,* and *ROL.* For autos, there are two, *ITBCS* and *Regular.* Y-28 is the designation for trucks sent to secondary inspection by the primary inspector. The ROL category is for all trucks released on-line at primary inspection under existing conditions. ITBCS is for the ITBCS participants. For autos, all vehicles currently fall under the Regular category. ITBCS is for the ITBCS participants.

To explore the trends in impacts, a range of scenarios is explored, from existing conditions to high penetration and deployment. Table ES-3 summarizes the scenarios.

Table ES-3. Canadian side scenario definitions.

CAN-WESTBOUND

Scenario	Trucks	Autos
S11	28% Y-28 72% Others 3 mixed use lanes	0% ITBCS participation 3 regular lanes 1 mixed use lane with ITBCS
S12	28% Y-28 72% Others 3 mixed use lanes	20% ITBCS participation 3 regular lanes 1mixed use lane with ITBCS
S2	20% ITBCS participation, proportionally drawn from both truck types 3 mixed use lanes	35% ITBCS participation 3 regular lanes 1 mixed use lane with ITBCS
S31	50% ITBCS participation, proportionally drawn from both truck types 3 mixed use booths	50% ITBCS participation 3 regular lanes 1designated ITBCS lane
S32	50% ITBCS participation, proportionally drawn from both truck types 3 mixed use booths	50% ITBCS participation 3 regular lanes 2 designated ITBCS lanes

For trucks, scenarios S 11 and S 12 are identical, and the same pertains to S3 1 and S32, so we can focus on them as single scenarios. From scenarios S1 l/S12 to S3 l/S32 we see a 40% decrease in the average time and a 34% reduction in the 90th percentile. In part, this can be traced to a reduction in the number of trucks sent to secondary inspection. This number shrinks from about 100 in Scenario Sl l/S12 to about 50 in S3 l/S32, a 50% reduction. Primary processing times also fall substantially. The average time in primary inspection drops 14%, from 199 seconds to 173, and the 90th percentile time falls 15%, from 253 to 214.

For westbound autos, the principal findings relate to the required capacity to handle the ITBCS traffic. At 35% participation (Scenario S2), it is effective to dedicate on elane to ITBCS traffic, rather than leaving it as a mixed-use lane. At 50% participation (Scenarios S31 and S32), it is important to have the second dedicated lane (Scenario S32). With only one dedicated lane, there is insufficient capacity to handle the ITBCS traffic stream, and very large delays result.

Institutional Issues

Implementation of advanced information technology at a border crossing presents many institutional challenges as well as technical ones. A border crossing is a complex institutional environment because there are many different agencies from both countries that have significant stakes in the operations. These agencies have different fundamental missions, different internal cultures, and varying viewpoints on any substantial change in operational procedures at the border. Chapter 9 of this report explores the institutional experience from the ITBCS project at the Peace Bridge in an effort to identify important issues that need to be addressed to create successful implementations of similar information systems in the future.

This component of the evaluation effort was largely accomplished through interviews with representatives of many of the organizations-government agencies in Canada and the United States and private and quasi-public organizations-with a stake in the Peace Bridge test. Such interviews required participants to describe their experiences during the test and to share their observations about and evaluation of the institutional environment during the test. While distinctly subjective in nature, when conducted well and with a diverse group of cooperative informants, interviews can provide a rich and surprisingly accurate picture of organizational life. Seventeen interviews were conducted for this study, ranging in length from one to two hours. In addition, interview data was augmented with documentary information associated with the Peace Bridge test and from evaluations of similar technology in other locations.

An important observation from the interviews concerns the viability of the actual test conducted at the Peace Bridge. Put simply, was the test a true proof of concept of the ITBCS system? Our impression after conducting our formal interviews and participating in numerous casual discussions with people connected to the Peace Bridge project is that it probably was not. While the test did generate some flow data; confirmed that some of the hardware, software, database and communication components can work as anticipated; and uncovered a number of potential institutional barriers to the use of these systems; it did not generate the volume or types of data that were anticipated. Indeed, several of our interviewees expressed the opinion that the test was not successful precisely because such data expectations were not met.

Why did this happen? The data we have, and our instincts, suggest that institutional disconnects led to faulty prototype design and the lack of a true climate for evaluation.

First. the ITBCS test at the Peace Bridge was conducted in a very complex institutional environment. In such an environment, it is likely that an action taken to optimize performance against one institutional mission will come into conflict with or sub-optimize another's mission. There is compelling evidence that- this mission conflict existed during the Peace Bridge test. When it did so, it was not generally caused by "bad" people pursuing unfair advantage or unrealistic ends. Instead, it resulted from dedicated institutional representatives trying to live up to their job requirements. To oversimplify, it could be said that the ITBCS test was conducted without a clearly defined overall vision or "common need" for the technology that was accepted by all participants.

There is some evidence that frustrations also occurred during the Peace Bridge ITBCS test because some stakeholders insisted upon using rigorous operational standards in a test environment. For example, the requirement to handle customs clearance procedures using both the new automated system and the old paper system may have been a disincentive for commercial carriers and customs brokers to participate in the ITBCS test. It may also have impacted the attitudes and ultimately the behavior of those participating in the test in ways that distorted test results.

Another manifestation of this issue may have occurred during the system definition phase leading up to the design of the Peace Bridge installation. As we understand it, the accuracy requirements put forth by U.S. Customs were extremely rigorous. In response, some technical personnel questioned whether any system could perform to such standards. Others asked whether the current system operated at the specified level of accuracy. The real issue, however, is whether operational "aspirations" should be used as a non-negotiable baseline to determine the feasibility of a new concept.

A theme that appeared throughout the interviews relates to data security. For a completely integrated border crossing system to be developed, the agencies have to agree on the creation of a comprehensive database that can be interrogated to support all regulatory requirements. The experience of the Peace Bridge ITBCS test, however, suggests that regulatory agencies are reluctant to cede control of their database out of concern for data integrity. At issue are such things as who maintains a database, who can access it, where is it located and, ultimately, questions of sovereignty and national security. It is obvious that this issue needs significant attention.

Many of the government agencies that participated in the Peace Bridge ITBCS test exist to regulate or oversee something. They were created, when all is said and done, to enforce legally defined standards. Day to day work in such organizations involves overseeing or policing some activity or product to assure that the right things are being done and, most importantly, that the wrong things are not being done.

One of the strongest themes in our interviews is that a regulatory culture can be a significant barrier to the smooth implementation of ITBCS technology. Expediting flow is not a central concern to those with a regulatory mission. Enforcement, often accomplished through face-to-face interaction with individuals and/or through direct inspection of documents, vehicles, products, etc. is at the traditional core of regulatory work. Certain regulatory agencies (especially the U.S. Customs Service) involved in the Peace Bridge ITBCS test appear, in our interviews, to be so captured by this enforcement world view that they have had a difficult time honoring seamless flow across the border as an objective that is important.

If the changing geo-political environment means that national borders will have a new meaning, then those who work at the border will have different jobs. The need for regulation will not go away, but it will be manifest differently. Introducing ITBCS systems to facilitate flow and cross-border transactions is less a technical issue, than it is an issue of work redesign. It must be handled as such, and cultural change is at the core of that enterprise.

Conclusion

In conclusion, it appears that the introduction of ITBCS technology can have a major impact on productivity at the Peace Bridge. Reductions in time in system ranging up to 50% seem possible even if the technological standards for the system are not made extremely high. Benefits are more substantial for the inbound than for the outbound flows because of the customs processing, and the U.S. side of the bridge stands to benefit more than the Canadian side because of operational efficiencies already introduced in Canada.

To achieve these impacts, however, a significant institutional hurdle must be overcome. It is apparent that inter-agency collaboration and cooperation is needed, and that the facilitation of flow needs to become a more central objective. If regulatory policing continues to be a dominant theme. then expeditious processing is likely to remain a significant challenge. Careful scrutiny of participants, ex-post-facto compliance inspections, and a broader definition of the border to include point of loading to point of delivery, may help disconnect the conflicts in goals that seem to have dampened the success actually achieved during the experiment.

It is clear the technology is available, and that if applied, it can produce significant beneficial impacts. The challenge for the future is to make it possible for those benefits to accrue.

CHAPTER 1

Introduction

Information Technology is revolutionizing the transportation industry. Levels of instrumentation and telecommunication that exist today were only fantasies a decade ago. Video detectors and other wayside sensors make it possible to see vehicle flows in real time. Vehicle tags let us monitor travel times, automate toll collection activities and expedite vehicle processing. Fiber optic networks and other high bandwidth technologies make it possible to pass large amounts of data from one place to another. At border crossings, in particular, greater use of information technology offers the promise of allowing us to expedite flows while at the same time increasing regulatory compliance (e.g., customs and immigration).

In 1993, the North American Free Trade Agreement (NAFTA) committed the United States, Canada and Mexico to facilitate movements of people and goods among the three member countries. In a subsequent agreement in February, 1995, Canada and the United States agreed to establish the Accord on Our Shared Border. The Accord commits both governments to promoting international trade by permitting commercial goods to flow easily between the two countries and to facilitating the movement of people by eliminating unnecessary impediments to cross-border travel. The strategy adopted in the Accord includes the following major elements (Accord on Our Shared Border, Executive Summary, 1996):

- streamline commercial and traveler procedures to make them friendlier and faster
- use freed-up resources to improve service and concentrate enforcement efforts on high-risk areas
- eliminate archaic paper-based processes that add little or no value
- use technology as a strategic tool
- rethink the way we do business to do it better and at less cost.

Several projects, including the North American Trade Automation Prototype (NATAP) program and the Advanced Technology for International and Intermodal Ports of Entry (ATIPE) project, have focused on developing improved technology for sensing, inspection, and communication that could reduce delays to commercial traffic (trucks and trains) crossing the U.S.-Mexican and U.S.-Canadian borders. One of the NATAP pilot studies was conducted at the Peace Bridge, a major border crossing facility joining Buffalo, New York and Fort Erie, Ontario. The project at the Peace Bridge is often referred to as the Intelligent Transportation Border Crossing System (ITBCS) project, and that nomenclature is used extensively in this report.

This report is an evaluation of the ITBCS experiment conducted at the Peace Bridge, but it also focuses on assessing the potential impacts of broader implementation of information technology investments at the Peace Bridge. The ITBCS project at the Peace Bridge involved a very small number of shippers and trucks, and the operational procedures used in the pilot project make it essentially impossible to extrapolate the experience to broader implementation. Thus, we have relied extensively on simulation modeling to assess the potential impacts of the technology.

Simulation models provide a way to estimate how large the impacts will be from introducing information system elements. Simulation models can be changed so that they behave as though the technology had been introduced. Analysts can see how the system's performance would improve. The effects of new options can be compared and contrasted to see which one is best. Thus, the value of these new devices can be explored without actually installing the equipment in the field.

The simulation models of the Peace Bridge discussed here focus on how trucks and automobiles are processed through the various customs and toll activities that take place on both sides of the bridge. Part II of this report (Chapters 2-5) focuses on the U.S. side while Part III (Chapters 6-8) considers the Canadian side. Part IV (Chapter 9) explores the institutional issues associated with conducting tests of such systems, and ultimately deploying them. Part V (Chapter 10) draws conclusions from all of these analyses and points to unanswered questions that need further study.

Within Part II, Chapter 2 describes the simulation model developed to assess the information technology impacts on the U.S. side of the bridge. Built using the simulation language ARENA (Systems Modeling Corp., 1996), the model is configured so that a variety of "scenarios" can be explored. We can explore different penetration rates and configuration options so that the impacts on the facility's operation can be understood. Chapter 3 describes the development of the input parameters for the simulation model and how the model was calibrated and validated. Chapter 4 describes a set of experiments to test the effects of various levels of performance in the automated system for processing incoming trucks. Chapter 5 then presents a series of scenario analyses to illustrate the effects of different levels of penetration for the technology in the population of trucks and automobiles entering the U.S.

Part III has a structure that roughly parallels that of Part II. Chapter 6 presents the ARENA model for the Canadian side of the bridge and Chapter 7 discusses the input parameter development, calibration and validation. Chapter 8 presents scenario analyses for the Canadian side.

This study is a follow-on to prior work that produced both a first-generation model of a border crossing facility (see Nozick, List, and Turnquist, 1996) and a generic model of a northern U.S. border crossing facility (see List, Nozick, Tumquist, and Wu, 1997). The model presented here extends and enhances those prior efforts by adding more realism to the modeling environment, especially the treatment of how information is handled and the effect that different handling strategies have on system performance.

Implementation of advanced information technology at a border crossing presents many institutional challenges as well as technical ones. A border crossing is a complex institutional environment because there are many different agencies from both countries that have significant stakes in the operations. These agencies have different fundamental missions, different internal cultures, and varying viewpoints on any substantial change in operational procedures at the border. Chapter 9 of this report explores the institutional experience from the ITBCS project at the Peace Bridge in an effort to identify important issues that need to be addressed to create successful implementations of similar information systems in the future.

CHAPTER 2

Modeling Peace Bridge Operations in the U.S.

The simulation model for the U.S. side of the Peace Bridge represents the processing of trucks and automobiles both entering and leaving the U.S. This chapter describes the processing logic involved and the simulation software environment in which the model has been built.

The logic described here has been implemented in ARENA, a commercially available simulation modeling environment (Systems Modeling Corp., 1996). ARENA provides an attractive way to define the vehicle types, the processing steps involved, the logic that governs processing, and the resource requirements involved. It also provides animation capability and automated statistics collection. The animation allows a user to watch the simulation run in progress, and the automated statistics collection allows convenient summarization of important model outputs.

2.1 Facility Layout

Figure 2-l presents a picture of the facility layout, as it is represented in the simulation model. North is at the bottom of the diagram and East is at the left.

Vehicles coming from Canada enter the facility at bottom right, as they depart the bridge. Trucks use the right lanes of the exit ramp and enter one of the three right-most processing lanes, adjacent to the administrative offices. There they pay a toll (the first set of blocks) and pass through primary inspection (the second set of blocks). Autos use the remaining lanes up to the left-hand end of the inspection booths, near the middle of the diagram. Autos sent to secondary inspection move to the parking area adjacent to the southern (topmost) end of the administrative building on the right. Trucks turn left into the secondary inspection area adjacent to the Customs Warehouse in the middle of the top portion of the picture. Once a vehicle has been cleared for entry, either from primary or secondary inspection, it either exits to I-190 via the ramp at the top right-hand comer of the picture, or threads its way through the truck parking area to Baird Drive, passing through the traffic signal at upper left in the picture.

Vehicles leaving the U.S. arrive either on the exit ramp from I-190, which runs right-to-left along the top edge of the picture, or via Baird Drive, which is located in the upper left-hand comer. In both cases, the vehicles pass through the signalized intersection in the top left-hand portion of the diagram. The signal controls three approaches: 1) the I-l 90 ramp, 2) Baird Drive northbound (the traffic enters the intersection moving top to bottom), and 3) the exit lanes from the secondary inspection area adjacent to the Customs Warehouse. Occasionally, inspections are conducted by customs officials in the small pullout on the left-hand side of the intersection. All exiting vehicles pass through the toll booths and then onto the bridge.

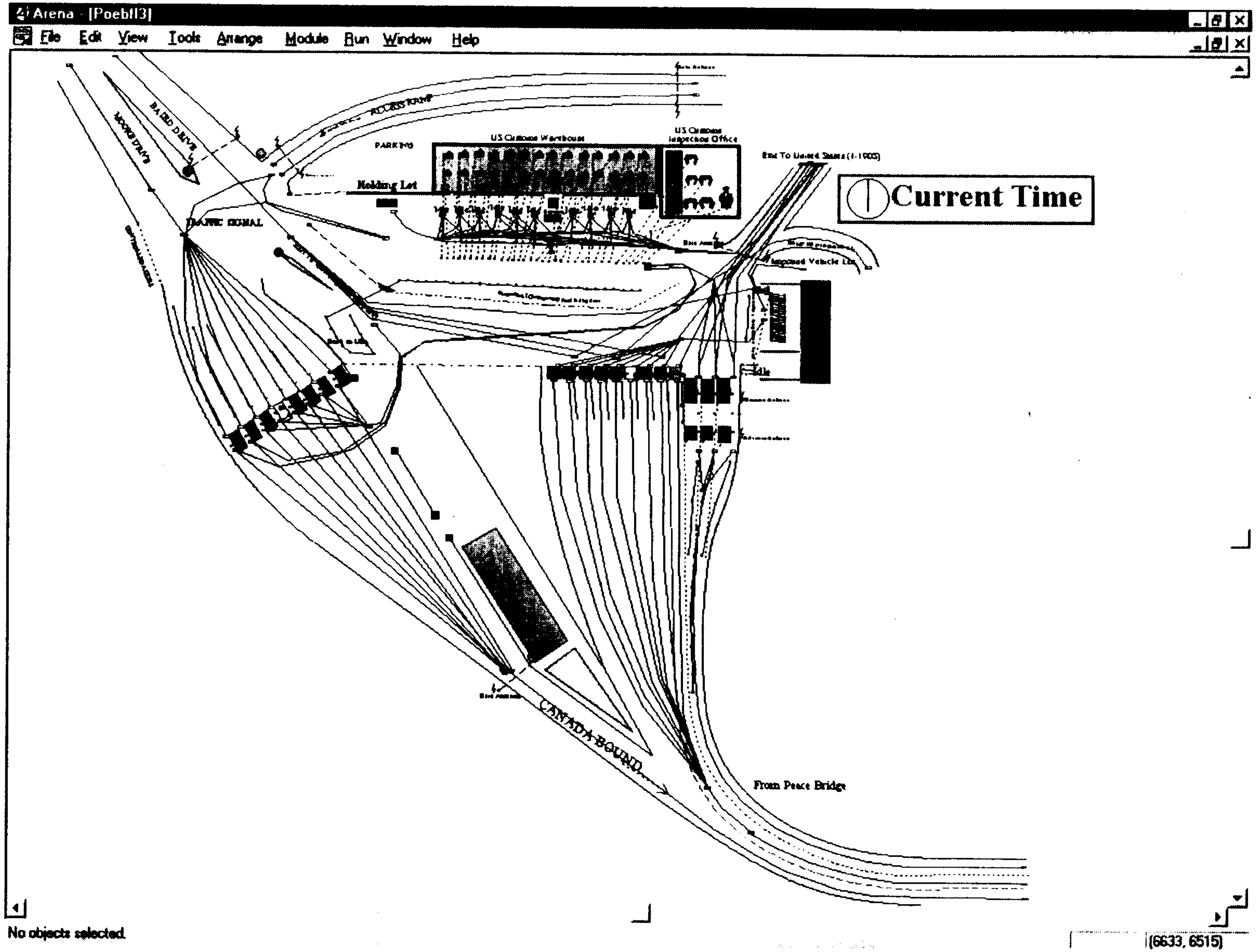

Figure 2-1. Pictorial View of the U.S.-side Peace Bridge Model

2.2 Vehicle Types

Both trucks and autos are included in the model. Buses are a minor portion of the total traffic and have not been included. For the trucks, designations are made of type *(Monthly, In-Transit, C4, ITBCS, Empty, and General)* and toll payment *(ETC, Charge and Cash).* Autos are divided into three toll categories *(ETC, coin/token and cash).* For each of these categories, the model uses a set of specified attributes:

- percentage of vehicles in each category;
- toll collection time probability distribution;
- primary inspection time probability distribution;
- secondary processing time probability distributions; and
- likelihood of being referred to secondary inspection.

For trucks, the six categories are defined as follows:

1. *Monthly:* Monthly trucks are pre-cleared for entry into the U.S. All the parties involved - shippers, consignees, commodities, trucks and drivers - are well known, and customs has determined that a monthly resolution of the customs paperwork is sufficient to ensure compliance with regulations. Random secondary inspections occur but they are rare. In general, these trucks carry automobiles or parts for the major auto manufacturers who operate in both Canada and the U.S.
2. *In-Transit:* In-transit trucks are passing through one or both countries. For example, the truck might have passed through Canada carrying goods from Detroit to Buffalo, or have been loaded in Canada and be destined for a point in Europe. Trips like Asia to Europe via the U.S. and Canada are also possible. Except for spot checks, these trucks are rarely sent to secondary inspection.
3. *Line Release(C4):* C4 trucks are part of an expedited clearance program. In most cases, they are released directly by the primary inspectors as long as their paperwork is in order. Occasionally these trucks are sent to secondary inspection.
4. *ITBCS:* ITBCS trucks are those that will be given an information technology upgrade so that the customs and toll collection processing can be expedited. These trucks will be the main focal point of the impact assessment.
5. *Empty:* Empty trucks typically see just inspections related to the driver and the truck.
6. *General:* Trucks in the general category do not fit any of the five categories above. Either the parties involved are not participating in a pre-clearance program or the shipment is one that occurs infrequently. These trucks have the longest overall processing times and the greatest likelihood of being sent to secondary inspection.

The Line Release (C4) program is an expedited procedure that is available from U.S. Customs and is intended for high volume, low risk repetitive shipments. To participate in the program, the shipper must have a history of error free documentation, and not present an enforcement risk. At primary inspection, the inspector scans a Line Release code and checks that it matches the invoice data in the Customs system. If it does match, the inspector enters the quantity of the item, an entry number is generated and the duty is calculated. The record of this transaction will be communicated to the customs broker the next day. Thus, this program provides an effective way of expediting border crossings. Line Release shipments are not inspected nearly as frequently as regular shipments. However, they are subject to secondary inspection on a random basis.

Autos entering the U.S. fall into one of three categories based on their treatment by Customs. No toll is collected for autos entering the U.S.:

1. *AutoPass*. AutoPass holders are people have been pre-cleared for entry into the U.S. and identify themselves by presenting a special card. Predominantly, they are people who live in Canada but work in the U.S. (or vice versa), and who cross the border regularly at the same point. There is currently a special lane established for cars carrying only AutoPass users.
2. *Regular*. Currently, this category captures all other autos. The occupants of the car must be cleared by Customs Inspectors in the regular auto lanes before entering the U.S.
3. *DCL (designated commuter lane)*. Eventually intended to replace AutoPass, the DCL will allow electronic processing of a pre-registered automobile and up to four occupants. The simulation model provides a capability to investigate the effects on the overall system of various potential levels of use in a DCL.

Cars and trucks leaving the U.S. must pay a toll to cross the bridge, but generally they do not have any Customs inspection (unless a special enforcement action is underway, which is not currently modeled). Both cars and trucks are divided into three categories depending on how they pay their toll. For trucks, the categories are: electronic toll collection (ETC), ChargeCard, and cash. Trucks in the ETC category have a tag that is read electronically to collect the toll. Those in the Charge&-d category swipe a card through a card reader to pay their toll. The processing time for the ETC-equipped trucks is the shortest, followed closely by ChargeCard and then, significantly longer, cash.

For exiting autos, the three categories are: ETC, coin/token, and cash. Paying with coins (exact change) is technically different from using a token, but the processing times are effectively identical. The third category is cash (with change given). ETC has the shortest processing time, followed by coin/token, and then cash.

2.3 Vehicle Processing

The model contains processing logic for trucks and cars moving eastbound (into the U.S.) and westbound (exiting the U.S.). The times for the various activities are represented in the model by probability distributions. For example, the model specifies a time between successive truck arrivals. As the simulation runs, inter-arrival times are sampled from a specified probability distribution. The process of specifying these various distributions, and estimating their parameters, is a vital part of building a successful simulation. This process is discussed in detail in Chapter 3.

2.3.1 Inbound Trucks Figure 2-2 presents a macro-scale representation of the processing logic for vehicles moving eastbound, entering the U.S. from Canada. The "CREATE" block is for the arrival of trucks and cars as they leave the bridge. For trucks, the model assigns a toll category (i.e., ETC, Charge, or Cash) and a truck class (i.e., Monthly, C4, Empty, etc.). These randomized designations simulate the co-mingled traffic actually found in the arriving traffic stream.

After type designation, all trucks enter the U.S. Point of Entry (POE) and choose a lane (toll booth and primary Customs inspection). Two booths are always open and a third is opened when traffic is heavy. This leads to match point A in the diagram.

Beyond match point A, the trucks experience a service time and delay passing toll collection, and enter a primary inspection booth queue. If the primary inspector determines that all entry documents are in order, the vehicle is given clearance to enter the U.S., otherwise it is referred to the warehouse, or secondary inspection area (match point B).

If a secondary inspection is stipulated, the truck moves to the parking lot adjacent to the Customs warehouse. Each truck that enters secondary inspection follows the same logic and uses the same service time distributions. There is no differentiation by truck type. The first stop in this procedure is the warehouse parking lot. The driver parks the truck and then goes to find the broker who can help him/her complete the paperwork for the load. After the broker is finished, the driver delivers the paperwork to the reception counter in the Customs office and waits for his/her name to be called. Inside the Customs office, inspectors work on the manifests by checking them and running a selectivity program to determine whether a cargo inspection should be conducted or not. (The number of inspectors assigned to secondary inspection varies during the day in response to the rise and fall in demand.) If no cargo inspection is desired, and the paperwork is complete, the driver is released and the truck leaves the facility. If a cargo inspection is required, the driver then moves the truck to an empty bay at the Customs warehouse. Meanwhile, the Customs inspector deals with other tasks like reviewing the paperwork for other trucks. When the truck is ready for inspection, the same Customs inspector who originally reviewed the paperwork for the load must conduct the inspection. Shipments that fail the cargo inspection are then impounded until the problems identified are rectified.

2.3.2 Inbound Cars Figure 2-2 also shows the processing logic for inbound automobile traffic. After a vehicle is "Created" an "Immigration Type" is assigned. The base case choices are AutoPass or Regular. (The impact assessment scenarios include DCL). This type assignment determines which lanes are available to the vehicle, and the lane choice leads to match point A'.

Eastbound cars pay no toll, so lane choice leads directly to primary Customs inspection. Since secondary immigration processing is not a major focal point, the model simply imposes a service time for primary inspection, and then clears the automobile (and its occupants) for entry. The vehicle then departs from the system.

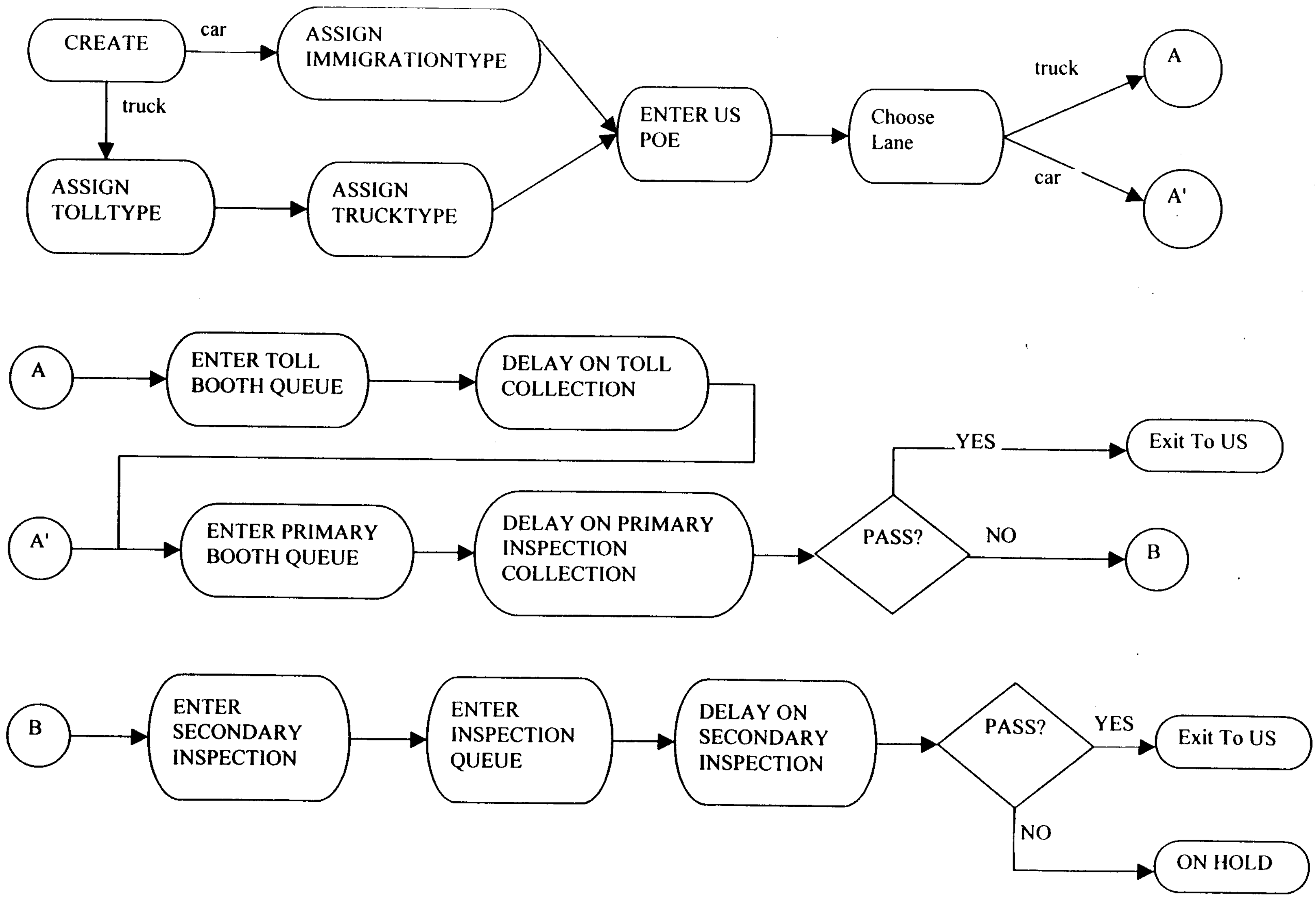

Figure 2-2. U.S. bound flow logic

2.3.3 Outbound Trucks Figure 2-3 presents an overview of the processing logic for vehicles (both trucks and autos) moving westbound, leaving the U.S. Trucks are generated in the "CREATE" block and assigned a toll payment category (ETC, ChargeCard or Cash) and an entry point (I-190 or Moore Drive). They proceed onward to the Traffic light where they must wait for a green light before proceeding to the common point “A” in the upper right-hand comer of the diagram. They choose a toll lane, pay their toll, and are prepared to exit to Canada. The model contains logic to allow exit signals (and potential secondary cargo inspections) for ITBCS-equipped trucks, but this logic is currently not in use.

2.3.4 Outbound Cars Cars are “created” and assigned an arrival direction (I-l 90 or Moore Drive) and a toll payment category (ETC, Coin/Token, or Cash). They must pass through the traffic signal, and then choose a toll lane. After a delay for queuing and toll payment, they are cleared to proceed to Canada.

2.4 Resources

Resources represented in the model are as follows:

- *Human resources:* This category includes people filling several different roles:

    1. *Toll collectors:* Each toll booth has a toll collector. The number of toll collectors used (and hence the number of toll booths open) depends on the level of traffic.
    2. *Brokers:* Brokers handle the paperwork associated with imports and exports. At the Peace Bridge these people principally solve problems for the shipments whose paperwork is incomplete.
    3. *Customs inspectors:* Customs inspectors check the vehicles, drivers, and cargo. They can be assigned either to primary or secondary inspection.

- *Facility resources:* These resources include the weigh stations, the toll booths, the primary inspection booths, and the parking lot and inspection bays in secondary inspection.

Availability of these resources determines the capacity of the system, and delays that will ensue for various levels of traffic. Use of these resources is a critical element of performance assessment.

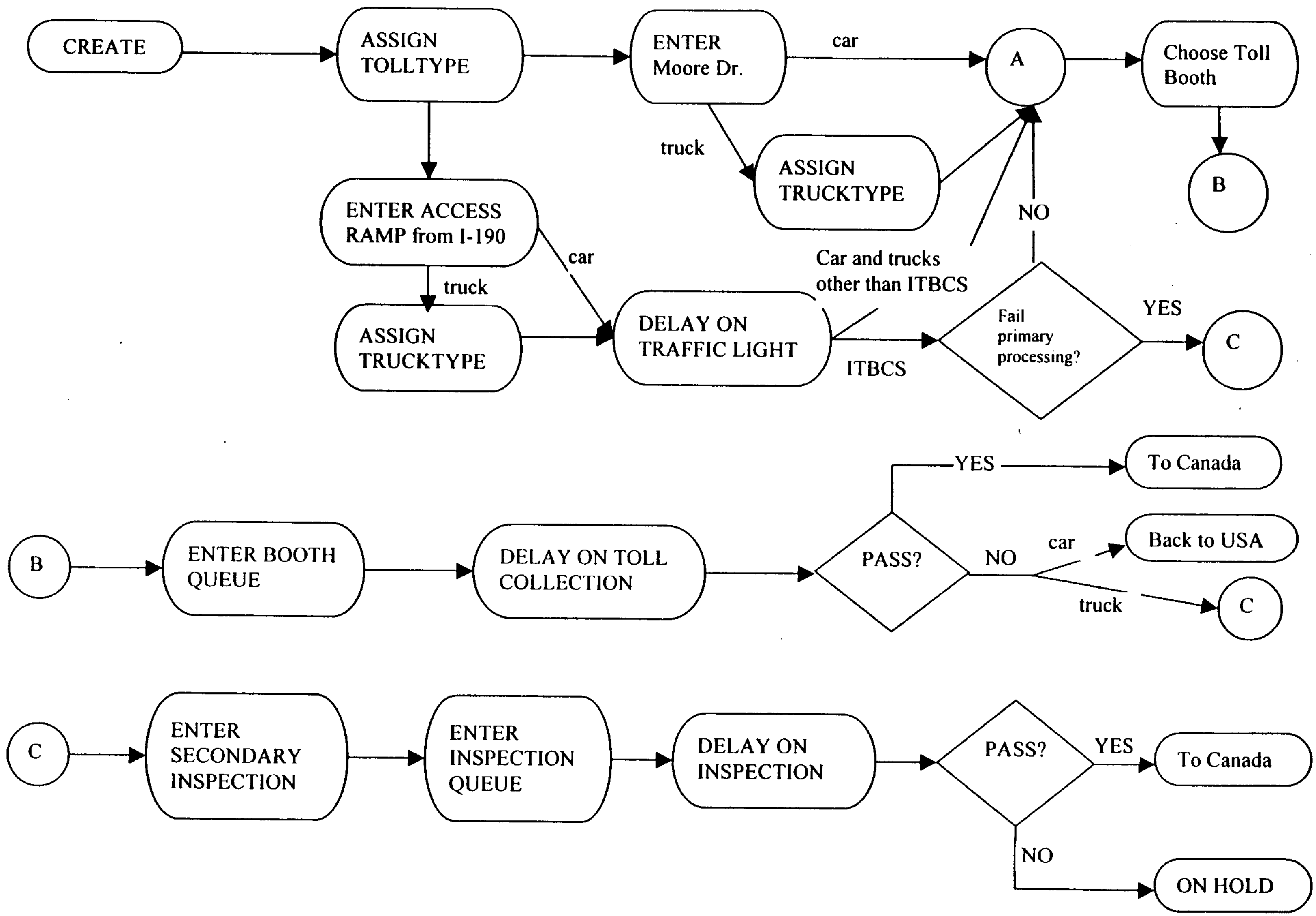

Figure 2-3. Canada bound flow logic

2.5 Impact Assessment

Four main performance measures are used in the model to evaluate the effectiveness of introducing advanced information technology. They are:

- the time required for a vehicle to go through the entire crossing process (time in system), in aggregate, and disaggregated 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 Customs inspectors.

These measures provide considerable insight into the system's performance.

A collection of scenarios is used to explore the impacts of introducing advanced information technology. These are described in Chapter 4. Market penetration rates are a major element, both in total and by category. This affects primary inspection processing times, toll payment times, and the likelihood that vehicles (trucks especially) will be sent to secondary inspection.

CHAPTER 3

Calibration and Validation of the U.S. Model

The simulation model described in Chapter 2 requires estimates for many different parameters. We have developed estimates of these parameters from empirical data collected in several different ways. Some of the data were collected by videotaping operations on the U.S. side of the Bridge. Other data were obtained from toll records maintained by the Bridge Authority. Some detailed data were recorded directly by Customs inspectors, and some information was obtained through on-site data collection by project staff. The combination of data sources has allowed us to estimate parameters for the following major elements of the model:

Trucks

1. Truck interarrival time distribution
2. Distribution of time required for primary inspection of trucks entering the U.S.
3. Proportions of trucks in each traffic category
4. Probability of referral to the warehouse (secondary area)
5. Truck delay times in the secondary area
6. Truck toll service times (entering or exiting the U.S.)

Cars

1. Car interarrival time distribution
2. Car toll service times (exiting the U.S.)
3. Distribution of time required for immigration inspection for cars entering the U.S.

The following sections describe the analysis for each of these sets of parameters, and then the validation tests conducted to determine that the resulting model accurately portrays the real system.

3.1 Truck Interarrival Time Distribution

The key question with respect to truck arrivals is whether it is appropriate to assume that trucks arrive at the bridge as a Poisson process. There is considerable evidence that the average arrival rate is not constant throughout the day – there is a clear diurnal pattern in the number of total hourly arrivals, for example. However, if the arrival process within a small time period (say one hour) can be reasonably modeled as a Poisson process, the simulation of interarrival times becomes very straightforward.

This question reduces to one of testing whether or not the probability distribution of time between successive truck arrivals can be represented as an exponential distribution. The probability density function for an exponential distribution is as follows:

$$f(x) = \lambda e^{-\lambda x} \quad for\ x \geq 0, \quad \lambda > 0$$

This distribution has a single parameter, λ, and the mean value is 1/λ.

There are three different truck arrival processes of interest on the U.S. side of the Peace Bridge. Trucks entering the U.S. arrive across the bridge from Canada. Trucks leaving the U.S. must be weighed and pay a toll before crossing the bridge, and these exiting trucks arrive from two different directions: I-190 and Moore Drive. The number of trucks arriving from Moore Drive is quite small (about 5% of exiting trucks), and it is difficult to see these arrivals on videotape from the available taping locations, so we have focused primarily on the westbound (exiting the U.S.) arrivals from I-190, and the eastbound (entering the U.S.) arrivals across the bridge.

3.1.1 Trucks Exiting the U.S. The data from a typical hour of videotape for arrivals from I-190 is graphed in Figure 3-1. Figure 3-2 shows potential fits of exponential, gamma, and Weibull distributions to the data. The gamma and Weibull distributions are different generalizations of the exponential distribution. By testing the fit of the data to each of these generalizations, we gain more information than we would if we just tested the exponential distribution alone.

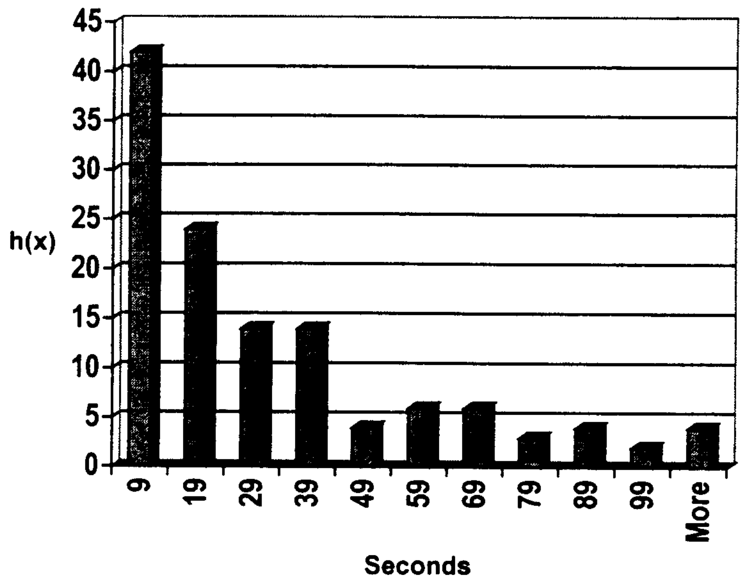

Figure 3-1. Histogram of interarrival times on the I-190 Ramp

The probability density functions for the gamma and Weibull distributions are as follows:

Gamma: $$f(x) = \frac{1}{\Gamma(\alpha)} \lambda^{\alpha} x^{\alpha-1} e^{-\lambda x} \quad for\ x \geq 0, \quad \lambda > 0, \quad \alpha > 0$$

Weibull: $$f(x) = \alpha\lambda\, x^{\alpha-1}\, e^{-\lambda x^{\alpha}} \quad for\ x \geq 0, \quad \lambda > 0, \quad \alpha > 0$$

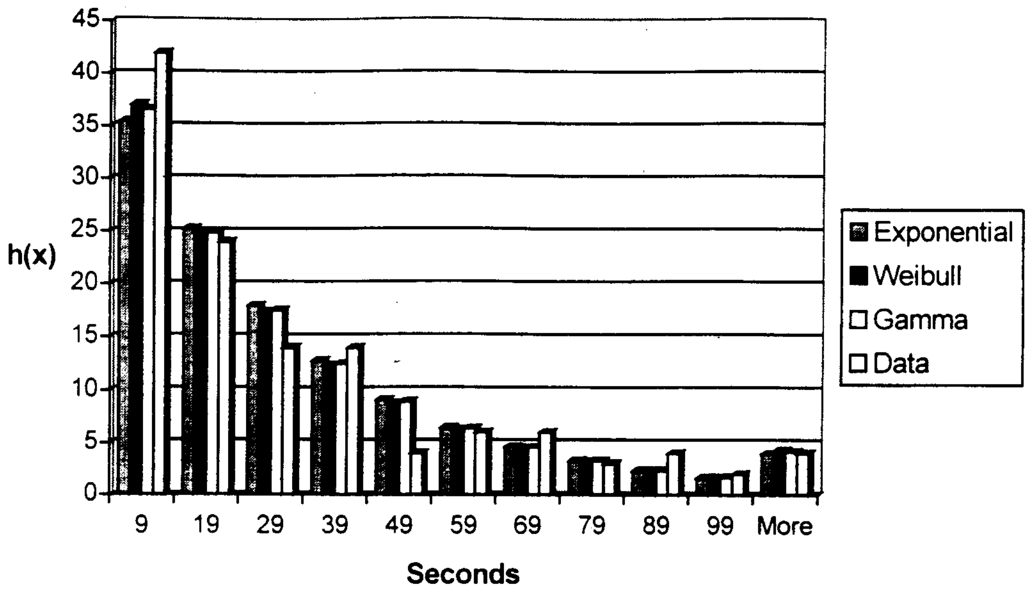

Figure 3-2. Comparision of the data and what we would have expected if the underlying distribution had been exponential, Weibull or gamma.

In the gamma distribution density function, $\Gamma(\alpha)$ is what is known as the gamma function, and if α is a positive integer, $\Gamma(\alpha) = (\alpha-1)!$. One of the important things to note about these three distributions is that if $\alpha = 1$, both the gamma distribution and the Weibull distribution collapse to the exponential distribution. Thus, both of these distribution families can be viewed as generalizations of the exponential distribution. The parameter α is called the "shape" parameter of both distributions because it determines the basic shape of the probability density functions.

In general, we have used both Chi-Squared and Kolmogorov-Smirnov tests of goodness of fit for the hypothesized distributions. In the following discussion, we report the test statistic (χ^2 for the Chi-Squared test, and D for the K-S test) as well as a "p-value". The p-value is the probability that we would have obtained the given value or larger for the test statistic when the hypothesized distribution was the true underlying distribution.

The p-values for the chi-squared and K-S test for each of the three potential theoretical distributions are given in Table 3-1. Table 3-1 illustrates that each of the three distributions would fit the data well. As mentioned previously, the gamma and Weibull distributions are generalizations of the exponential, and the estimated value of the shape parameter (0.96) is very close to the value which signifies an exponential distribution (1.0), so the simplest distributional form (exponential) is likely to be the best choice. The parameter value $\lambda = 0.034$, implies an average interarrival time ($1/\lambda$) of 29.4 seconds. Because it is easier to interpret the distributions in terms of the implied interarrival time, we will quote those results in subsequent tables, and designate the fitted distribution by EXP(29.4), for example. This should be understood to mean an exponential distribution with a mean of 29.4, or a parameter value of 0.034.

Table 3-1. p-values for three potential theoretical distributions.

Theoretical Distribution	Exponential ($\lambda = 0.034$)	Gamma ($\alpha = 0.96,\ \lambda = .033$)	Weibull ($\alpha = 0.96,\ \lambda = 0.033$)
p-value based on chi-squared test statistic	0.709	0.557	0.558
p-value based on the K-S test statistic	>0.15	>0.15	>0.15

3.1.2 Truck Arrivals from Canada Two hours of data for interarrival times of trucks coming east on the bridge have been analyzed. One hour of data was taken from a tape of traffic recorded on February 6, 1998 from 12 noon to 1:00 PM and a second hour was taken from a tape of traffic recorded on February 12, 1998 from 1:50 PM to 2:50 PM. Histograms of the data from February 6th and 12th are given in Figures 3-3(a) and 3-3(b) respectively.

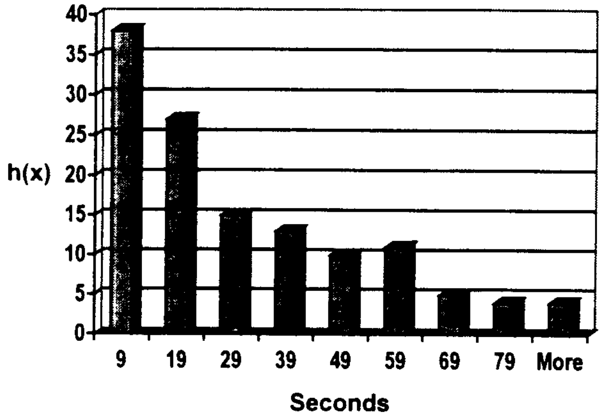

Figure 3-3(a). Interarrival times eastbound on the bridge, February 6, 1998, 12:00 PM to 1:00 PM.

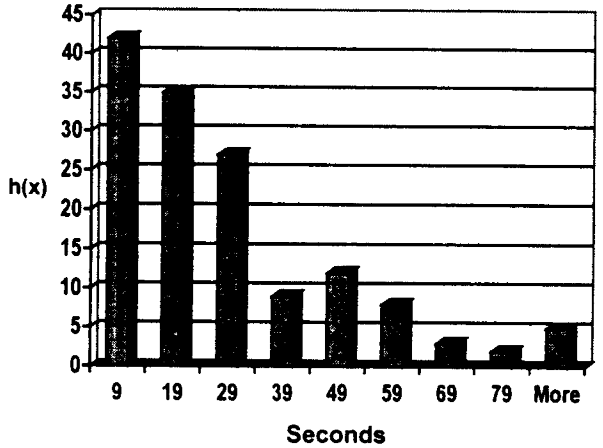

Figure 3-3(b). Interarrival times eastbound on the bridge, February 12, 1998, from 1:50 PM to 2:50 PM.

Table 3-2 presents the results of the chi-squared goodness-of-fit tests. Notice that in both time periods, a small offset from zero (a minimum feasible interarrival time) has been added to the exponential distribution. This offset allows the data to be fitted as close as possible by the hypothesized exponential distributions. In fact, a non-zero minimum interarrival time is realistic for truck arrivals, because their physical size precludes successive arrivals less than a few seconds apart. However, the actual impact on the simulation from using or not using a small minimum interarrival time is negligable, and the use of a standard exponential interarrival time is also quite reasonable.

Table 3-2. Hypothesis tests which compare each data set with exponential distributions.

Date	Distribution	P-value for the chi-squared statistic
February 6'"	1 +EXP(26.6)	***0.75***
February 12'"	2.5+EXP(22.4)	0.31

The p-values are quite large. which leads to the conclusion that the exponential distribution is a good model for the interarrival times of trucks to the U.S. plaza from Canada.

3.2 Distribution of Primary Inspection Time for Trucks

Two analyses have been performed. The first analysis investigates the aggregate distribution of time in primary across all truck categories. An aggregate distribution is useful because it is directly comparable to an earlier analysis (McCormick-Rankin, 1994). The second analysis is disaggregated by traffic category, because the simulation model requires service time distributions for each traffic category (i.e. C4, monthly, in-transit/empty and general).

3.2.1 Aggregate Distribution We have collected 3.25 hours of observations for primary inspection times from videotapes taken in February and March, 1998. These observations were drawn from five different blocks of time, as follows:

- February 9th from 1:30-2:15 PM
- February 9th from 3:10-3:40 PM
- February 1 1th from 2:15-2:45 PM
- February 12th from 2:30-3:00 PM
- March 10th from 1:35-2:30 PM

A histogram of the aggregated data from all inspectors is illustrated in Figure 3-4. The sample mean and standard deviation are about 35 seconds and 28 seconds, respectively. These observations are from "wheels stopped" to "wheels rolling," i.e., the actual time the truck is stopped in the inspection booth.

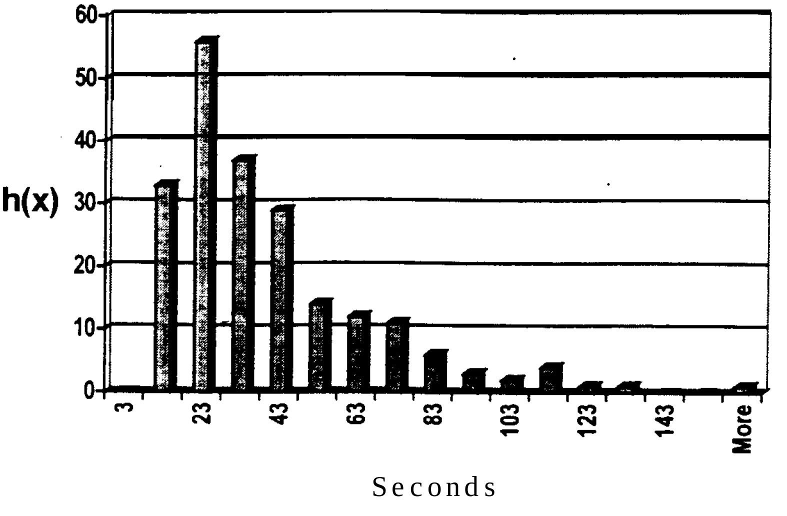

Figure 3-4. Histogram of Primary Inspection Times for Commercial Vehicles at the US Plaza.

However, the actual service time for a truck must also include time required to "pull up" from the waiting space in front of the booth. Observations from the videotapes indicate that the "pull up" time is approximately 17 seconds. Thus, the effective average service time for an inspection is about 52 seconds, implying an effective rate of approximately 69 trucks per hour through a single booth.

In the McCormick-Rankin study done in 1994, the average dwell time in the primary inspection booths was reported to be 57 seconds. "Pull up" times were not recorded specifically, but were guessed to be 5 – 10 seconds. This would imply an average effective service time of 64 – 65 seconds, or an effective rate of about 56 trucks per hour through a single booth. The McCormick-Rat&in report also states that some missing dwell time observations were replaced by estimates of 45 seconds, although the report does not indicate how many observations were "filled in" this way. It is also not entirely clear what times were recorded as "dwell times" (i.e., "wheels stopped" to "wheels rolling," as we recorded from the videotape, or "entry of tractor" into booth to "exit of trailer" from booth, etc.). Differences in definitions could account for a significant portion of the difference in the reported average dwell times, and the fact that our measured "pull up" times are substantially larger than the guesses in the McCormick-Rat&in report might indicate that the definition of dwell time in that report is different from our definition of stopped time.

Separate data from toll collection for trucks entering the U.S. is available by hour and by lane. These data indicate that hourly volumes in excess of 60 trucks per lane are relatively common during the peak periods of the day, and there are a few observations in excess of 70 trucks per lane per hour. This provides some confirming evidence that the times recorded from our analysis of the videotapes are likely to be more reliable than the older McCormick-Rankin results.

3.2.2 Component Distributions The simulation model requires estimated service time probability distributions for each truck traffic class. On April 28, 1998, from 12:30- 3:30 PM, U.S. Customs personnel collected 179 observations of primary inspection times for trucks, with each observation identified by traffic class. The traffic classes are C4, Monthly/In-transit, Empty, and General.

Table 3-3 reports the number of observations in each traffic class, the fitted probability distribution and goodness-of-fit tests. Only four trucks in the monthly/in-transit class were observed, so these observations were combined with the observations for empties for estimation of distributions.

Table 3-3. Summary of primary time distribution estimates by traffic category.

Traffic Category	# of Observations	Fitted Distribution (Time in seconds)	P-value for Chi-Squared Test	P-value for K-S Test
c4	78	2 1+ Erlang(17.2, 2)	< .005	> 0.15
General	62	10 + Erlang(23.4, 2)	0.008	0.115
Monthly/In-transit/ Empty	59	9.5 + Erlang(18.2, 2)	0.302	Not Calculated

The Erlang distributions estimated for the service times are special cases of gamma distributions where the "shape" parameter is integer. The p-values for the Chi-Squared test are not very convincing for the C4 and General categories, but the K-S test results are more encouraging. The p-value was not calculated for the Monthly/Empty/In-Transit category because the sample size was below 60, but the Chi-Squared test result is quite good. On the whole, these seem to be reasonable estimates for the service time distributions. Figure 3-5 shows the estimated distributions for the three categories of traffic.

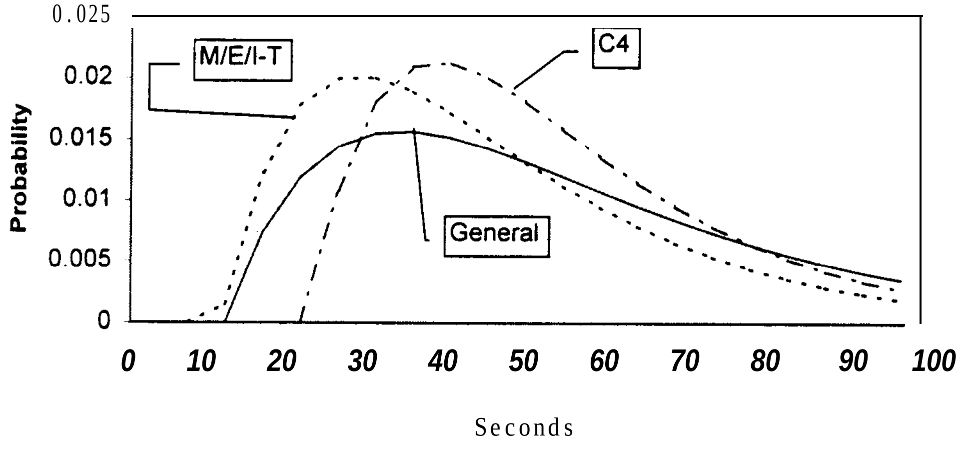

Figure 3-5. Fitted distributions of service times for primary inspection, by truck category.

The average service times for each distribution can be obtained by multiplying the Erlang parameters, and then adding the offset value. Thus, the average service times for the three categories are:

C4:	55.4 seconds
General:	56.8 seconds
M/E/I-T:	45.9 seconds

Note that the average service times for C4 trucks and General trucks are very similar, although the General times are more variable than the C4 times.

3.3 Proportion of Trucks in Each Category

On March 5, a 24-hour survey of truck entries by traffic category was conducted. The percentage of traffic in each of the categories is listed in the second column of Table 3-4. The last column of Table 3-4 shows the percentages of traffic by category as reported in a Customs document from 1996. These are generally consistent with the 24-hour survey. Thus, the percentages of trucks by traffic class from the 24-hour survey will be used in the model.

Table 3-4. Percentages of trucks, by category, in various data sets.

Traffic Category	24 -hour truck survey	Buffalo Customs Report
C 4	44%	48%
Empties/Monthly/In-transits	22%	18%
General	34%	34%

3.4 Probability of Referral to the Secondary Area

During the Customs data collection on April 28, 1998, a total of 55 out of 179 trucks (3 1%) were referred to the warehouse in the secondary area for further paperwork or cargo inspection. These 55 trucks were all in the General category (out of 62 total in that category), indicating that 89% of the General category trucks were referred, and none of the trucks in the other categories. However, it is clear from other information that a small fraction of trucks in the C4 and Monthly/Empty/In-Transit categories are also referred, so it is not entirely accurate to assume a zero probability of referral for those categories.

On May 7, 1998, the project team did additional on-site data collection in the secondary area, from 10:00 AM to 4:30 PM. Figure 3-6 illustrates the arrival rate by hour to the primary inspection area on May 7, as reported by toll collection data. A total of 2,526 trucks crossed into the U.S. over the Peace Bridge on May 7, making this a rather typical Thursday. Between 10:00 AM and 4:30 PM, there were 813 trucks arriving at primary inspection. Of these, 207 (25%) were referred to the warehouse for further processing.

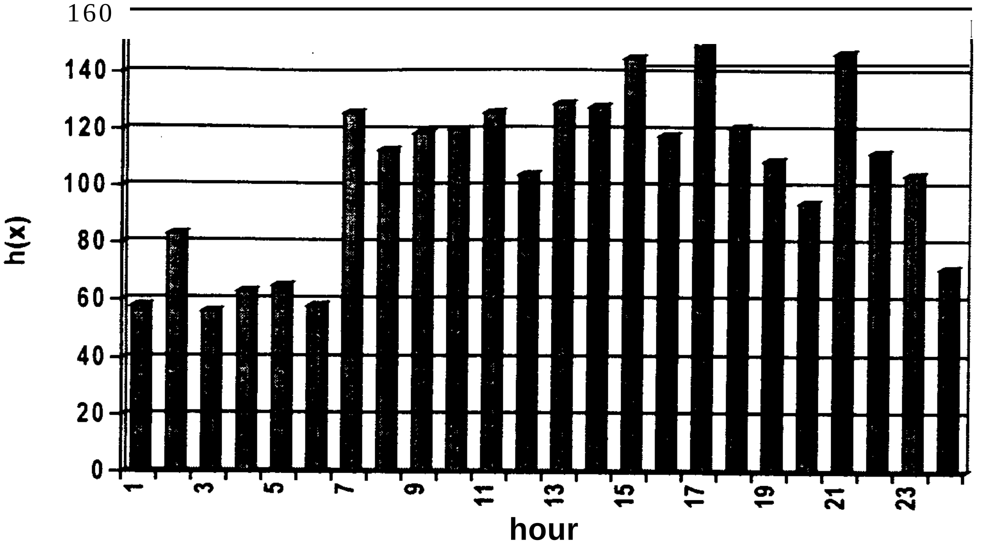

Figure 3-6. Truck arrivals by hour across the bridge.

The data from May 7 indicate a lower proportion of referral to secondary than the data from April 28. but neither day seems to be an "unusual" day. For the simulation model, we have specified a probability of 0.89 that trucks in the general category will be referred, and a zero probability for trucks in the other categories. This produces an aggregate referral rate of 0.89*0.34 = 0.30 across all truck traffic. This assumption will create a reasonable overall load on the secondary area in the simulation, and that is our principal concern.

3.5 Time Delay in the Secondary Area

The area between the primary inspection booths and the Customs warehouse is very constrained, and during some parts of the day drivers referred to the warehouse have great difficulty finding a parking space. Thus, the modeling of truck occupancy in the secondary area is of significant interest. To support parameter estimation for this part of the simulation model, data were collected by on-site observation on May 7, from 10:00 AM to 4:30 PM. The following four types of data were collected:

1. For each truck diverted into secondary, we recorded the time of arrival in secondary, if a cargo inspection was needed when it began and when it was completed, and the time of release from the secondary area.
2. Observations of driver entry and exit times to and from the warehouse. This time is the sum for each driver of time spent with the broker and time needed to process the revised paperwork at U.S. Customs. This also includes the time spent waiting for a Customs inspector to check the revised paperwork.
3. Observations of the time required to process revised paperwork by Customs. This does not include the time waiting for a Customs inspector.

Figure 3-7 presents a histogram for the 134 observations of elapsed time between the driver's entry into the warehouse and completion of Customs paperwork inspection. This data set can be effectively described by an exponential distribution with a mean of 2 1.1 minutes and an offset of 8 minutes. The p-value for the chi-squared test is 0.385.

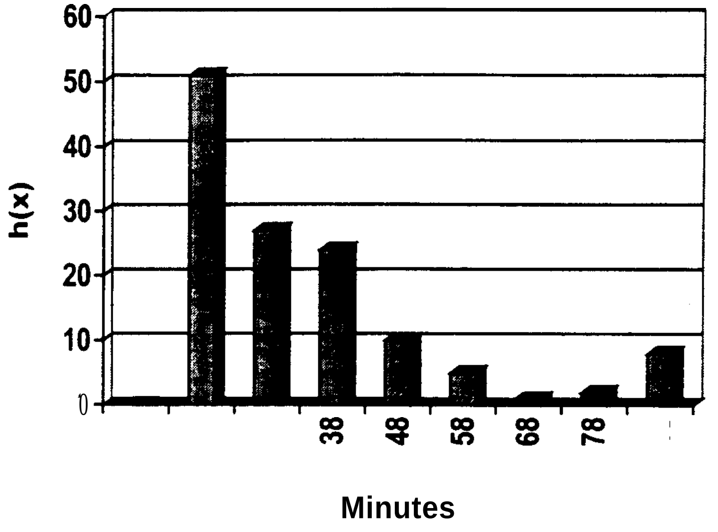

Figure 3-7. Observations of driver times in the warehouse.

Figure 3-8 presents a histogram of the observed time required for a Customs inspector to examine the revised paperwork. It was difficult to collect this data unobtrusively, and only 13 observations were collected. This data set can be described adequately as an exponential with a mean of 3.75 minutes. The p-value for the K-S test is greater than 0.15.

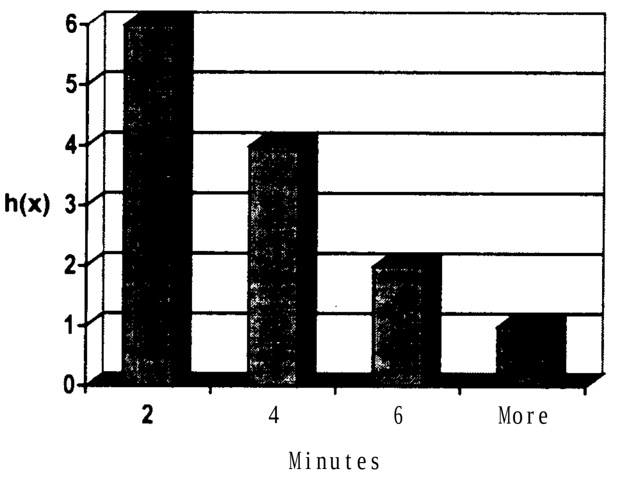

Figure 3-8. Histogram of time needed to examine paperwork.

Using the data (and fitted distributions) for total driver time in the warehouse and the time required for Customs paperwork inspection, we can derive an estimate of the time required for the driver to visit the import broker. The data in Figure 3-7 indicate that the mean total time in the warehouse is 29.1 minutes and the variance of total time is approximately 445 minutes^2. The mean delay at the broker plus the mean delay at Customs should equal 29.1 minutes. If the time required for the broker's activities and the time required for Customs inspection are statistically independent (which seems likely), then the variance of broker time plus the variance of Customs delay should equal the variance of total time (445 minutes^2).

The variance of Customs service time (based on the data in Figure 3-8) is about 14 minutes^2. This is very small compared to the variance of total time. An approximate calculation of waiting time at the Customs counter (prior to processing) indicates that the waiting time is very small (less than 1 minute) and this corresponds to observations on May 7, 1998. Thus, we have chosen to ignore that waiting time, and we have estimated the variance in broker time to be about 445 – 14 = 431 minutes^2.

Similarly, the mean broker delay should be about 29.1 – 3.75 = 25.35 minutes (again ignoring queuing delay at the Customs counter). This allows us to estimate a distribution for the broker time as:

$$\text{Broker time} = 4.55 + \text{EXP}(20.8)$$

This distribution has a mean of 25.35 minutes and a variance of approximately 431 minutes'. Other distributions could of course also match this mean and variance, but since the estimated distribution for the total time is an offset exponential, it is sensible to use an offset exponential as the distribution of the largest component of the total time.

From 10:00 AM – 4:30 PM, 10 cargo inspections were started and completed. The average duration of an inspection was 3 1 minutes from the time the truck backed into the inspection bay until it left again. The probability of a cargo inspection once a truck is diverted into secondary based on this data set is about 5% (10 trucks out of 207). Figure 3-9 presents a histogram of these observations. These data are insufficient to estimate a probability distribution with high confidence, but it is clear that the inspection times are highly variable. The times recorded in Figure 3-9 also do not include maneuvering time for the driver to move the truck from the parking lot into an inspection bay. We have estimated the maneuvering time to be 6 minutes, and the resulting distribution for inspection time to be:

$$\text{Inspection time (minutes)} = 12 + \text{EXP}(25)$$

This estimate preserves the mean value observed in the small sample of inspection data collected, and also approximately matches the (large) observed variance. This is not a very precise estimate of the distribution, but because so few trucks are actually inspected physically, errors in estimating this distribution do not have a very significant effect on the distribution of total delay in the secondary area.

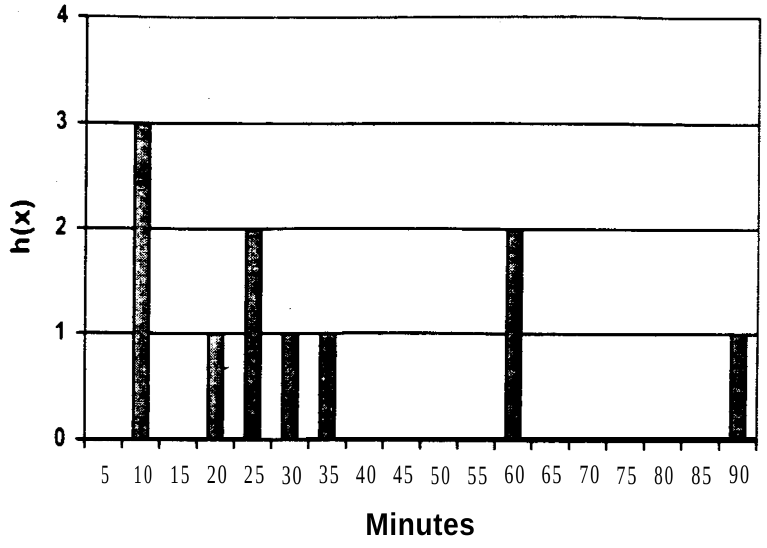

Figure 3-9. Observations of time required for cargo inspections.

3.6 Truck Toll Service Times

Trucks pay tolls both entering and leaving the U.S. We have focused on analyzing the toll collection service times for entering trucks, because it is easier to obtain data from the videotape in that direction. The same distribution is used for toll collection for exiting trucks in the model.

Three hours of service time data for toll collection for trucks entering the U.S. were analyzed. The tape used was taken March 27th from 10:30 AM to 12:00 PM, and showed all three truck lanes. The data analyzed was of the two lanes that were open for the entire 1.5 period. A histogram of service time data is presented in Figure 3-10. There are 184 observations with a mean and standard deviation of about 20 and 10 seconds, respectively.

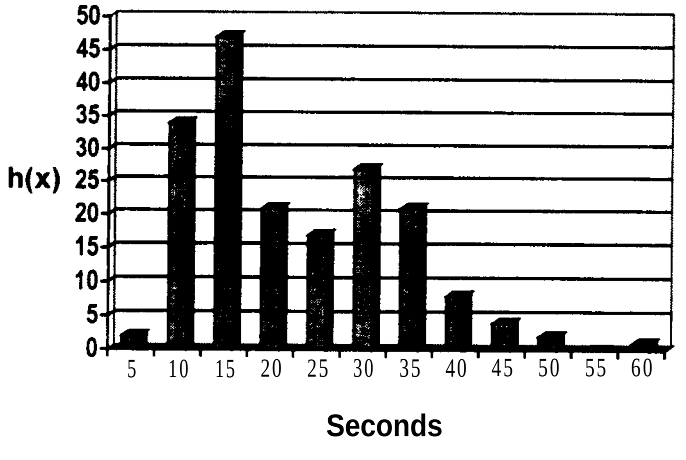

Figure 3-10. Histogram of service time for truck toll collection at the U.S. Plaza.

A truck may pay the toll with cash or a charge card. The observations in Figure 3-10 suggest that these two payment schemes may have different distributions for the time required. Therefore 61 observations of the toll collection service time were collected on May 17th from 3:45- 4:45 PM and the payment mechanism was recorded. 39 of the 61 observations were cash and the remaining 22 were charge. The means of the cash and charge observations were 26 and 15 seconds respectively. Notice that these means are very close to the two modes in Figure 3-l 0. Figures 3-11 and 3-12 illustrate the histograms of the cash and charge observations.

An Erlang (7.11, 2) – a special case of a gamma distribution – with an offset of 11.5 seconds provides a good tit for the distribution of time required to collect a cash toll. The p-value for the Chi-squared statistic is 0.229. An exponential with mean 7.95 and an offset of 7.5 provides a good fit for the distribution of time when a charge card is used. The p-value for the Chi-squared statistic is 0.09. Notice that the largest observation is causing some difficulty with the fit by creating a relatively heavy tail in the small sample available.

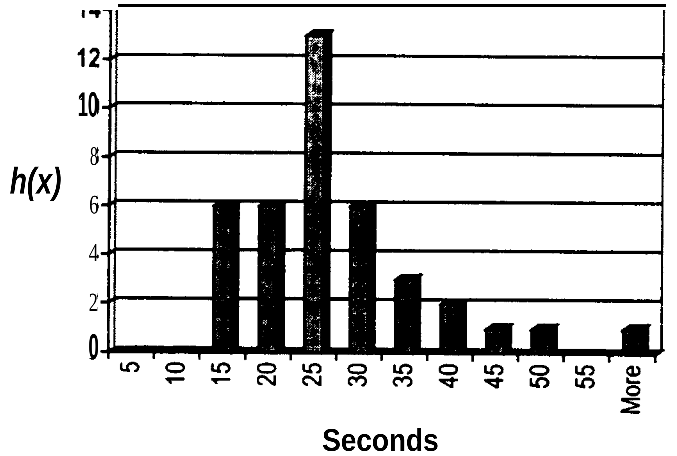

Figure 3-l 1. Observations for time to collect cash toll.

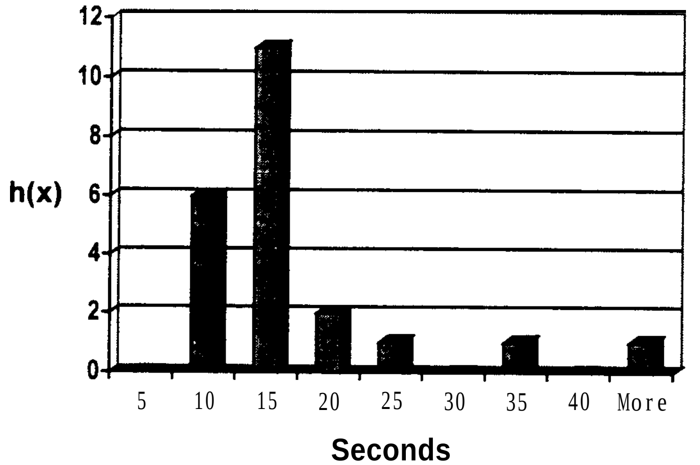

Figure 3-12. Observations for time to collect charge toll.

3.7 Auto Traffic Interarrival Times

Canada-bound automobile traffic enters the U.S. facility from Moore Drive and the I-190 access ramp. U.S.-bound automobile traffic enters across the bridge. We have analyzed videotape from all three traffic streams to test whether an assumption of exponential interarrival times is appropriate for auto traffic as well as for trucks.

3.7.1 Westbound (exiting the U.S.). Thirty minutes of Canada-bound auto arrivals from Moore Drive were analyzed. The tape used was taken March 12, 1998, from 10:00 AM to 10:30 AM. A histogram of the interarrival time data is presented in Figure 3-13. The average interarrival time in the data set is about 15 seconds.

The p-value for the Chi-Squared statistic for a fitted exponential distribution with a mean of 15.5 seconds is 0.391. This leads to the conclusion that the exponential interarrival times distribution is appropriate in the simulation.

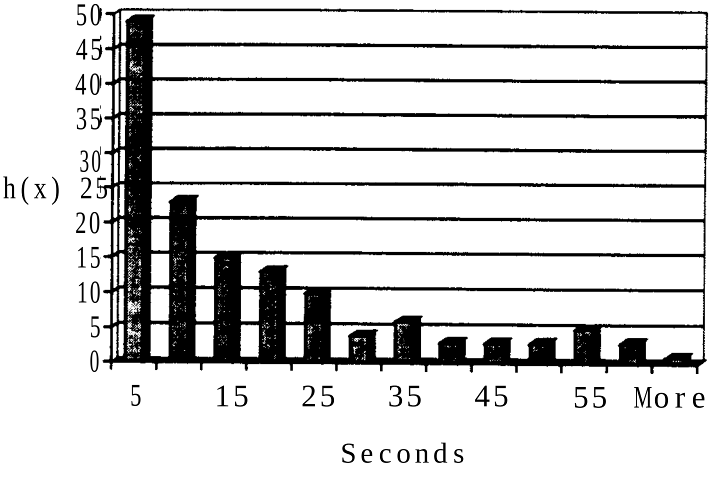

Figure 3-13. Observations for interarrival times to the U.S. Plaza via Moore Drive for automobiles.

One hour of car arrivals from I- 190 was analyzed. The tape used was taken December 18, 1997, from 1:50 PM to 2:50 PM. A histogram of the interarrival time data is presented in Figure 3-14. The average inter-arrival time in the data set is about 18 seconds. The p-values for the K-S and Chi-Squared tests for an exponential distribution with a mean of 17.7 seconds are both very high, leading to a conclusion that the arrival process for cars on the I-l 90 ramp can be modeled with exponential interarrival times.

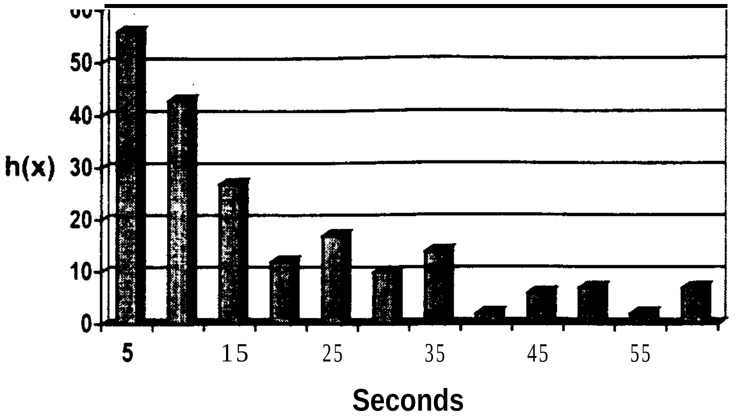

Figure 3-14. Observations for interarrival times to the U.S. Plaza via I-190 for automobiles.

3.7.2 Eastbound (Entering U.S.) During the period taped for analysis of arrivals to the U.S. from Canada, two lanes on the bridge were moving eastbound into the United States. The right lane is primarily truck traffic and the left lane is mostly car traffic. One hour of videotape (1:50-2:50 PM) from December 18, 1997, was analyzed to determine whether the interarrival time distribution is exponential or not. Figure 3-l 5 shows interarrival times (352 observations) for the left lane. These interarrival times can be adequately modeled as exponential with a mean of about 10 seconds (p-value for the chi-squared statistic of 0.154). In the right lane, the car interarrival times are distorted by the presence of a high concentration of trucks, and there were only 21 cars observed. Since the volume of car traffic in this lane is small in comparison to the left, for modeling purposes we can assume that this arrival process is also Poisson and merge the right-lane car traffic with the car traffic in the left lane.

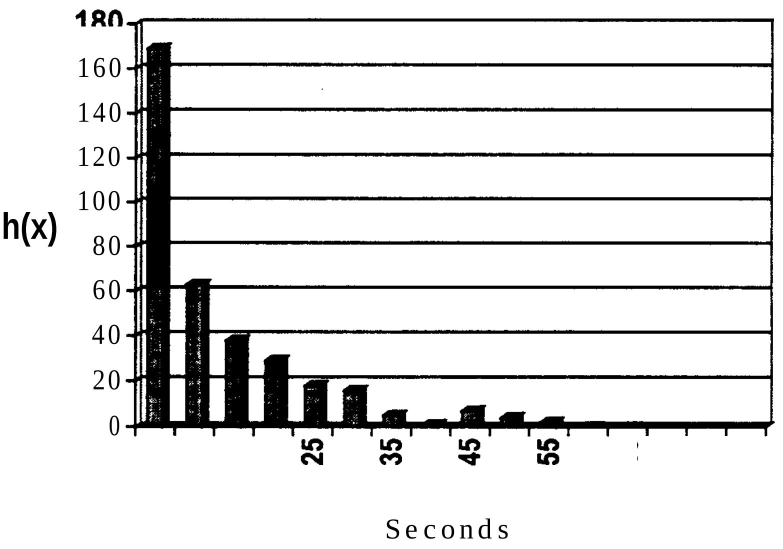

Figure 3-l 5. Interarrival times for cars in the left lane of the bridge; entering the U.S.

3.8 Car Toll Service Times (Exiting the U.S.)

Tolls can be paid electronically, via tokens (or exact change), or cash (with change given). There are currently very few vehicles using the ETC facility, so the available data pertain to token and cash transactions only. The following subsections describe the data analysis for each.

3.8.1 Cash Ninety minutes of service time data for auto toll collection at the U.S. plaza were analyzed. The tape used was taken March 27, 1998, from 10:30 AM to 12:00 PM. A histogram of the service time data is presented in Figure 3-16. The mean is about 8 seconds and the standard deviation is about 9 seconds. A lognormal distribution yielded a p-value of about 0.175 for the chi-squared test.

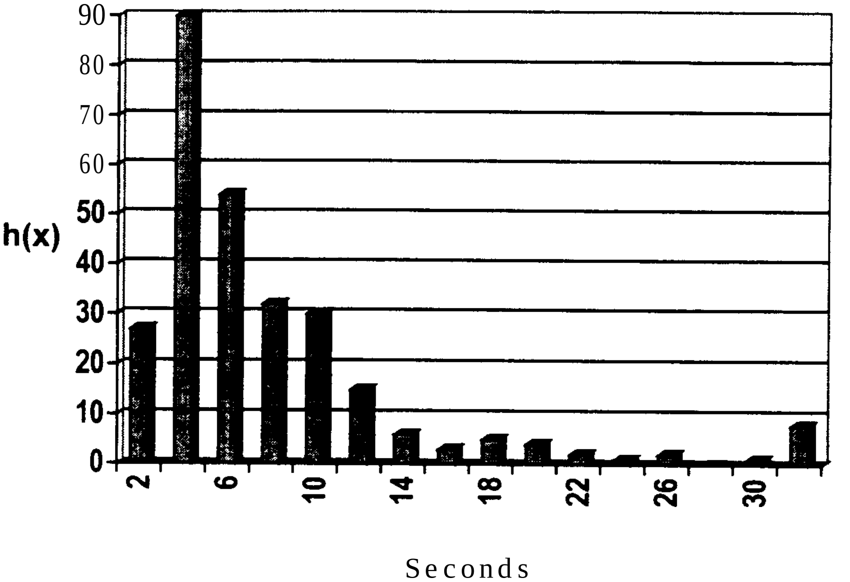

Figure 3-l 6. Observations for service times for automobiles in the cash lanes at the toll plaza.

3.8.2 Tokens Twenty minutes of service time data for automobile token collection at the U.S. plaza were analyzed. The tape used was taken May 15, 1998, from 11:00 AM to 11:20 AM. A histogram of the service time data is presented in Figure 3-17. The mean is about 4.5 seconds and the standard deviation is about 1.3 seconds. The fitted distribution is:

Service time (seconds) = 2.5 + Lognormal(2.59, 2.28)

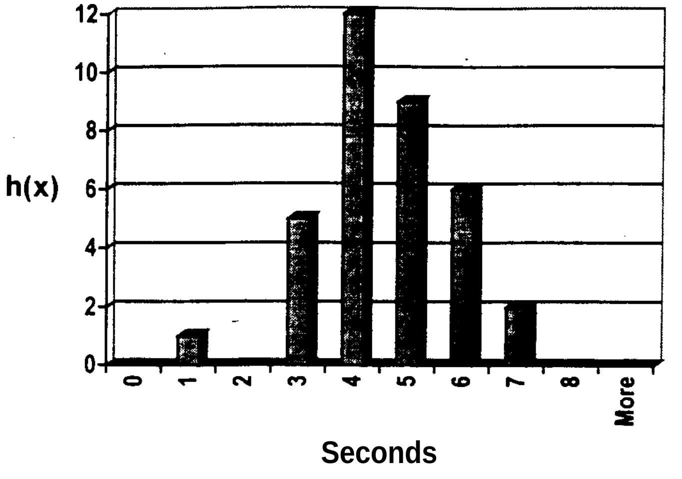

Figure 3-l 7. Observations for service times for automobiles paying with tokens.

3.9 Distribution of Time Required for Immigration Inspection for Cars Entering the U.S.

Sixty-six observations of time in primary immigration for automobiles (across two lanes) were collected from videotape recorded on March 10, 1998, between 11:30 AM and 12:00 noon. Figure 3- 18 illustrates those observations. The theoretical distribution that provides the best fit is an exponential with a mean of 20.7 and an offset of 5. The p-values for chi-squared and K-S test are 0.16 and greater than 0.15, respectively.

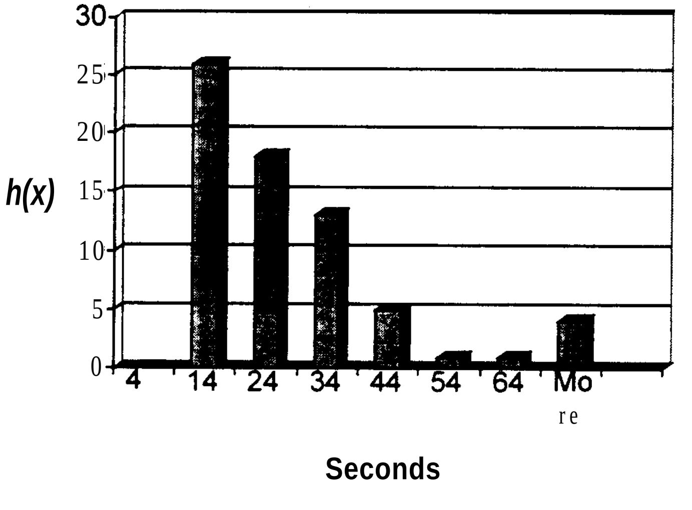

Figure 3- 18. Observations for time in immigration inspection for automobiles entering the U.S.

The two inspection lanes observed on the videotape are both regular lanes, so the data in Figure 3-18 pertain to the "Regular" class of entering cars. There is an additional lane reserved for AutoPass users, and special taping was necessary to estimate a time distribution for that lane.

The estimated distribution for service time in the AutoPass lane is a lognormal with parameters 5.43 and 5.57, and an offset of 1.5 seconds. This produces a mean service time of 7.2 seconds, as compared to the mean of 25.7 seconds in the regular lanes.

3.10 Model Validation

The various parameter values and probability distributions estimated in the previous sections allow us to establish the base case conditions for simulation experiments, and to test the model for validity. Model validation efforts for the U.S. model have focused on eastbound traffic (entering the U.S.), and our major concern has been whether or not the model accurately reflects the total number of trucks in the system (waiting for primary inspection or parked in the secondary area) because this measure includes the effects of virtually all the parameters in the model.

Two hours of video data were collected on the U.S. side of the bridge on July 30, 1998, covering the period from 3:45 PM to 5:45 PM, the peak period during the day. The data collected includes footage of the bridge deck, the toll booth plaza, and the exits from the facility (both I-190 and Baird Drive). These views enable an analysis of facility throughput in the eastbound direction, and a count of total system occupancy at any instant of time during that two-hour period. The toll data from July 30 was used to construct hourly arrival rates of trucks for the entire day to create the input rates for the model.

Three model runs were made using different random number streams to sample from the probability distributions in the model, with all inputs and parameters held constant. Figure 3-19 shows the plot of total trucks in the system, sampled at five-minute intervals from 3:45 PM to 5:45 PM, for the three model runs. It is clear from Figure 3-19 that the total number of trucks in the system at any given time is highly variable, and depends greatly on the specific sampled sequence of interarrival times, processing times, etc.

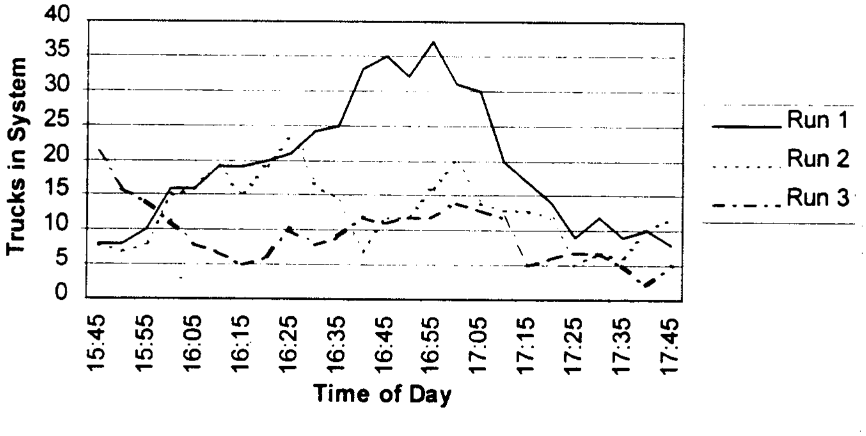

Figure 3-19. Total trucks in the system for three model runs, using the same input data.

The variability between runs results from the fact that the system is quite heavily utilized during the peak period of the day, so small perturbations can have significant effects over an extended time period. This variability from run to run implies that it is very unlikely that any given model run will match closely the observed temporal pattern of system occupancy, since that observed pattern is itself only a single "sample" of a highly variable process.

The run-to-run variability suggests that it is necessary to examine an average of several runs as the basis for any conclusions regarding model results. It also suggests that the standard for validation of the model is that the average of several model runs show a total system occupancy that is close to the average occupancy on the observed day, and that the range of numbers of trucks in the system across model runs be close to the observed range.

Figure 3-20 shows a comparison of the three-run average truck occupancy against the recorded data from July 30. The average of the model runs varies somewhat less than the observed series of data, as we might expect. On the whole, the model predictions of occupancy approximately correct on average across the period, and the values are in the same range as the observed values (0 to 40 trucks, across the three runs). Both the model and the observed data show a decrease in total system occupancy near the end of the afternoon. This seems to be a reasonable outcome of the validation experiment for eastbound trucks.

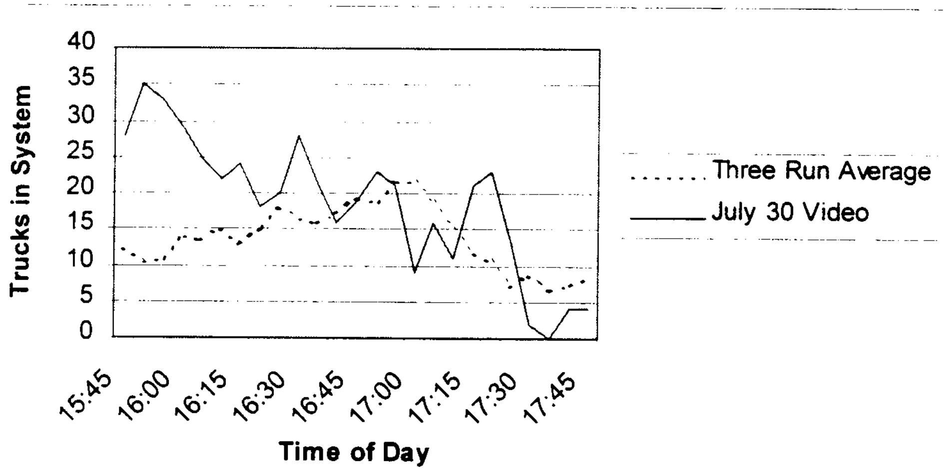

Figure 3-20. Comparison of the three-run average with observed data from July 30.

We can now proceed to a series of experiments to explore the effects of implementation of the advanced information technology. Chapter 4 describes experiments to test different performance specifications for the ITBCS implementation, and Chapter 5 discusses experiments to test various scenarios on penetration rate of the ITBCS technology and implementation of the system.

CHAPTER 4

Technology Performance Simulation

The effectiveness of the ITBCS technology depends on the improvements it offers in primary inspection service times, the degree to which it reduces the need for referral to the warehouse for further processing, and the percentage of trucks which are equipped to use the technology (the "market penetration"). In this chapter, we construct a set of simulation experiments to test the effectiveness of the technology for reducing primary inspection service times. As a by-product of the experiments, we also can gain some insight into the effects of reducing the number of trucks referred to the warehouse. The following chapter discusses additional simulations designed to test the effects of different levels of market penetration and provide additional insight into the effectiveness of the ITBCS system in reducing the congestion in the secondary area around the warehouse.

It would be desirable to have sufficient information from the actual pilot implementation to represent the effects of the ITBCS technology on improving primary inspection service times, but the pilot implementation did not provide that information. The available data on reliability and response time of critical system elements are confounded by both operating procedures in place during the test and other experiments that were being performed. Thus we have had to construct an alternative approach to answer the question: How responsive and reliable does the system have to be to produce significant benefits at primary inspection?

The chapter is structured as follows. Section 4.1 describes how we modeled the ITBCS system. Section 4.2 outlines the performance options we considered. Section 4.3 describes the various traffic conditions under which these options are evaluated and Section 4.4 presents the results of those investigations. Finally, Section 4.5 summarizes our findings and identifies conclusions that can be drawn from the analysis.

4.1 Modeling the ITBCS Installation

Eastbound trucks (entering the U.S.) are the main focus of this investigation. Figure 4-l presents a diagram of the ITBCS system for these trucks as it is represented in the ARENA model. The model is consistent with the system implementation on the U.S. side of the Peace Bridge.

The system includes tag readers (antennae), a local computer (referred to as the Border Crossing Computer, or BCC), a display screen inside the Customs inspector's booth, and communication links. The BCC is linked to U.S. Customs' local computer network, and through this network to Customs' remote computer in Washington, DC. The computer at the remote site manages the database pertaining to U.S.-bound truck trips.

The advance antenna is the first system element to see an arriving truck. Located above the toll booth (see Figure 2-1), and upstream of the customs inspection booth, the advance antenna

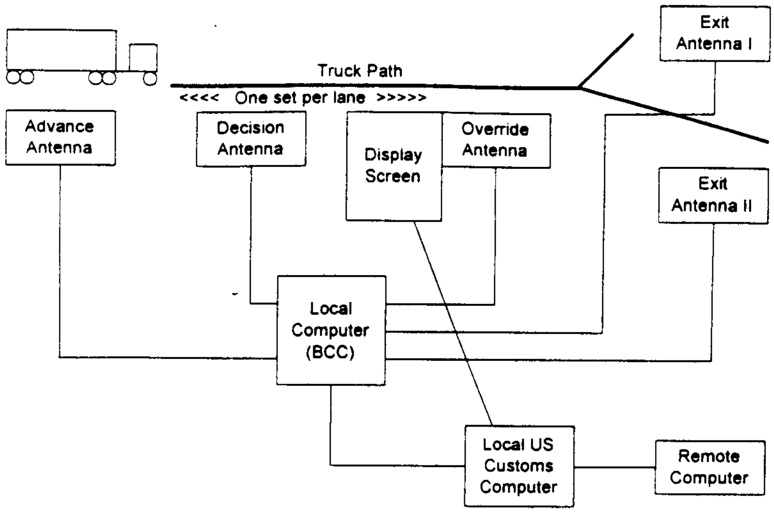

Figure 4-1. ITBCS System Block Diagram

queries the truck's tag and sends to the BCC the Trip ID it reads. That ID identifies not only the arriving truck, but also its load and driver. The BCC in turn sends the ID information to the remote computer through the local Customs network. The remote computer then accesses the record in its database corresponding to the Trip ID and processes it to determine what, if any, special U.S. Customs treatment will be required (e.g., random cargo inspection of arriving shipments).

The next series of events is triggered by the decision antenna. The decision antenna is located at the primary inspection booth, so it can read the tag of the truck that is entering the booth. When it detects a truck, it forwards the Trip ID from the truck's tag to the BCC, and the BCC transmits it through the local Customs network to the remote computer. The remote computer responds by sending back the data record belonging to the Trip ID. (Also, if this is the first time the tag has been read, the remote computer does the preliminary processing described before.)

When the local Customs computer receives the Trip ID record from the remote computer, it sends information about the arriving truck to the display screen in the primary inspection booth. (This includes any special treatment identified by the remote computer in preprocessing the Trip ID record.) The Customs inspector uses this information to decide whether the truck should be cleared for entry or sent to secondary inspection. When a decision is made, the Customs inspector enters the decision to the local Customs computer, which then notifies the BCC. The BCC activates the override antenna and sends a signal to the truck tag indicating to the driver whether the truck has been cleared for entry or not. The local Customs computer notifies the remote site of the decision.

When the truck has been cleared for entry, it exits the system via either the ramp to I-190 or Baird Drive. In both cases, the truck passes by an exit antenna. The exit antenna reads the truck's tag for the Trip ID. That information is sent by the BCC to the local Customs computer, and then on to the remote computer. The record. belonging to that Trip ID is found and the disposition of the truck identified at the remote site. Once that disposition is determined, a signal is sent back by the remote computer to the local Customs network, and then to the BCC. The BCC activates the exit antenna to notify the tag in the truck, indicating whether the truck has been cleared for entry (green) or not (red). If red is displayed, the truck is expected to return to the customs warehouse for further processing.

4.2 Parameter Values

Two types of parameters are important for simulating the performance of the system: failure rates for the various antennas and service times for the data processing activities.

In an attempt to estimate parameter values, we obtained from the Peace Bridge an event database that showed transactions registered by the BCC across a 10 month timeframe from May 1997 to February 1998. Almost 14,000 records are present, for about 1100 eastbound trips and a similar number of westbound trips. Each record shows: Trip ID, tag number, date and time of the event, trip type, event type, and log number. Many of the trips recorded are not for ITBCS-equipped trucks because the antennae often registered EZ-Pass tags, etc. Thus the set of “real” ITBCS trips is a small subset of the total trips registered. Additional description of this event data set and our analysis of it is contained in Appendix A.

The eight types of events in the file are:

- *AdvArriv:* truck tag is seen by the advance antenna and the Trip ID is read
- *AdvNot:* advance data packet is sent by the BCC to the remote site (via the local Customs network)
- *DecArriv:* truck tag is seen by the decision antenna and the Trip ID is read
- *DecNot:* decision data packet is sent by the BCC to the remote site (via the local Customs network)
- *DecRes:* the BCC receives the decision status from the Customs local network based on the inspector’s action
- *ExitArrv:* truck tag is seen by the exit antenna and the Trip ID is read
- *ExitNot:* exit data packet is sent by the BCC to the remote computer (via the local Customs network)
- *ExitRes:* exit antenna sends exit status to truck based on remote site response.

4.2.1 Antenna Failure Rates In principal, we should be able to estimate failure rates for the advance and decision antennae from the events database. Specifically, the percentage of trips where these antennas failed to see an arriving truck’s tag should give us an estimate of the antenna’s failure rate. However, as Appendix A shows, the failure percentages for the trips in the database are very high. It appears that the antennas were periodically being taken out of service to conduct various types of experiments. Thus, the event data cannot be used.

In late 1997, the Information Exchange and Automation Working Group (IEAWG) formed as part of the NATAP program tested the equipment used in the Buffalo-Ft. Erie pilot program, as well as the equipment used in the other NATAP pilots. They found that the sets of antennae used for U.S. imports, U.S. exports, Canadian imports and Canadian exports had successful read rates ranging from 65% to 98% (NATAP Interoperability Test, 1998). There is reason to believe that the eventual "in use" read rates should be higher than observed in the IEAWG tests, but we have no solid data from the actual pilot implementation at the Peace Bridge to allow us to estimate antenna failure rates.

We assumed two different failure rates, given the differences in the conditions under which the advance and decision antennae operate. For the advance antenna, we have assumed a 10% failure rate, and for the decision antenna, we have assumed a 1% failure rate. In an implementation of a dedicated short-range communication (DSRC) system, it should be possible to achieve failure rates lower than these assumptions, but Atalla (1998) has noted the problems observed in all of the NATAP experience to date, so our assumptions appear plausible. Furthermore, the results described in section 4.4 indicate that this assumption is not critical to evaluation of overall delay reductions for entering trucks.

4.2.2 Service Times The critical service time for processing trucks is the response time of the remote computer when the truck enters the primary inspection booth. If the ITBCS technology is to improve primary inspection processing, the computer system must respond fast enough to allow the total time that the truck occupies the booth to be reduced. During the pilot test at the Peace Bridge, Customs inspectors were required to do dual processing of ITBCS-equipped trucks – that is, the trucks had to have all the paper documents normally required for entry into the U.S. as well as the electronic tags, and the Customs inspector had to process the paperwork in addition to using the electronic system. The implication of this is that the observed service times from the test system provide almost no information about how the system would function in the absence of dual processing.

The overall time in the primary inspection booth is approximately the interval between the *DecNot* and *DecRes* events recorded in the database. This interval includes the time for the remote computer to respond to the message from the BCC, the "painting" of the screen in the primary booth by the local Customs computer, processing of the vehicle by the inspector and entering a decision, and the forwarding of that decision by the local Customs computer to the BCC for notification of the vehicle. Figure 4-2 shows the cumulative density function for the *DecNot-DecRes* intervals recorded. Only about 10% of the times are a minute or less, which is the average time for processing vehicles through primary inspection today. The 50th percentile is at 250 seconds (more than 4 minutes), and the 90th percentile is at 750 seconds (about 12.5 minutes). These times are much too long for effective operation in a full-scale implementation.

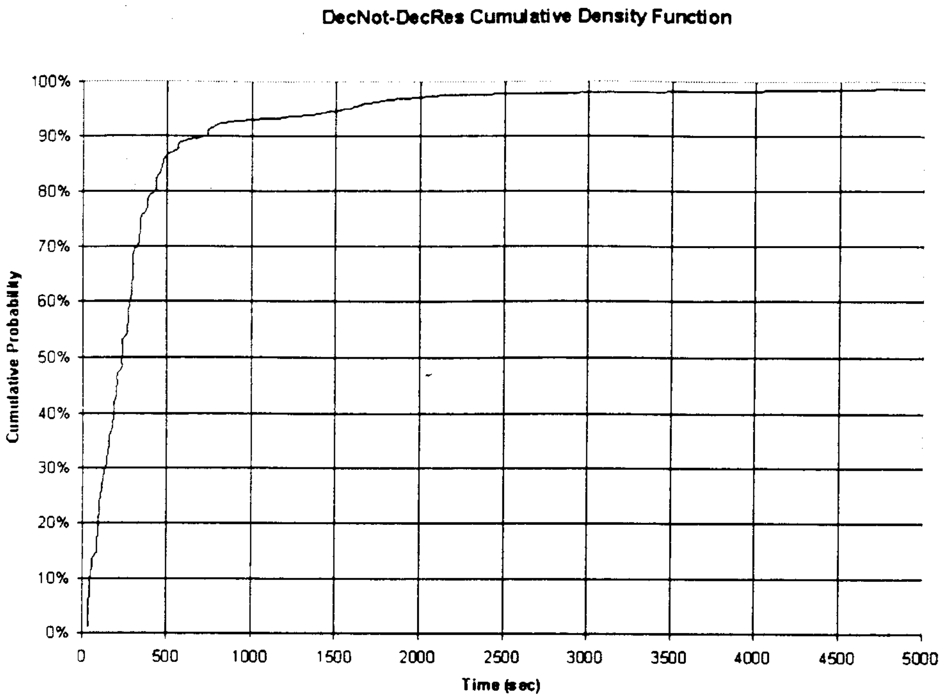

Figure 4-2. Cumulative Density Function for the time from Decision Notification to Decision Response.

Because the available data from the pilot implementation don't provide a reasonable basis for estimating the service times for an electronic clearance system without dual processing, we have made assumptions about plausible "high" and "low" performance systems. The assumptions we made are reflected in Table 4-1. The top portion of the table lists the antenna failure rates for the advance and decision antennas. These failure rates are as indicated in section 4.2.1, and are the same under both the high and low performance specifications for service times. The middle portion lists the inspection time distributions assumed to pertain for each combination of outcomes from the advance and decision antennas. For example, for the low performance system, if the advance antenna fails to read the tag, but the decision antenna succeeds, then the inspection time distribution is assumed to be uniformly distributed between 35 and 50 seconds (represented as 30 + UNIF(5,15)). The bottom portion of the table shows the probabilities that trucks will be sent to secondary inspection. If the decision antenna works and the truck's data is displayed on the screen in the primary inspection booth, then 2% of the trucks go to secondary

Table 4-1. Primary Inspection Times

Antenna Failure Rates		
Advance	Decision	System Performance
10%	1%	High and Low
Read Outcomes		
Advance	Decision	Inspection Time
	High Performance System	
Y or N	Y or N	17+ UNIF(5,15)
	Low Performance System	
Y	Y	20 + UNIF(5,15)
N	Y	30 + UNIF(5,15)
Y or N	N	20 + UNIF(5,15)
Read Outcomes		
Advance	Decision	Percent to Secondary
Y or N	Y	2%
Y or N	N	100%

inspection. If the decision antenna fails, then the truck is automatically sent to secondary inspection. This is because we assume that no data will be readily available for processing the truck.

The rationale for the service time assumptions is as follows. For the high performance system, we assume the display screen is painted in less time than it takes the truck to advance from first in queue to the inspection booth. Hence, the overall inspection time is 17 seconds for pull-up plus 5-15 seconds for primary inspection. This condition pertains as long as the decision antenna successfully reads the tag. For the 1% of cases where the decision antenna fails, the inspection time is the same, but the truck is automatically sent to secondary inspection.

For the low performance system, if the advance antenna has read the tag (90% of the time), we assume that the interval between decision antenna read and display screen paint is 20 seconds, 3 seconds longer than the 17 second pull-up time. The inspection time is still 5-15 seconds. If the advance antenna fails, we add an additional 10 seconds, to allow time for preprocessing the record at the remote site. As in the high performance system, for the 1% of reads where the decision antenna fails, the inspection time is the same, but the truck is automatically sent to secondary inspection.

4.3 Investigation Plan

To provide realistic truck traffic volumes for the simulation experiments, we have used actual hourly volumes from October 27, 1997, a Thursday with truck volumes that lie at about the 75th percentile among all days in 1997.

First we establish base case results by simulating the existing conditions on 10-27-97. Then we construct a series of simulations to test the high and low performance options described above. In both instances, we assume that 20% of the trucks are equipped with electronic tags, and are able to be processed by the tested system. The equipped trucks are all assumed to be diverted from the "General" category. These trucks have the largest average primary inspection time, and 89% of them are normally referred to secondary inspection. Drawing all the equipped trucks from the General category is somewhat unrealistic, but it does create an experimental environment in which there is a maximum chance for the technology to have an impact. Additional experiments with various percentages of truck traffic converted from all the existing categories are described in Chapter 5.

Insofar as outputs are concerned, we look at the total time in system and the total time in primary inspection (the average and 90th percentile for both) and the number of trucks processed through secondary inspection. These measures give us a clear sense of the change in performance of the border crossing system as a whole.

4.4 Results

Table 4-2 shows the base case conditions for the time period between 3:00 PM and 6:00 PM on the test day. About 400 trucks arrive for primary inspection and 25% of these are referred to secondary inspection. The average time in system is 810 seconds (about 13 minutes), and the 90th percentile is 2217 seconds (about 40 minutes). The primary inspection time, which starts when the truck joins the back of queue (on the bridge) and ends when primary inspection is complete, averages 280 seconds (4.5 minutes) and has a 90th percentile value of 5 12 seconds (8.5 minutes).

Table 4-2. Base Case Conditions

Base Case Conditions - Trucks - 3-6pm			
'Number of vehicles	396		
Number to secondary	98 (25%)		
	Times (Seconds)		
	Minimum	Average	90th Pctle
System	70.7	810.1	2217.0
Primary	39.7	278.5	511.7
Secondary	516.7	2041.6	3908.7

Table 4-3. Variations in System Performance

	Servicing Times by Scenario				Vehicles to
Scenario	Sys-90	Sys-Avg	Pri-90	Pri-Avg	Secondary
Base	2217.0	810.1	511.7	278.5	98
Low	613.0	388.9	418.0	218.5	30
High	392.3	353.8	280.7	160.9	31

Table 4-3 shows how the system's performance is affected by the introduction of an electronic system for clearing 20% of the trucks. For the low performance scenario, the average time in system drops 52%, from 8 10 seconds to 389. For the high performance scenario, an even lower average of 354 seconds is obtained. This is a reduction of 56% from the base case. More dramatically, the 90th percentile time in system drops 72%, from 2217 seconds to 613, for the low performance system and 82%, to 392 seconds, for the high performance system.

The dramatic reduction in the 90" percentile values, representing the "tail" of the distribution of times, is largely because the number of trucks sent to secondary inspection drops dramatically. About 400 trucks arrive during the three-hour period of interest, and in the base case there are about 136 (34%) trucks in the General category. Of these, 89% (about 120) are referred to the warehouse. and in the run data recorded 98 have been cleared by the end of the period and have their times recorded. In the simulations for the low and high performance scenarios, 20% (about 80) of the total trucks are diverted from the General category to the ITBCS category, and only about 3% of these trucks (2% sampled randomly and 1% due to decision antenna failure) are referred to the warehouse. This reduces the number of trucks sent to secondary by about 70 over the three-hour period, and in fact in the simulation data recorded, the number of trucks referred dropped to about 30.

Figure 4-3 shows these findings graphically. It is easy to see that the improvement from the base case to the low performance system is dramatic. The next increment to the high performance system is smaller, but still notable, and is most significant for the 90th percentile measures. Also, the trends for time in system are more noteworthy than those for time in primary. This is because the number of trucks sent to secondary inspection affects the total time in system but not the time in primary inspection.

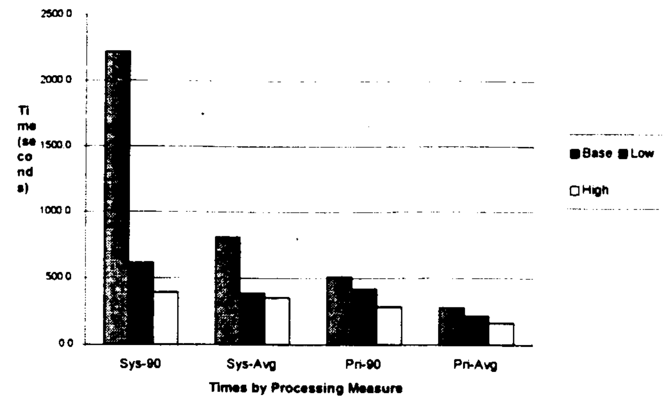

Figure 4-3. Average and 90th percentile times for eastbound trucks under various levels of technology performance.

4.5 Discussion

Two observations stand out on the basis of this investigation. The first is that the introduction of ITBCS technology can clearly have a significant impact on the performance of the facility. Our experiments with 20% of the truck fleet equipped with the technology showed 50-70% reductions in both the average time in system and in the 90th percentile time for all trucks. Admittedly, we chose to focus on diversion from trucks in the "General" category, which maximizes the potential impacts, since these trucks have both the longest primary inspection time and the greatest probability of being sent to secondary inspection. However, additional experiments in the following chapter provide additional insight into the effects of different levels of penetration of the technology.

The second observation is that there is a critical interval of time for the system to respond to the presence of a truck entering the primary inspection booth. We have seen from videotape data that the pull-up time for a truck (the time to move from first-in-queue into the booth and stop) is about 17 seconds. This is the critical interval for the computer system to respond to the presence of the truck. If the response time of the computer system is fast enough so that the inspector has the information on his/her screen within three seconds of the time the truck stops (our low performance system), reductions of total time in system for all trucks can reach 50% or more. Reducing the response time so that the information is already on the screen when the truck stops can produce about 10% more savings in delay.

In conclusion, it is clear that the ITBCS technology can have a dramatic impact on system performance. But a major challenge must be overcome to obtain these impacts. It is vital to find a process for data record management that will allow response times within the interval of the truck pull-up time. A strategy of downloading records pertaining to truck entry to a local computer before the truck actually arrives in the primary lane (as is done in Canada) is likely to be an effective way of accomplishing rapid response times.

CHAPTER 5

Scenario Impact Investigations – U.S. Side

To evaluate the potential effectiveness of implementing advanced information technology at the Peace Bridge, this chapter considers a variety of scenarios for the U.S. side of the bridge, ranging from base case conditions to extensive market penetration of the new technology. Both eastbound and westbound impacts are examined, for trucks and autos. Experimentation with changes in facility configuration lets us see how improvements in resource utilization might also be achieved.

To make the scenario investigations as realistic as possible, we selected three days from 1997 to act as the case study settings. June 26, August 19, and August 28 were chosen because of their traffic flow conditions. For each of these days, and for every scenario, three replications of the simulation have been conducted, so that run-to-run variations in the simulation experiments can be averaged out. The resulting average statistics have been used to give us an indication of the trends in system performance that might arise.

5.1 Case Study Conditions

To select the case study days, toll data were obtained from the Peace Bridge for calendar year 1997. These data contain truck volumes for both directions and westbound auto volumes (exiting the U.S.). Autos do not pay tolls coming eastbound. The data were available for 297 days, or 8 1% of the year. The missing days appear to be randomly distributed throughout the year, so no apparent seasonal bias exists.

The raw data, daily counts of vehicles by toll category, were summed to yield five main pieces of information: date, total eastbound trucks, total westbound trucks, overall total trucks and total westbound autos.

From these data, we calculated each day’s percentile position with respect to total truck volumes (both directions) and westbound auto volumes. For example, we discovered that August 2 1 ranked as the 91st percentile day with regard to truck volumes and the 75th percentile day regarding westbound auto volumes. In general, the truck volumes were highest during the week (especially Tuesday, Wednesday and. Thursday) while the auto volumes were highest on weekends and holidays.

Figure 5-l shows a plot of the car and truck traffic volumes for the 297 days. Each point is a specific day, plotted on the basis of its westbound auto volume (the X-axis) and total (bi-directional) truck volume (the Y-axis).

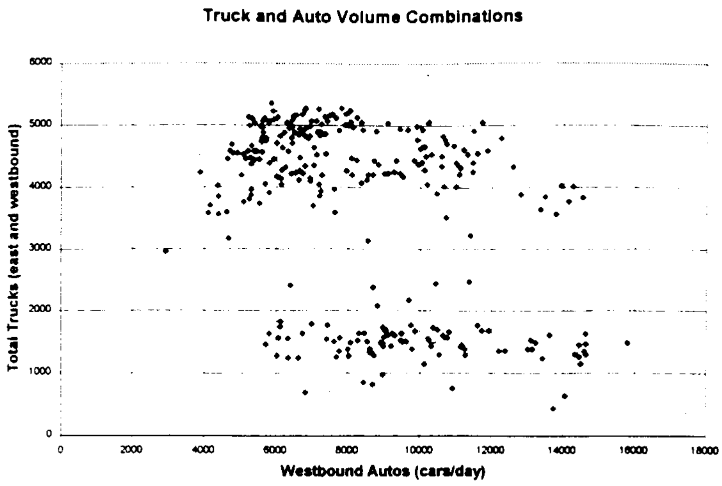

Figure 5-1. Traffic Combination Trends

From the plot, weekday-weekend tendencies in the traffic volume patterns are quite apparent. For the trucks, the volume on the weekdays is 4,000-5,000 while on weekends and holidays it drops to 1,000-2,000. Very few days have values in-between. For the auto traffic, on the other hand, a more continuous distribution exists, with slightly higher volumes on weekends and holidays.

From among all of these days, our objective was to find a select few where the truck and auto volumes were both high (in the upper right part of Figure 5-1), so that the simulation tests would focus on conditions for which the systems is "stressed."

Table 5-1 shows 20 days we identified as candidates. In each case, the truck and auto volumes are at or above the 50th percentile and the difference between them is less than 20 percentile-points. The first column shows the date, as in 8-21-97 for the first record. The second column shows the total westbound auto volume while the third through fifth show the eastbound, westbound, and total truck volumes. Columns 6 and 7 show the percentile ranking of the day based on the westbound autos and the total trucks. The "Day" column indicates the day of the week with "R" indicating a Thursday.

Table 5-1. Candidate Days for Analysis

date	Car-Total	Trk-East	Trk-West	Trk-Total	Car-Pctle	Trk-Pctle	Day
TF082197	10227	2541	2521	5062	75.3%	90.5%	R
TF082897	11721	2404	2648	5052	89.1%	89.8%	R
TF081397	10206	2500	2540	5040	75.0%	88.5%	W
TF082797	9890	2435	2555	4990	70.9%	85.8%	W
TF062597	9422	2484	2466	4950	66.5%	83.1%	W
TF082697	9642	2440	2498	4938	68.9%	82.4%	T
TF081297	10056	2466	2470	4936	72.6%	82.0%	T
TF081497	11482	2382	2531	4913	88.1%	81.0%	R
TF081997	10620	2379	2455	4834	79.3%	76.6%	T
TF080797	12252	2409	2387	4796	90.8%	75.0%	R
TF062697	9897	2346	2428	4774	71.2%	73.6%	R
TF072397	10682	2379	2389	4768	80.7%	73.3%	W
TF072497	10728	2249	2464	4713	81.4%	71.2%	R
TF071697	10930	2340	2338	4678	82.7%	70.6%	W
TF072297	10069	2359	2307	4666	72.9%	69.9%	T
TF082097	10114	2215	2449	4664	73.3%	69.5%	W
TF071597	9986	2257	2376	4633	71.9%	68.5%	T
TF073097	11202	2315	2298	4613	85.4%	68.2%	W
TF070997	10304	2250	2292	4542	76.3%	64.5%	W
TF090597	10152	1876	2634	4510	74.3%	62.8%	F

We selected three of these days for the case study conditions. They are August 28 (a Thursday), August 19 (a Tuesday), and June 26 (a Thursday). They are days when the traffic volumes are nearly matched, and, in combination, they cover a range of conditions. The first, August 28, represents 90th percentile conditions for both trucks and cars. August 19 is approximately the 76th percentile for trucks and the 79th percentile for autos. June 26 is at the 73rd percentile for trucks and the 71st percentile for autos. June 26th represents a more "typical busy" day, while August 28th represents a "very heavy" day, i.e., one when the auto and truck volumes were both at very high levels simultaneously. In fact, there is no other day in 1997 when the truck and auto volumes were at higher levels simultaneously, i.e., at or above the 90” percentile for both.

We created input files to represent arrival patterns for both trucks and automobiles across the day for each of these three days. This creates a set of base case experimental conditions for the simulation.

5.2 Scenario Definitions

Ranging from the base case to conditions-of high penetration and deployment, a set of scenarios was developed for impact investigation. As summarized in Table 5-2, each one is a particular penetration rate for the technology and a specific facility configuration.

Scenario 1 (S1), the base case, reflects existing conditions. For the trucks, there is no ITBCS participation (eastbound) and the existing pattern of toll payment is assumed (42% card swipe). Two lanes are always open eastbound, and a third is opened when the truck queue is long. Westbound. two toll lanes are just for trucks, and third one is shared with autos. In addition to the one shared auto/truck lane, autos also have one other cash lane and four token-only lanes.

Scenario 2 has two variations, S21 and S22. In both instances, the main feature is common: the level of ITBCS use. It is 20% for trucks and 35% for autos. The difference pertains to the number of eastbound lanes available for ITBCS use by autos. In S21, one ITBCS lane is employed while in S22, two are available. For westbound traffic in scenarios 21 and 22, it is assumed that the 35% auto participation in ITBCS is converted entirely from token traffic, so that the remaining 65% of the autos are still cash toll payers. The 20% truck participation in ITBCS is assumed to come entirely from former charge customers, reducing the charge percentage to 22% of the truck traffic stream.

Scenario 3 also has two variations, S31 and S32. Eastbound, they are the same, but westbound, for trucks. they are different. In S3 1, three truck booths are available for mixed use (cash and ITBCS) while for S32, an additional fourth booth is available for ITBCS-only use. In scenarios 31 and 32, the auto ITBCS participation level is 50%, and the remaining 50% of cars are assumed to be cash toll payers. The truck ITBCS participation is also 50%, with the remaining 50% assumed to pay cash for tolls.

5.3 Postulated Processing Times for ITBCS Experiments

The prototype system implemented at the Peace Bridge to test the ITBCS technology was designed to require dual processing (both paper and electronic) of equipped trucks entering the U.S. and relied on data stored in a Customs computer in Washington, rather than on-site at the Bridge. For both of these reasons, the actual data collected in the field on processing times at primary inspection provide no useful indication of the potential of the ITBCS technology to reduce delays to entering trucks. A more complete description of the actual field data collected, and its analysis, is contained in Appendix A. However, for the purposes of the simulation experiments, it was necessary to postulate service time distributions for primary inspection of ITBCS-equipped trucks.

Table 5-2. Scenario Definitions

US-EASTBOUND

Scenario	Trucks	Autos
Sl	0% ITBCS 1st & 2nd lanes in constant use, 3rd lane use depends on demand	20% AutoPass use 1 designated AutoPass lane 5 regular lanes
S21	20% ITBCS participation, proportionally drawn from all truck types; 1st & 2nd lanes, mixed use; 3rd lane. no ITBCS	35% ITBCS participation 1 designated ITBCS lane 5 regular lanes
S22	20% ITBCS participation, proportionally drawn from all truck types; 1st & 2nd lanes, mixed use; 3rd lane, no ITBCS	35% ITBCS participation 2 designated ITBCS lanes 5 regular lanes
S31 , S32	50% ITBCS participation, proportionally drawn from all truck types; 1st & 2nd lanes, mixed use; 3rd lane, no ITBCS	50% ITBCS participation 2 designated ITBCS lanes 5 regular lanes

US-WESTBOUND

Scenario	Trucks	Autos
S1	0% ITBCS muticipation.42% card swipe Three booths with-mixed use, the 3rd is' shared with autos cash	35% token use 4 token booths 2 cash booths (1 shared w/ trucks)
S21, S22	20% ITBCS participation, 22% card swipe Three booths with mixed use, the 3rd is shared with autos cash	35% ITBCS participation 4 designated ITBCS lanes 2 mixed use booths (1 shared w/ trucks)
S3l	50% ITBCS participation, 0% card swipe Three booth with mixed use, the 3rd is shared with autos cash	50% ITBCS participation 4 designated ITBCS lanes 2 mixed use booths (1 shared w/ trucks)
S32	50% ITBCS participation, 0% card swipe Two booths with mixed use; the 3rd is shared with autos cash, plus one booth for ITBCS only	50% ITBCS participation 4 designated ITBCS lanes 2 cash-only booths (1 shared w/ trucks)

Notes:
1. Truck ETC toll delay : 5 seconds
2. Auto ETC toll delay : 2 seconds
3. Eastbound auto primary failure rate: 0%

For the simulation tests in this chapter, the eastbound toll collection time for ITBCS-equipped trucks is assumed to be equivalent to the current charge card times (a mean of 15.45 seconds). This is a conservative assumption (i.e., the actual performance of an electronic toll collection system is likely to be better), but because the eastbound toll booths are in line with the primary inspection booths and primary inspection takes longer than paying the toll, the toll collection time has very little effect on the queuing delays at the primary line. Thus, the assumption made for toll collection time has very little effect on overall system performance.

For primary inspection, the "high performance" system described in Chapter 4 is assumed. That is, the processing time distribution at primary inspection for ITBCS-equipped trucks is assumed to be 17 + UNIF(.5,15) seconds, with a 1% failure rate on the read from the transponder. Trucks whose transponders are not read correctly are referred to the warehouse in the secondary area. This processing time distribution has a mean value of 27 seconds, as compared to means of about 36 seconds for monthly/empty/in-transit trucks, 55 seconds for C4 trucks, and 57 seconds for General trucks. This represents a substantial reduction in average primary processing time for trucks that adopt the ITBCS technology.

For automobiles, the primary inspection time for transponder-equipped vehicles in the dedicated commuter lane (DCL) is assumed to be the same as the distribution currently observed in the AutoPass lane, with a mean value of 7.2 seconds, as compared to a mean value of 25.7 seconds in the regular lanes.

5.4 Simulation Results for System Performance

This section presents the findings from the scenario investigations. Individual subsections focus on eastbound trucks, eastbound cars, and westbound traffic. As might be expected, the impacts for eastbound cars and trucks are more dramatic, since substantial decreases in processing time are involved. For westbound cars and trucks, the changes in system performance are less dramatic, although the simulations show that introducing dedicated lanes is a reasonable option.

5.4.1 Eastbound Trucks The change in system performance for eastbound trucks is quite dramatic, as shown in Table 5-3. The table shows average and 90th percentile times in system averaged across the three case study days. From scenario S1 to S32 we see a 66% decrease in the average time, and a 78% decrease in the 90th percentile time. Clearly the ITBCS technology produces significant benefits for overall eastbound time-in-system.

Table 5-3. Time in System for Eastbound Trucks

Scenario	Avg	90%
S1	932	3005
S21	563	1715
S22	530	1650
S31	338	786
S32	321	677

In part, this is due to major changes in secondary inspection. As Table 5-4 shows, the number of trucks sent to secondary inspection drops 64% from 90 to 33, and the times in secondary inspection are reduced significantly. The average falls 34% from 2873 seconds to 1838, and the 90th percentile time drops 3 1% from 4829 seconds to 3362.

Table 5-4. Secondary Processing Times for Eastbound Trucks

Scenario	Count	Avg	90%
S1	90	2873	4829
S21	61	2119	3932
S22	60	2009	3620
S31	31	2020	3901
S32	33	1838	3362

Primary inspection delays also fall dramatically. As Table 5-5 indicates, the average time in primary inspection drops 64% from 225 seconds to 8 1, and the 90th percentile time falls 68% from 407 to 129. (Variations between S21 and S22 are due only to randomness in the simulation, since the same system configuration exists in both conditions for eastbound trucks. The same pertains to S31 and S32.)

We can gain a sense of the consistency in these results by viewing Figure 5-2. It shows the average times in system for the three case study days, and all scenarios. The trends across scenarios persist regardless of the day considered. Scenario S1 always produces the largest times, S21 and S22 are better and comparable, and S31 and S32, are similarly better yet, and comparable.

Table 5-5. Primary Inspection Delays for Eastbound Trucks

Scenario	Avg	90%
S1	225	407
S21	118	192
S22	128	212
S31	83	134
S32	81	129

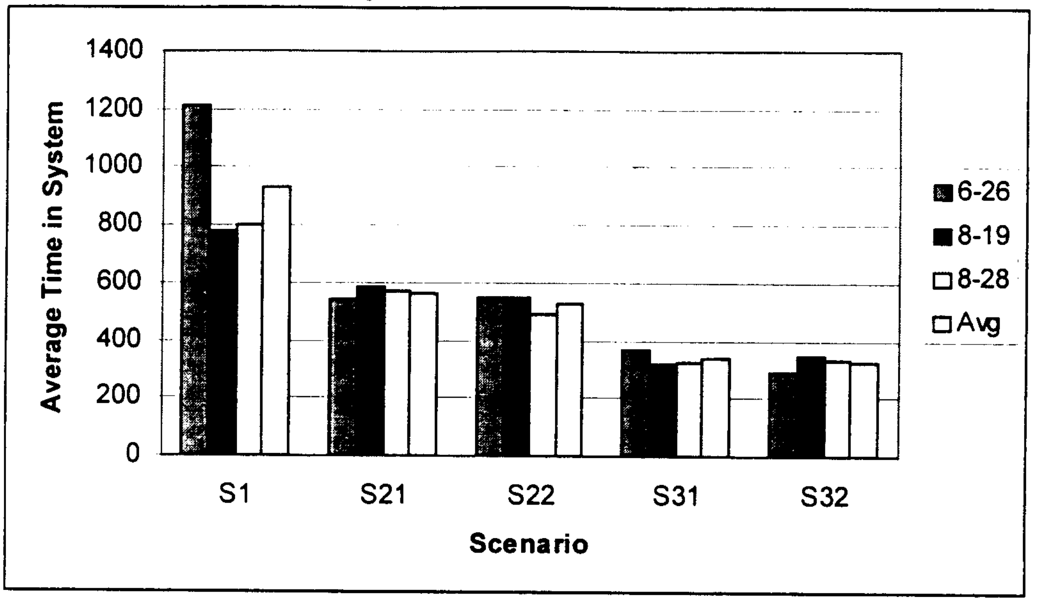

Figure 5-2. Average Time in System for Eastbound Trucks.

Table 5-6. Eastbound Auto Time in System

Scenario	Avg	90%
S1	166	295
S21	152	263
S22	120	190
S31	108	155
S32	108	155

5.4.2 Eastbound Autos The change in system performance for eastbound autos is also dramatic, as shown in Table 5-6. From Scenario S1 to S32, average time in system drops 35% from 166 seconds to 108. The 90^{th} percentile time drops even more, 48% from 295 seconds to 155. Again, the ITBCS technology produces significant benefits. Moreover, there are significant differences between S21 and S22. Remember that in S21, there is one designated ITBCS lane, while in S22 there are two. That extra lane produces a 21% drop in average time in system, and a 28% decline in the 90^{th} percentile time in system. Considering that this benefit accrues to all system users, primarily due to a decrease in time in queue waiting to reach primary inspection, the benefits should be carefully weighed against the costs of providing the second ITBCS booth.

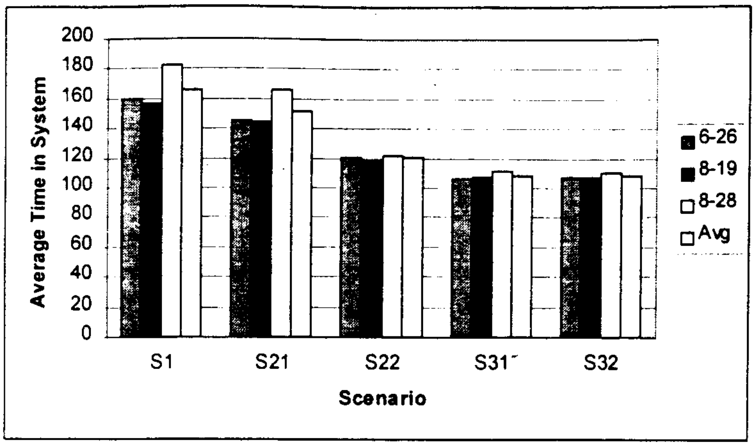

Figure 5-3. Average Time in System for Eastbound Autos

Again we can gain a sense of the consistency in these results by considering each case study day, as shown in Figure 5-3. Very little day-to-day variation exists, although August 28th, the busiest day, here shows the largest average times in system among all case study days.

Trends among the scenarios echo the results from Table 5-6. S1 has the highest times, while S21 is slightly better. A substantial change exists between S21 and S22, due to the extra ITBCS booth. S31 and S32 are "identical" in performance, and reflect the benefits of the 50% ITBCS penetration rate (and the two ITBCS booths).

5.4.3 Westbound Trucks and Autos For westbound trucks and autos, the changes across the scenario experiments are quite small. As Table 5-7 shows, the average and 90th percentile times decrease by only a few seconds among the scenarios. We can understand this set of results by considering the situation in the base case (scenario S1).

Table 5-7. Westbound Time in System

	Trucks		Autos	
Scenario	Avg	90%	Avg	90%
S1	105	132	89	117
S21	103	131	87	115
S22	103	131	87	116
S31	99	127	83	110
S32	101	133	83	110

The arrival rate for autos during the middle parts of the day for the simulated days is about 600 vehicles/hour. About 35% of this traffic uses the token-only booths and 65% uses the cash booths. Thus, in the token lanes, the arrival rate is about 210 vehicles/hour, or 0.058 vehicles/second. The service rate (combined) of the four token lanes is about 0.89 vehicles/second (four booths operating with an average service time of 4.5 seconds, as discussed in Chapter 3). Thus, the service intensity (or utilization) of the system is only about $\rho = 0.058/0.89 = 0.065$. From basic queuing theory, this means that about $100(1-\rho)$ percent (93.5% in this case) of the time, there is at least one open lane with no queue. Hence, the waiting time for token-paying autos is extremely small, even in the base case, and the portion of the time-in-system for actually paying the toll is only about 5 seconds.

For cash-paying autos, the arrival rate is about 390 vehicles/hour, or 0.108 vehicles/second. These autos use two lanes, one of which is shared with trucks. The average service time for autos paying cash is about 8 seconds, as discussed in Chapter 3. If we assume that the aggregate service rate is equivalent to 1.5 lanes operating with an average service time of 8 seconds, the average service rate is about 0.188 vehicles/second, for a utilization level of $\rho = 0.108/0.188 = 0.57$. At this service rate, and with a standard deviation of service times equal to 9 seconds (see

Chapter 3), queuing theory indicates the average number of vehicles in queue should be about 0.9, and the average delay for paying the toll (wait in queue plus actual service time) is about 16 seconds.

The simulation shows an average time-in-system of 89 seconds for scenario S1, but only about 12 seconds (the weighted average of 5 and 16, from the analysis above) is due to toll paying. The remainder of the time is mostly the delay for the traffic light at the end of the ramp from I-190, which also affects entrants from Moore Drive. Implementation of ETC technology thus has no effect on the bulk of the delay incurred by westbound autos. It can only affect the portion of the delay associated with paying the tolls. For scenarios 21 and 22, this is limited to reducing the service time for token-paying cars (4.5 seconds) to that of ETC cars (2 seconds), for an overall effect of only about 2-3 seconds, and this is what the simulation results show. For scenarios 31 and 32, there is additional change in the traffic mix for autos, with more of them incurring smaller delays, but still the net result is only a few seconds on average.

For trucks, we can do a similar assessment. In the base case (scenario Sl), the truck arrival rate during the peak part of the day is about 140 trucks/hour (0.039 trucks/second), 42% of them paying with a charge card, and 58% paying cash. In Chapter 3, we estimated average service times of approximately 15 seconds for charge payments and 26 seconds for cash payments. A weighted average service time estimate is thus 0.42(15) + 0.58(26) = 21.4 seconds. If we assume an equivalent of 2.5 effective lanes, this equates to an aggregate average service rate of 0.117 trucks/second. The service intensity is thus about r = 0.039/0.117 = 0.33.

Queuing theory suggests then that the average number of trucks in queue should be about 0.1, and the average time-in-system for toll collection should be about 24 seconds. This is approximately 12 seconds higher than for autos (the simulation indicates 16 seconds difference). This estimate is generally consistent with the implication that about 80 seconds of the total time-in-system measured by the simulation is due to maneuvering up the ramp from I-190 and delay at the traffic signal.

The implementation of ETC for trucks reduces the average service time from 21.4 seconds to about 19.4 seconds in scenarios S21 and S22, and to about 15.5 seconds in Scenarios S3 1 and S32, but it cannot affect the bulk of the time, which is associated with the traffic signal delay. The reductions of 2-6 seconds in average service time for trucks is almost exactly what the simulation shows as the effects of the scenarios in Table 5-7.

CHAPTER 6

Modeling Peace Bridge Operations in Canada

The simulation model for the Canadian side of the Peace Bridge focuses on the processing of trucks and automobiles in the westbound direction (entering Canada). In the current configuration of the facilities at the Peace Bridge, there are no processing activities for cars or trucks leaving Canada – they simply drive onto the bridge. There has been discussion of possible changes at the bridge to implement some processing of eastbound trucks on the Canadian side, but these proposals are not reflected in the current simulation model. This chapter describes the processing logic and the simulation software environment in which the model has been implemented.

The logic described here reflects the ARENA model that has been developed. ARENA is a commercially available simulation modeling environment (Systems Modeling Corp., 1996). ARENA provides an attractive way to define the vehicle types, the processing steps involved, the logic that governs processing, and the resource requirements involved. It also provides animation capability and automated statistics collection. The animation allows a user to watch the simulation run in progress, and the automated statistics collection allows convenient summarization of important model outputs.

6.1 Facility Layout

Figure 6-1 presents the facility layout, as it is represented in the simulation model. North is at the bottom of the diagram and East is at the left.

Vehicles coming from the U.S. enter the facility at the left, as they depart the bridge. Trucks turn right and travel via the serpentine exit ramp to the primary customs inspection area. Autos continue straight ahead and join one of the queues waiting for customs clearance at the line of booths in the middle of the diagram. Autos sent to secondary inspection move to the administration building to the right of and beyond the primary inspection booths. Trucks turn left as they leave primary inspection and, if directed to secondary inspection, proceed to the parking lot opposite the customs building. Once a truck has been cleared for entry, either from primary or secondary inspection, it exits via Walnut Street and proceeds to the Queen Elizabeth Way (QEW) or the ramp for Fort Erie. Similarly, cars, once released proceed toward the right-hand side of the picture and exit to the QEW or Fort Erie.

Vehicles leaving Canada arrive from the QEW or Fort Erie at the right hand side of the facility. They pass through without stopping and move from right to left toward the bridge. If processing activities are initiated for such traffic on this side of the bridge, the model is prepared to accommodate it, but that future activity is not currently being modeled.

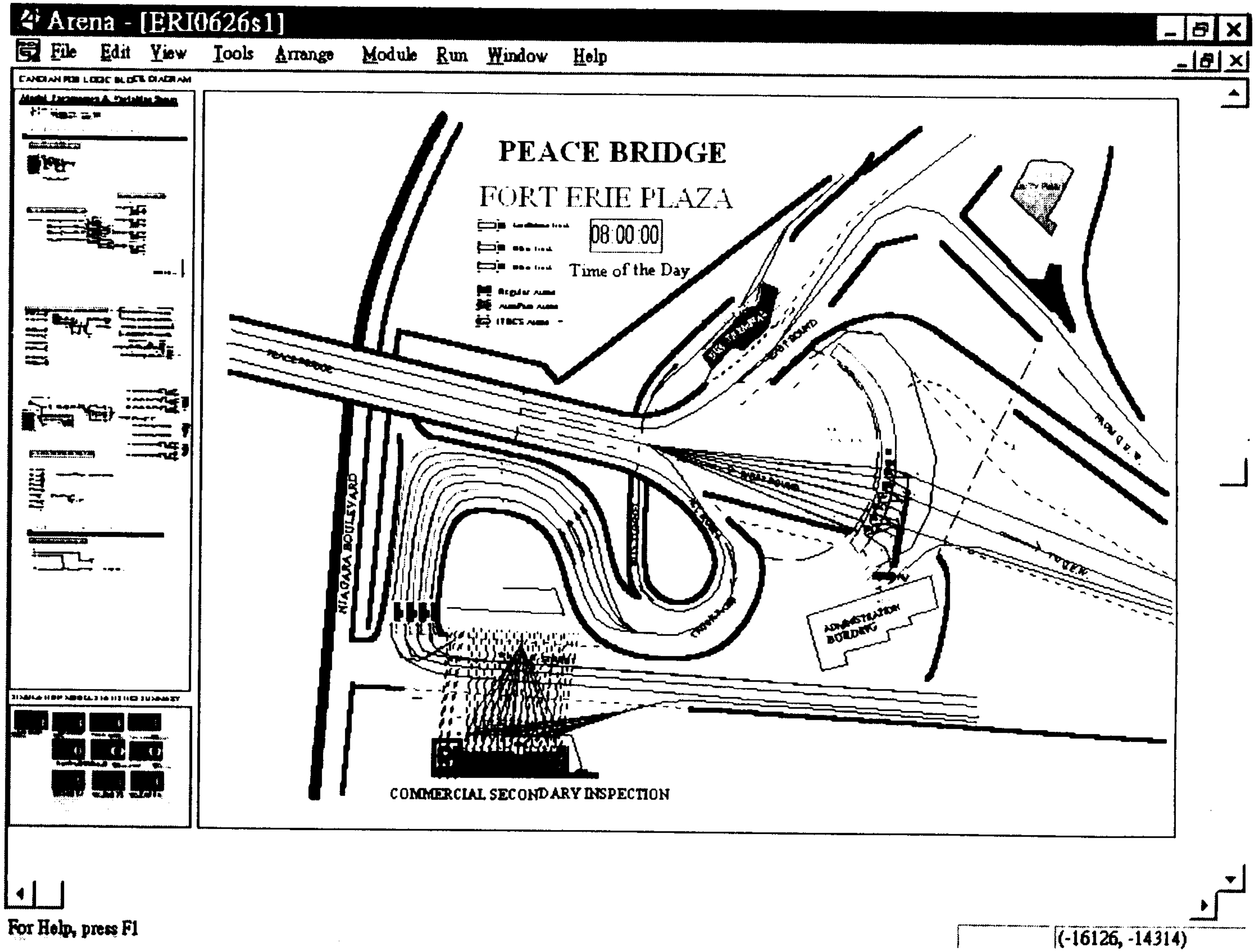

Figure 6-1. Peace Bridge Canadian plaza simulation model layout.

6.2 Vehicle Types

Both trucks and autos are included in the model. Buses are not included because they are a minor portion of the total traffic. For the trucks, three categories exist (Y-28, *ITBCS, ROL).* Autos are divided into two categories *(ITBCS and Regular).* For each of these, the model has the following attributes:

- percentage breakdown by category;
- primary inspection time probability distribution;
- secondary processing time probability distributions; and
- likelihood of being referred to secondary inspection.

In addition, for trucks, there is a probability of being subjected to a cargo inspection as part of the secondary inspection.

The truck categories are defined as follows:

1. Y-28: Y-28 trucks are sent to the warehouse (secondary area) by the primary customs inspectors. This categorization of the truck actually represents the decision made by the primary inspector. If the inspector decides the truck must be referred to the warehouse, he/she will issue a Y-28 form to the driver to take into the warehouse. Unlike the U.S. operation, no simple correspondence exists between the classification of the trucks and the types of loads being carried. In terms of service times, the Y-28 trucks take longer to process than the others (see below) because paperwork must be completed once the primary inspector has decided that the truck is to be referred to the warehouse.
2. *ROL:* Trucks in this category are released-on-line (hence, ROL) at the primary inspection booths. They are not referred to the warehouse for secondary inspection. Since there is no paperwork to complete in preparation for a secondary inspection, these trucks have a shorter service time at primary inspection than do the Y-28's.
3. *ITBCS:* These trucks are the focal point of our impact investigation. They are assumed to have been given an information technology upgrade so that the customs and toll collection processing can be expedited. They are drawn proportionally from the Y-28 and ROL categories.

Autos entering Canada fall into one of two categories based on their treatment by Customs:

1. *Regular.* This category captures all current autos. The occupants of the car must be cleared by Customs Inspectors in the regular auto lanes before entering Canada.
2. *ITBCS (CanPass).* These vehicles carry people have been pre-cleared for entry into the Canada and can identify themselves electronically in that regard. Predominantly, they are people who live in the U.S. but work in Canada (or vice versa) and cross the border regularly at the Peace Bridge.

6.3 Vehicle Processing

The model contains processing logic for trucks and cars moving westbound (entering Canada) and eastbound (leaving Canada), but the principal focus is on vehicles entering Canada. The times for the various activities are represented in the model by probability distributions. For example, the model specifies a time between successive truck arrivals. As the simulation runs, inter-arrival times are sampled from a specified probability distribution. The process of specifying these various distributions, and estimating their parameters, is a vital part of building a successful simulation. This process is discussed in detail in Chapter 7.

6.3.7 Inbound Trucks Figure 6-2 presents a macro-scale representation of the processing logic for trucks moving westbound, entering Canada from the U.S. The "CREATE" block is for the arrival of trucks as they leave the bridge. Trucks are randomly designated as being ITBCS, Y28 or ROL, dependent upon the proportion of ITBCS participation being examined. Autos are randomly assigned to the ITBCS or Regular categories using proportions specified by input parameters.

Once a truck reaches primary inspection, its service time is sampled from the appropriate time distribution (Y28, ITBCS or ROL). Three primary inspection booths are always open and can accommodate both ITBCS and non-ITBCS trucks. If clearance to enter Canada has been obtained, the vehicle leaves the system; otherwise it is referred to the warehouse, or secondary inspection area.

If a secondary inspection is stipulated, the truck moves to the parking lot across from the Customs building. Each truck that enters secondary inspection follows the same logic and uses the same service time distributions. No differentiation is made by the type of load carried. (No suitable data exist for doing so.) After the truck is parked, the driver finds the broker who can help him/her complete the paperwork for the load. After the broker finishes his/her work, the driver delivers the paperwork to the reception counter in the Customs office and waits for his/her name to be called. Inside the Customs office, an inspector reviews the documentation and determines whether the load is to be released or a cargo inspection is to be ordered. All of these activities are represented in Figure 6-2 by the "Delay on Inspection" block which is modeled as a probability distribution of delay time.

If no cargo inspection is to be performed, the driver is released and the truck leaves the facility. If a cargo inspection is required, the driver then moves the truck to an empty bay at the Customs building. Meanwhile, the Customs inspector deals with other tasks like reviewing the paperwork for other trucks. When the truck is ready for inspection, the same Customs inspector who originally reviewed the paperwork for the load must conduct the inspection. Shipments that fail the cargo inspection are then impounded until the problems identified are rectified.

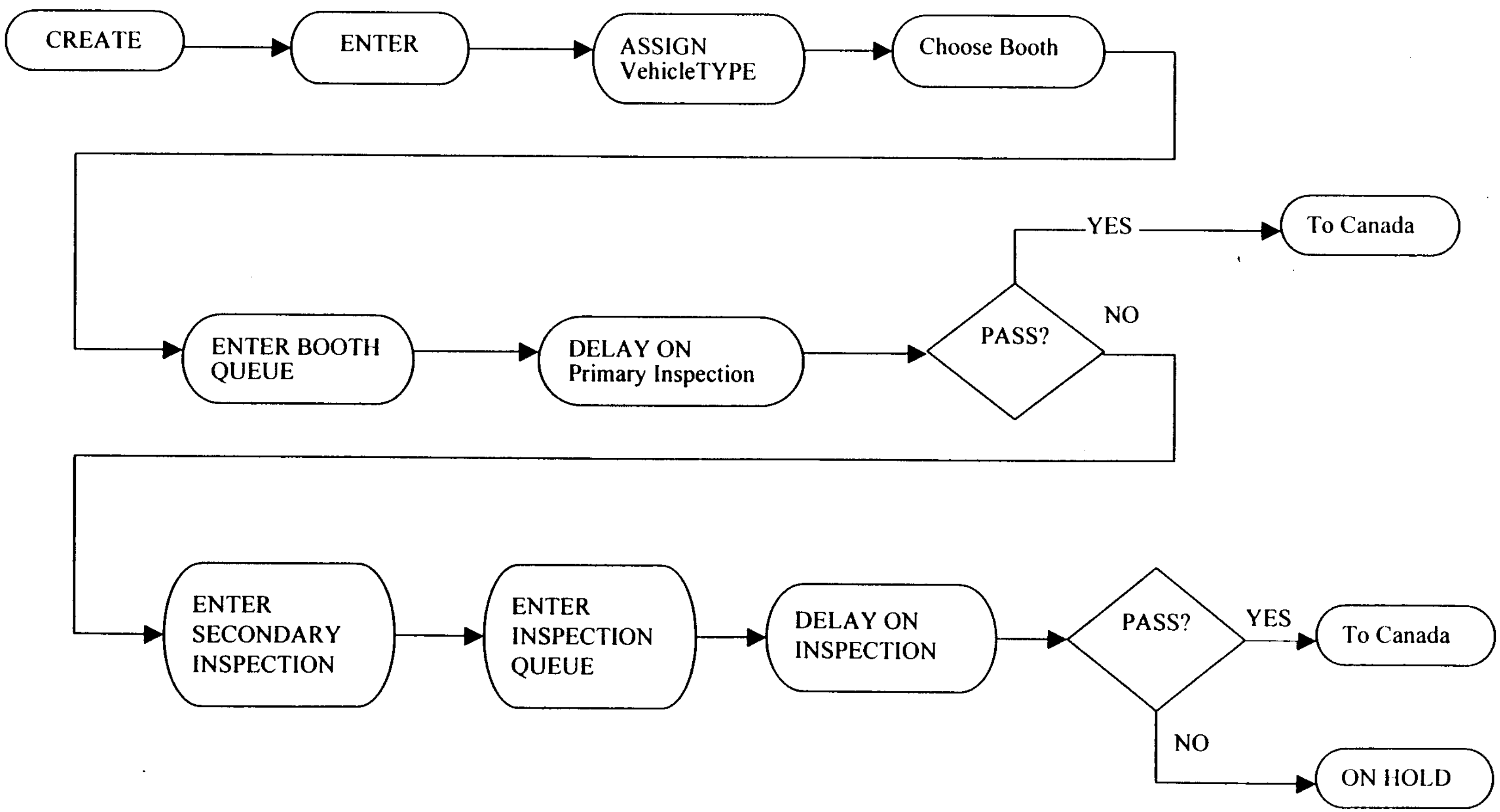

Figure 6-2. Westbound vehicle processing logic for Canadian model.

6.3.2 Inbound Cars *The* processing logic for inbound automobile traffic is very straightforward. After a vehicle is "Created" a vehicle type designation is given. The choices are Regular or ITBCS, and the proportion depends on the scenario being explored. This type assignment determines which lanes can be used by the vehicle as it enters primary inspection. The delay at primary inspection depends on the vehicle type. If an automobile fails primary inspection, it is referred to a secondary area near the Administration Building shown in Figure 1, and it is subject to an additional delay.

6.3.3 Outbound Trucks and Cars Outbound trucks and cars are given service times for passing through the system. No other processing is performed. If at some juncture, pre-processing of U.S. bound traffic occurs in Canada, a representation of this activity will need to be added to the model.

6.4 Impact Assessment

Four main performance measures are used in the model to evaluate the effectiveness of introducing advanced information technology. They are:

- the time required for a vehicle to go through the entire crossing process (time in system), in aggregate, and disaggregated 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 Customs inspectors.

These measures provide considerable insight into the system's performance.

A collection of scenarios is used to explore the impacts of introducing advanced information technology. These are described in Chapter 8. Market penetration rates are a major element, both in total and by category. This affects primary inspection processing times, toll payment times, and the likelihood that vehicles (trucks especially) will be sent to secondary inspection.

CHAPTER 7

Calibration and Vakdation of the Canadian Side Model

There are several basic processes on the Canadian side of the bridge that require parameter estimation in order to calibrate the simulation model. These processes are similar to those on the U.S. side of the bridge, but some of the operations are different and require separate parameter estimates. The processing time distributions of interest on the Canadian side of the Peace Bridge are as follows.

<u>Trucks</u>

1. Distribution of time required for primary inspection for trucks entering Canada
2. Truck delay times in the secondary area

Cars

1. Distribution of time required for immigration inspection for cars entering Canada

In addition to these processing time distributions, there are other parameters required by the simulation. These include the proportions of trucks in various classes entering Canada, the probability that a truck will be released on-line at the primary inspection, and the probability that a physical inspection of the cargo will be required.

The estimates of the probability distributions for processing times and the various other parameters of the simulation have been constructed from a combination of videotape analysis, direct data recording by Revenue Canada, and processing of standard operations data collected by Revenue Canada. Sections 7.1 - 7.4 describe the analysis.

In the Canadian model, it has been assumed that the arrival processes of both cars and trucks across the Bridge from the U.S. are Poisson (with rates that vary by time-of-day). We have expended considerable effort to verify the Poisson assumption on the U.S. side (see Chapter 3) and, having found it to be accurate, we have maintained the assumption for the Canadian side.

Section 7.5 discusses validation experiments with the Canadian model.

7.1 Truck Categories and Proportions

Canada Customs reports incoming cargo shipments in at least a dozen different categories, but more than 95% of incoming shipments (excluding in-transit cargoes not actually entering Canada) are in one of three major categories:

PARS	(Pre-Arrival Release System)
FIRST	(Frequent Importer Release System)
RMD	(Release on Minimum Documentation).

PARS shipments have had documentation filed (either electronically or on paper) prior to arrival at the border, so that a tentative decision on whether or not to release the shipment for entry has already been made when the truck arrives at the primary inspection line. Most of these shipments are released directly from the primary inspection line. The FIRST program is similar to the C4 program on the U.S. side (see Chapter 2), and includes shippers who make regular, low risk shipments into Canada. These shipments are also normally released directly from the primary inspection line. RMD shipments require processing by Customs agents in the warehouse and are not released directly from the primary inspection line.

It is important to note that Canada Customs reports release statistics by *shipment,* not by *truck*. This complicates the estimation of categories of trucks entering Canada because one truck may carry more than one shipment.

For purposes of simulation, however, the important distinctions among trucks entering Canada are related to two characteristics:

- The processing time at the primary inspection line; and
- The probability of referral to the warehouse for further processing.

If a truck is referred to the warehouse, a specific form (Y28) must be filled out and given to the driver by the inspector in the primary booth, and this extends the processing time at the primary line. Our detailed analysis of primary inspection times on the U.S. side indicated that the major difference across categories is between trucks that require very little processing by the primary inspector (empties, in-transits, auto carriers, etc.) and those that require more attention and a decision on whether or not to refer the truck to the warehouse. This also appears to be true on the Canadian side, and thus we have modeled incoming trucks in two categories on the Canadian side – those that require a Y28 form and referral to the warehouse, and those that can be released directly from the primary line (denoted release-on-line, or ROL trucks).

Data from Canada Customs indicates that over the four-month period January-April, 1998, Y28 forms were issued for about 28% of entering trucks, and we have used this percentage breakdown between categories in the model.

7.2 Processing Time at the Primary Inspection Line

For the 72% of trucks that are released on-line at the primary booths, the processing time in the simulation is the same distribution used for empties, in-transits, etc. on the U.S. side:

$$\text{Service time (seconds)} = 9.5 + \text{Erlang}(18.2, 2)$$

That is, the service time for primary processing is a random variable that is represented by an offset Erlang-2 distribution. The offset (minimum processing time) is 9.5 seconds, and the Erlang-2 distribution has a scale parameter of 18.2, implying that the overall average service time is 45.9 seconds (2* 18.2 + 9.5), and the standard deviation is 25.7 seconds.

For the 28% of trucks that are referred to the warehouse (Y28), the service time at the primary inspection line is the same distribution used for the General category of trucks on the U.S. side:

$$\text{Service time (seconds)} \quad = \quad 10 + \text{Erlang}(23.4, 2)$$

This distribution has a mean of 56.8 seconds, and a standard deviation of 33.1 seconds.

Figure 7-1 illustrates the two distributions.

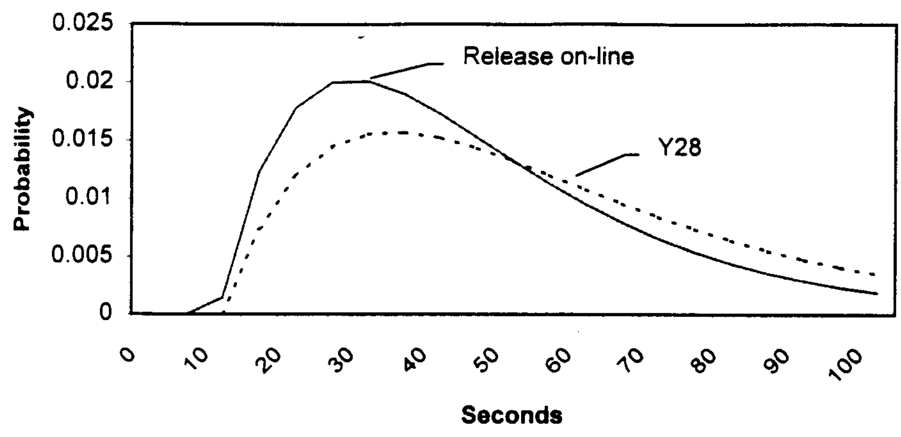

Figure 7-1. Distributions of primary inspection time.

7.3 Delay Time in the Secondary Area

In May, 1998, Revenue Canada performed an audit of processing times for RMD trucks in the Customs Warehouse. The data collected serves as the basis for estimating a distribution of time at Customs for trucks referred to the warehouse on the Canadian side. A total of 120 observations were provided by Canada Customs. For this analysis, we have used the total time from submittal of paperwork to notification of the driver as an estimate of service time, and we have constructed an $M/G/\infty$ queuing model to represent the total delay to trucks referred to the warehouse.

Summary statistics for the observed data collected by Canada Customs are as follows:

Mean =	18.5	minutes	10^{th} percentile =	6 minutes
Std. Deviation =	9.6	minutes	25^{th} percentile =	11 minutes
			50^{th} percentile =	17 minutes
			75^{th} percentile =	23 minutes
			90^{th} percentile =	33 minutes

Figure 7-2 shows a plot of the observed data, organized as an empirical cumulative distribution function (CDF). The empirical CDF is nearly linear from approximately 5 minutes to 23 minutes, including approximately 75% of the observations. From 23 minutes to the maximum observed time of 49 minutes, the empirical CDF shows a different, somewhat nonlinear, character.

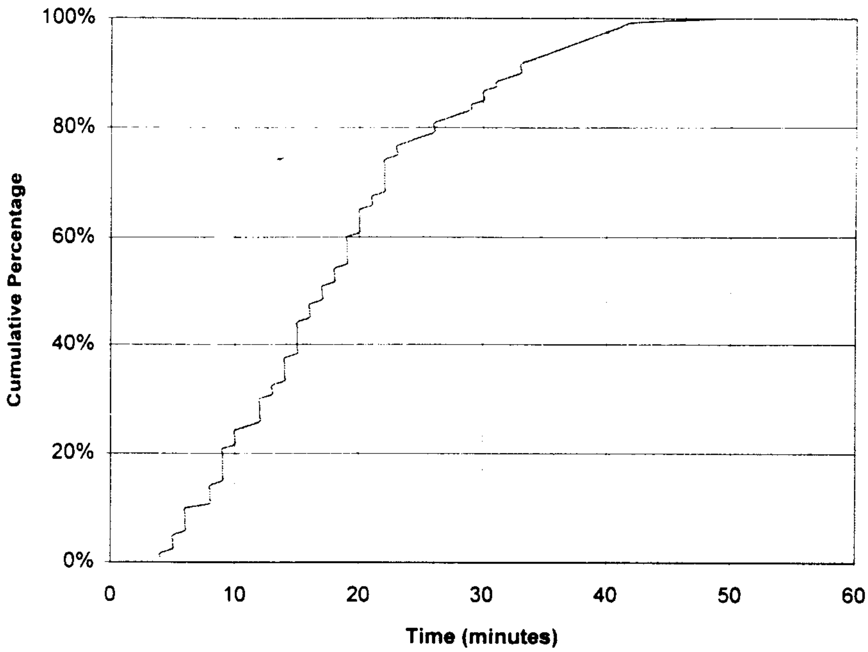

Figure 7-2. Cumulative distribution of total service time at the warehouse.

This observation has led us to construct an approximation for use in the simulation that is uniform from 5 to 23 minutes, and then has a triangular "tail" from 23 minutes to 50 minutes, as shown in Figure 7-3. The uniform portion has an area of 0.75, and the triangular portion an area of 0.25. The maximum value on the triangular portion is set at 50 (the maximum observed time is 49).

This distribution has the following summary characteristics:

Mean =	18.5	minutes	10^{th} percentile =	7.4 minutes
Std. Deviation =	9.55	minutes	25^{th} percentile =	11 minutes
			50^{th} percentile =	17 minutes
			75^{th} percentile =	23 minutes
			90^{th} percentile =	30.3 minutes

The mean, the standard deviation, and the middle three percentile values are very close matches to the observed data. The 10^{th} percentile value is a little larger than the observed value, and the 90^{th} percentile value is a little smaller than the observed value. However, on the whole, this distribution seems to reflect the observed data relatively well, and is suitable for the simulation.

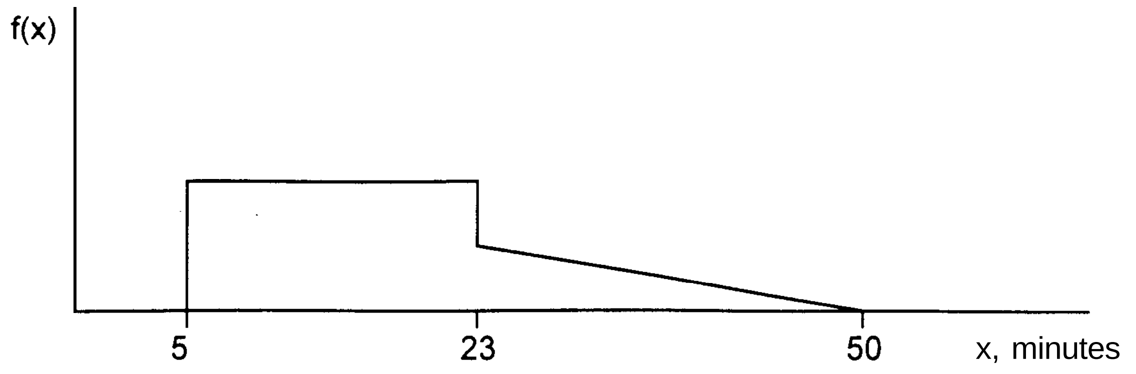

Figure 7-3. Probability distribution for Canada Customs service time.

For the total time "in secondary" (at least for loads that are not physically inspected) on the Canadian side, we need to add an estimate of the time required to visit the broker (prior to submittal of paperwork to Customs). We were not able to observe samples of broker time on the Canadian side directly, so we have assumed the broker time distribution to be the same as on the U.S. side:

$$\text{Broker time (minutes)} = 4.55 + \text{EXP}(20.8)$$

Thus, for an RMD vehicle referred to the warehouse, we sample from the distribution of broker time for a delay in visiting the broker, and then from the distribution of Customs delay time for paperwork processing. If the vehicle is not selected for physical inspection, then the truck is released after those two delays.

During the four-month period January-April, 1998, the physical inspection rate at Canada Customs was about 1.62%. That is, about 1.62% of all entering shipments were examined in the warehouse. This is equivalent to 5.8% of shipments contained in trucks that were referred to the warehouse. For the simulation, we have used a probability of 0.06 that a truck referred to the warehouse (a Y28 truck) will be selected for examination.

There is very little available data on the distribution of times to conduct a physical examination of cargo. For the model, we have assumed a distribution of 12 + EXP(25), the same as assumed on the U.S. side. Because a very small percentage of total entering truck are physically inspected, this time has very little effect on the overall statistics for average delay to trucks.

7.4 Automobile Service Time

Automobiles entering Canada undergo immigration/customs inspection at a line of booths as shown in the facility layout diagram in the previous chapter (Figure 6-l). On the Canadian side, these booths are equipped with automatic license plate readers, and data from these readers has been used to estimate a distribution of service times for automobiles. For use in the simulation model, *service time* is the sum of a *pull-up time* for the vehicle to enter the booth after the previous vehicle departs, plus the actual *processing time* in the booth. The data available from Customs are average processing times, for each inspector working during each hour of the day. Two days of data from September, 1998, were analyzed.

The data indicate that there are variations in processing time between inspectors. However, the purpose of the model is to reflect aggregate degree of congestion in the facility, so we have not included this level of detail in the analysis. A single approximate distribution has been estimated for the primary inspection time, and this distribution is used for all inspection lanes that are open.

The data available indicate an average processing time of approximately 14 seconds, with a standard deviation of approximately 6 seconds. The empirical cumulative distribution of processing times is shown in Figure 7-4.

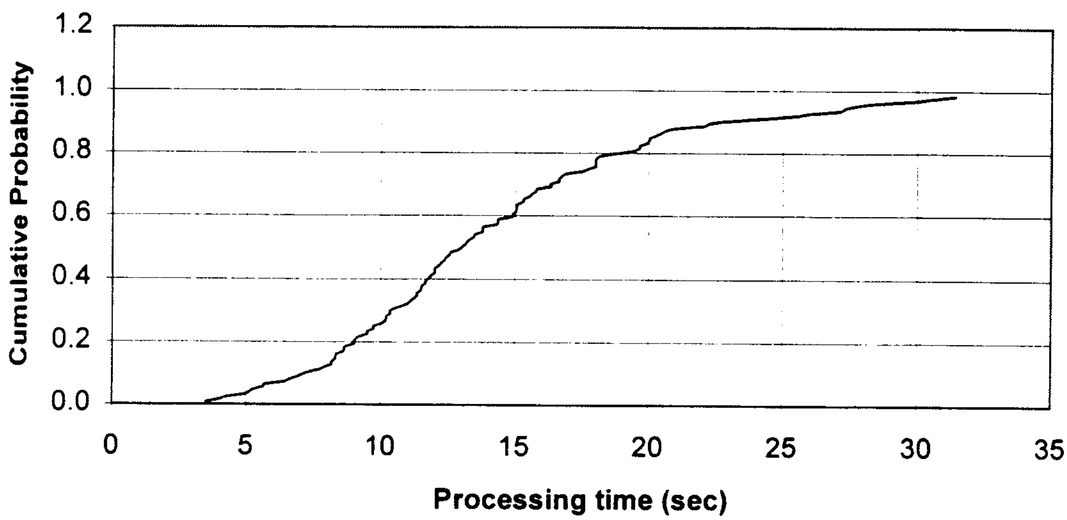

Figure 7-4. Empirical cumulative distribution function for primary processing of incoming automobiles in Canada.

We have added a 4 second pull-up time to each of these observations, and estimated a gamma distribution from the transformed data to reflect the distribution of service times. The resulting estimated distribution (in seconds) is 7 + GAMMA(3.76, 2.93). This is used as the distribution of primary inspection times in the simulation model.

With these parameters estimated, we are in a position to construct a base case simulation run of the Canadian side, for validation testing and as the basis for comparing the effects of various operational changes.

7.5 Validation Testing

For validation testing of the Canadian side model, we collected videotape data of trucks entering and leaving the Customs facility over a 110-minute period (9:00 AM – 10:50 AM) on December 22, 1998 (a Tuesday). During that period, the weather was cloudy but otherwise not affecting traffic flows. During the first hour of the tape, the arrival rate of trucks to the Canadian plaza was approximately 136 trucks/hour. During the second hour, the arrival rate increased somewhat, to approximately 152 trucks/hour, although we do not have actual observations for the entire hour.

During the period observed, Canada Customs had three primary booths open and the truck queue waiting for primary inspection was very small. The videotape was recorded using the in-place observation cameras operated by the Bridge Authority. The primary inspection line is actually out of view of these cameras, so actual inspection times could not be observed. Furthermore, the back of the truck queue is only visible if there are more than three trucks in a given inspection line waiting for entry into the booths. During the taped period, the back of the queue was never visible on the tape, so we can conclude that the queues in front of the primary inspection booths never exceeded three trucks.

With the primary inspection time distributions described in section 7.2, the aggregate average primary inspection service time is approximately 49 seconds/truck. During the second hour, at the higher average arrival rate, the average interarrival time between successive trucks is approximately 23.7 seconds, or about 71 seconds in each of the three lanes. This means that the service intensity of each lane is approximately $p = 49/71 = 0.69$. The discussion in section 7.2 also indicates that the standard deviations of the two truck category (ROL and Y28) primary inspection service times are 25.7 seconds and 33.1 seconds respectively. In an aggregate service time distribution, the standard deviation will be larger, because we are aggregating two distributions that have different means, but a reasonably conservative assumption is that it might be equal to the aggregate mean, 49 seconds.

Under these conditions, we can use queuing theory to estimate the average length of the truck queue for each lane, and the average time in system for trucks in the ROL category. Theoretically, we would compute the average queue length as $p^2/(1-p) = 1.5$, and the average time in system for ROL trucks would then be approximately 2 minutes. These computations are quite consistent with the fact that we observed no queues of more than three trucks on the tape.

To check the average time in system, we attempted to match up arrivals and departures of trucks from the videotapes. This proved quite difficult, but we were able to identify a total of 61 matches over the 110-minute period. Of these, 54 had times between arrival and departure of 9 minutes or less, and the average of these 54 times was 4 minutes. Figure 7-5 shows a histogram of these 54 times.

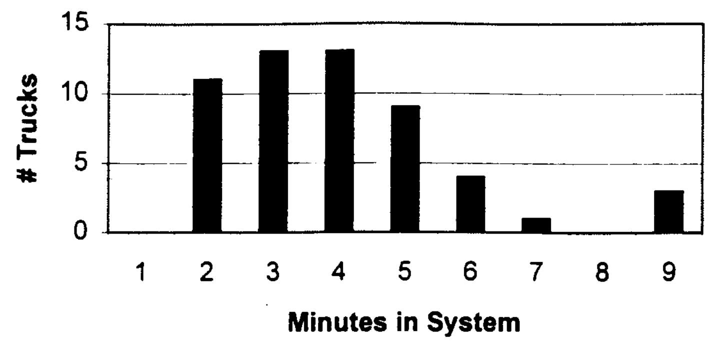

Figure 7-5. Histogram of time between arrival and departure for 54 trucks observed on the videotape.

The calculated theoretical average time-in-system does not account for actual maneuvering time, but the arrivals on the videotape were recorded when the trucks passed in front of a camera just as they left the bridge to enter the Customs area, and the departures were recorded after they left the Customs area and turned onto a street to depart, so there is easily 1-2 minutes of maneuvering, even if there were no delay at Customs at all. Thus, we conclude that the observed data and the estimated service time characteristics used for the primary inspection line in the simulation model are quite consistent.

For the Y28 trucks that must enter the warehouse, there is additional delay that includes both time for the driver to visit a broker's office and time for Canada Customs to act on the resulting paperwork. It was much harder to match arrivals and departures of trucks on the videotape when their times were widely separated, but we did manage to find seven matches. Although this sample is very small, the average of 33 minutes is not inconsistent with the assumed distributions of broker time and Customs processing time described in section 7.3.

Thus, we conclude that the estimates of parameters for the Canadian side simulation model are reasonable, and we can proceed to tests of the implementation of ITBCS technology.

CHAPTER 8

Impact Investigations – Canadian Side

This chapter considers a variety of scenarios for the Canadian side of the bridge, ranging from base case conditions to extensive market penetration of the ITBCS technology. Westbound impacts are the only ones examined, since there are no processing activities eastbound. Experimentation with changes in facility configuration illustrates how important certain decisions on ITBCS lane provision can-be, particularly for auto traffic at high penetration rates for the technology.

The simulation experiments are based on the same three days as in the U.S. facility investigations, June 26, August 19, and August 28. The detailed description of these days, presented in Chapter 5, is not repeated here. For each of these days, and for each scenario, three simulations have been conducted, so that a sense of the variation in system performance can be observed within the context of a single day. The resulting average statistics have been used to provide an indication of the overall effects on system performance that might arise. Generally, in what follows, we give a description of how the introduction of advanced information technology is expected to affect both trucks and autos, for a variety of assumed conditions.

8.1 Scenario Definitions

Table 8-l summarizes the scenarios explored in the simulation investigation. Each scenario combines a penetration rate with a facility configuration. Three truck primary inspection booths (lanes) are assumed to be open in all runs.

Scenario 1 is the base case and reflects existing conditions for trucks combined with two different realizations for autos. As described in Chapter 7, the trucks comprise two categories – Y-28, which are sent to secondary inspection, and ROL, which are released on-line at primary inspection. 28% of the trucks are Y-28, and the remainder are ROL.

The two realizations for autos involve different levels of ITBCS participation. In the first (S 1 I), there are no ITBCS users. It can be argued that this reflects operations today. For the second (S 12), 20% ITBCS participation is assumed. (This then matches the 20% AutoPass conditions on the U.S. side.) In both situations, four lanes are open – three regular lanes and one mixed-use lane (ITBCS and all other).

Scenario 2 (S2) involves a higher level of ITBCS participation for both trucks and autos. For trucks, 20% participation is assumed, with participation drawn proportionally from the Y-28 and ROL categories. The three primary inspection lanes (booths) are all assumed to be equipped to accommodate ITBCS and non-ITBCS trucks. For cars, a 35% ITBCS participation is assumed. The facility configuration is as before, with three regular lanes and one mixed-use lane for both ITBCS and non-ITBCS vehicles.

Table 8-l. Canadian side scenario definitions.

CANADA WESTBOUND

Scenario	Trucks	Autos
S11	28% Y-28 72% ROL 3 mixed use lanes	0% ITBCS participation 3 regular lanes 1 mixed use lane (Reg. + ITBCS)
S12	28% Y-28 72% ROL 3 mixed use lanes	20% ITBCS participation 3 regular lanes 1 mixed use lane (Reg. + ITBCS)
S2	20% ITBCS participation, proportionally drawn from both truck types 3 mixed use lanes	35% ITBCS participation 3 regular lanes 1 mixed use lane (Reg. + ITBCS)
S31	50% ITBCS participation, proportionally drawn from both truck types 3 mixed use lanes	50% ITBCS participation 3 regular lanes 1 designated ITBCS lane
S32	50% ITBCS participation, proportionally drawn from both truck types 3 mixed use lanes	50% ITBCS participation 3 regular lanes 2 designated ITBCS lanes

Note:
1. Truck ITBCS primary delay: UNIF(17, 18)
2. Autos ITBCS primary delay: TRIA(6, 9.5, 13)
3. Autos primary failure rate: 1%

Scenario 3 has two realizations, with the difference pertaining to the number of ITBCS lanes available for autos. In S3 1 there are three regular lanes and one designated ITBCS lane, while for S32 an additional designated ITBCS lane is assumed. Both of these conditions differ from S2 in that the ITBCS lane(s) are for exclusive ITBCS use.

8.2 ITBCS Processing Time Assumptions

Assumptions are necessary for primary inspection service times for both autos and trucks under ITBCS implementation on the Canadian side of the bridge. For trucks, there is some limited empirical data based on the prototype experiment conducted. In the prototype experiment, Canada Customs chose to handle data for pre-filed trips differently from the way U.S. Customs handled the data on the U.S. side. In Canada, the trip data were downloaded to a local computer at the Peace Bridge ahead of time, so when the truck's transponder was read as it entered the primary inspection booth, the recommendation for release or referral of the truck was immediately available to the Customs inspector. Our videotaping of primary inspection operations on the U.S. side indicated an average time of 17 seconds for a truck to pull up into the booth from the first-in-line position. It is during this pull-up that the transponder is read and the information is displayed to the inspector. We have assumed that the additional time required for the primary inspection is nearly trivial, and have specified that the distribution to be used in the simulation for the overall service time is UNIF(17, 18) seconds.

For autos, there is some data on average service times in the existing lanes, but little empirical basis for specifying a service time distribution for potential ITBCS implementation. Based on a discussion with Canada Customs officials and a "reasoned speculation," we have estimated a range between 6 and 13 seconds for primary inspection service times. As a simple representation of an ITBCS service time distribution for the simulation, we converted this into a triangular distribution with a most-likely value half-way between the endpoints: TRIA(6, 9.5, 13).

8.3 Simulation Results

This section presents the findings from the scenario investigations. Impacts for westbound trucks are considered first, followed by westbound autos. Of greatest interest is the overall time in system, and for trucks, the number sent to secondary inspection. For both cars and trucks, the most dramatic changes in system performance are produced by scenarios S3 1 and S32 where the ITBCS penetration rate is 50%. It is also clear that at this level of penetration, two ITBCS booths are required for the auto traffic.

8.3. 1 Westbound Trucks For trucks, we can ignore the differences between S 11 and S 12, and between S3 1 and S32, since the differentiation pertains to the autos.

Simulation results for truck time-in-system are shown in Table 8-2. The numbers presented are the averages across the three case study days. From scenarios Sl l/S 12 to S3 l/S32 we see a 40% decrease in the average time-in-system and a 34% reduction in the 90th percentile. Clearly the ITBCS technology produces significant benefits in this measure of effectiveness.

Table 8-2. Time in System for Westbound Trucks

Scenario	Avg	90%
S11	1166	3480
S12	1172	3532
S2	970	3081
S31	695	2210
S32	730	2442

In part, this can be traced to a reduction in the number of trucks sent to secondary inspection. As Table 8-3 shows, this number shrinks from just over 100 in Scenario S 1 l/S 12 to about 50 in S3 1/S32, a 50% reduction. Given how secondary processing is modeled (see Chapters 6 and 7), it is not possible to determine impacts on average processing times, but, assuming the resources available (e.g., customs inspectors) remain constant, a decrease' in average processing time should also result.

Table 8-3. Secondary Processing for Westbound Trucks

Scenario	Obs
S11	101
S12	103
S2	79
S31	50
S32	52

Queuing delay for primary processing also decreases substantially between the base case (S 1 l/S 12) and the higher levels of ITBCS penetration. As Table 8-4 indicates, the average time in primary inspection drops 14% from 199 seconds to 173, and the 90th percentile time falls 15% from 253 to 2 14.

Table 8-4. Primary Inspection Delay for Westbound Trucks

Scenario	Avg	90%
S11	200	252
S12	198	254
S2	188	241
S31	173	214
S32	173	214

We can examine the degree of consistency in these results by inspecting the results for the individual days, as presented in Figure 8-1. The pattern among scenarios for all three days is very similar. S2 has a slightly smaller average time in system than S11/S12, and the improvement from S2 to S31/S32 is much greater. Although the volumes on August 28 are higher than those for either August 19 or June 26, this variation is not enough to produce major differences in system performance.

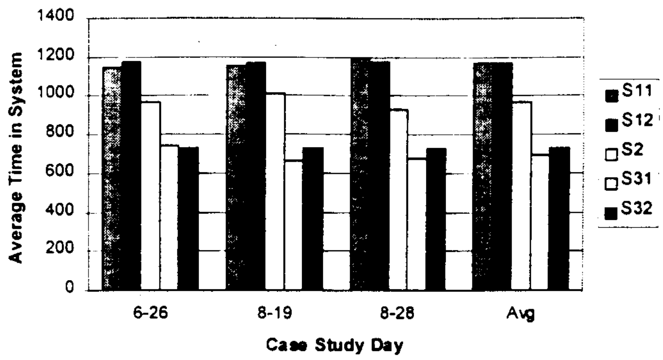

Figure 8-1. Average Times in System by Case Study Day for Westbound Trucks

8.3.2 Westbound Autos One of the key questions raised by Canada Customs regarding auto traffic entering Canada is whether two dedicated ITBCS lanes would be necessary to handle equipped autos if the penetration rate of the technology were higher than 20% – say 35% or 50%. This provides the basis for the specification of scenarios S2, S31 and S32 for auto traffic.

The data collected to support the simulation study can be analyzed to answer this question, and the simulation has been run to confirm the analysis. For the three days selected as representative analysis days (June 26, August 19 and August 28), the auto traffic entering Canada is about 600 vehicles/hour between 10 AM and 7 PM (somewhat higher than that on August 28 and somewhat lower on June 26). Canada Customs is assumed to have four booths open in scenarios S2 and S31, and five booths in scenarios S32. In each case three lanes handle regular traffic only. In scenario S2 the fourth lane is mixed-use (ITBCS and regular). For scenario S31 that fourth lane is dedicated to ITBCS traffic, and in scenario S32 an additional dedicated ITBCS lane is provided.

For scenario S2, we assume that 35% of the auto traffic is ITBCS-equipped. At a total arrival rate of 600 vehicles/hour, this means that the arrival rates are 390 vehicles/hour in the regular category and 210 vehicles/hour in the ITBCS category. As an approximation, let us assume that the regular arrivals split equally among the three regular booths, yielding an arrival rate of 130 vehicles/hour/booth. The ITBCS arrivals all use the mixed-use lane, so the arrival rate at that lane is 210 vehicles/hour.

We have estimated a service time distribution for regular vehicles with a mean of 18 seconds, and a standard deviation of 6 seconds. This implies a coefficient of variation (standard deviation / mean) in the service time, denoted *C(s)*, of 0.33. At an arrival rate of 130 vehicles/hour, the mean interarrival time at each regular booth is 27.7 seconds. Thus, the *traffic intensity* of the lane is ρ = 18/27.7 = 0.65. This is a measure of the utilization of the lane, and is important for analysis of queuing delays.

Each lane can be considered to be approximately a queue with Poisson arrivals, and the formula:

$$L_q = \left[\frac{\rho^2}{1-\rho}\right]\left[\frac{1+C^2(s)}{2}\right]$$

can be used to estimate the average length of the queue waiting for primary inspection in each lane (Hall, 1991). For the regular lanes in scenario S2, this calculation produces L_q = 0.67 vehicles.

For the ITBCS lane, the service time distribution is estimated to have an average of 9.5 seconds and a standard deviation of 1.4 seconds. At an arrival rate of 210 vehicles/hour, the average interarrival time is 17.1 seconds. This produces estimates of parameters and queue length as follows:

$$\rho = 9.5/17.1 = 0.56$$

$$C(s) = 1.4/9.5 = 0.15$$

$$L_q = 0.36 \text{ vehicles.}$$

In all lanes the average queues are less than one vehicle, implying very small delays. The differences in the average queue length between the regular lanes and the mixed-use lane is small enough to support our assumption that the split of traffic will be approximately such that the mixed lane will be used mostly by ITBCS vehicles and the three other lanes will be used by the regular vehicles.

Thus, for scenario S2 we can conclude that one ITBCS lane is sufficient, and that at the 35% penetration level for the ITBCS technology, it is reasonable to dedicate one lane to ITBCS, rather than have it as a mixed-use lane.

In scenarios S31 and S32, we increase the ITBCS participation to 50%. At a total arrival rate of 600 vehicles/hour, this means the arrival rate of ITBCS-equipped vehicles is 300 vehicles/hour, or that the average interarrival time is 12 seconds. A similar queuing analysis to the one done for scenario S2 yields the following parameters and results:

$$\rho = 9.5/12 = 0.79$$

$$C(s) = 1.4/9.5 = 0.15$$

$$L_q = 1.5 \text{ vehicles.}$$

This is not an unreasonable average queue, although we must also consider the situation in the regular lanes. Here an aggregate regular arrival rate of 300 vehicles/hour is split across three lanes, so each one sees about 100 vehicles/hour arriving. The queuing analysis for these three lanes produces estimates as follows:

$$\rho = 18/36 = 0.5$$

$$C(s) = 6/18 = 0.33$$

$$L_q = 0.28 \text{ vehicles.}$$

Thus. the queues in the regular lanes are significantly smaller than in the ITBCS lane, and this may be perceived as unsatisfactory service for the ITBCS customers.

Furthermore, the capacity of the ITBCS lane (at an average service time of 9.5 seconds) is about 3600/9.5 =: 380 vehicles/hour. At 50% ITBCS participation, this corresponds to an ability to handle aggregate arrival rates of less than 760 vehicles/hour. For days with total westbound auto traffic in excess of about 10,000 vehicles (approximately the busiest 30% of all days), there are frequent hours with more than 760 total vehicle arrivals, and during these times there will be extensive queuing at the ITBCS lane. For days with total westbound automobile traffic in excess of about 12,000 vehicles (approximately the busiest 10% of all days), auto arrival volumes in excess of 760 vehicles/hour can last for several hours, and the queuing at the ITBCS lane would be intolerable.

This has been confirmed by simulation of scenario S31 for the three case study days, in which there is a period of peak arrivals above 760 vehicles per hour. The queue at the ITBCS lane grows rapidly, and the average delay time exceeds 20 minutes. This corresponds to a queue length of more than 200 cars, which would extend most of the way across the bridge. This would undoubtedly be perceived as an intolerable degradation of service.

Thus, for levels of ITBCS participation approaching 50%, it is critical that a second dedicated lane be provided. In the simulation of scenario S32, where such a lane is opened, the queue lengths drop back down to very reasonable levels, with very small average delays.

8.4 Summary

This chapter considers a variety of scenarios for westbound traffic (both autos and trucks) the Canadian side of the bridge. Simulation experiments based on the same three days as used in the U.S. facility investigations (June 26, August 19, and August 28) have been performed to provide an indication of the overall effects on system performance that could result from the introduction of advanced information technology. The investigation has focused on three basic scenarios.

Scenario 1 is the base case and reflects existing conditions for trucks combined with two different realizations for autos (S 11 and S 12). In both situations, four lanes are open – three regular lanes and one mixed-use lane (ITBCS and all other).

Scenario 2 (S2) involves a higher level of ITBCS participation for both trucks and autos. For trucks, 20% participation is assumed, with participation drawn proportionally from the Y-28 and ROL categories. The three primary inspection lanes (booths) are all assumed to be equipped to accommodate ITBCS and non-ITBCS trucks. For cars, a 35% ITBCS participation is assumed.

The facility configuration is as before, with three regular lanes and one mixed-use lane for both ITBCS and non-ITBCS vehicles.

Scenario 3 has two realizations, with the difference pertaining to the number of ITBCS lanes available for autos. In S3 1 there are three regular lanes and one designated ITBCS lane, while for S32 an additional designated ITBCS lane is assumed. Both of these conditions differ from S2 in that the ITBCS lane(s) are for exclusive ITBCS use.

Simulation results for truck time-in-system show a 40% decrease in the average time-in-system and a 34% reduction in the 90th percentile between the base case and Scenario 3. Clearly the ITBCS technology produces significant benefits in this measure of effectiveness.

In part, this can be traced to a reduction in the number of trucks sent to secondary inspection. This number shrinks from just over 100 in Scenario S1 l/S12 to about 50 in S3 l/S32, a 50% reduction. Queuing delay for primary processing also decreases substantially between the base case (S 11/S 12) and the higher levels of ITBCS penetration. The average time in primary inspection drops 14% from 199 seconds to 173, and the 90th percentile time falls 15% from 253 to 214.

For auto traffic, the primary question analyzed is how much dedicated lane capacity is necessary under higher levels of ITBCS participation. For scenario S2, we conclude that one ITBCS lane is sufficient, and that at the 35% penetration level for the ITBCS technology, it is reasonable to dedicate one lane to ITBCS, rather than have it as a mixed-use lane.

The capacity of the ITBCS lane (at an average service time of 9.5 seconds) is about 3600/9.5 = 380 vehicles/hour. At 50% ITBCS participation, this corresponds an ability to handle aggregate arrival rates of less than 760 vehicles/hour. For days with total westbound auto traffic in excess of about 10,000 vehicles (approximately the busiest 30% of all days), there are frequent hours with more than 760 total vehicle arrivals, and during these times there will be extensive queuing at the ITBCS lane. For days with total westbound automobile traffic in excess of about 12,000 vehicles (approximately the busiest 10% of all days), auto arrival volumes in excess of 760 vehicles/hour can last for several hours, and the queuing at the ITBCS lane would be intolerable.

Thus. for levels of ITBCS participation approaching 50%, it is critical that a second dedicated lane be provided. In the simulation of scenario S32, where such a lane is opened, the queue lengths are at minimal levels, with very small average delays.

CHAPTER 9

Institutional Issues in ITBCS Implementation

As part of the evaluation of potential benefits that will accrue from the use of the intelligent Transportation Border Crossing System (ITBCS) at the international crossing (Peace Bridge) between Buffalo, New York and Fort Erie, Canada, the evaluation team conducted a modest exploration of the institutional environment impacting the use of such technology. The goal was to identify institutional barriers that arose during the Peace Bridge test of the ITBCS technology. The presumption behind this investigation was that barriers experienced at a single test site might be indicative of the coordination problems that may arise in a pervasive operational deployment of such technology.

This component of the evaluation effort was largely accomplished through interviews with representatives of many of the organizations-government agencies in Canada and the United States and private and quasi-public organizations-with a stake in the Peace Bridge test. Such interviews required participants to describe their experiences during the test and to share their observations about and evaluation of the institutional environment during the test. While distinctly subjective in nature, when conducted well and with a diverse group of cooperative informants, interviews can provide a rich and surprisingly accurate picture of organizational life. Seventeen interviews were conducted for this study, ranging in length from one to two hours. In addition, interview data was augmented with documentary information associated with the Peace Bridge test and from evaluations of similar technology in other locations.

Before proceeding with the major findings, several contextual comments are in order. These should not be taken as formal data or authoritative results. They are offered as the opinions and/or impressions of an experienced organizational analyst, and may be useful in assessing the findings.

First, this exploration of the institutional environment of the ITBCS test at the Peace Bridge should not be construed as an “evaluation” of that test. This is simply a retrospective look at the test to identify inter-organizational issues that arose during the test. In essence, it is a reconstruction of the test from the observations and experiences of those who participated in it.

It is clear that this distinction was not always evident to those we were interviewing, and several times we found it necessary to clarify this point with interviewees. If the institutional environment that surrounds the use of a new technology is an important contributor to the viability of that technology-and in situations where there are many organizational players with differing missions, that is clearly the case-then an assessment of the impact of that environment should be an integral part of the actual test of the technology. This minimally requires real-time collection of data about inter-organizational dynamics, by an objective “third-party,” during both the planning and development and the operational testing phases. Data collection in this manner tends to be far more observational than reconstructive and is not as subject to the vagaries of memory, or the subtle pressures to revise events to “protect” oneself or one’s organization. Given the complexity of the institutional environment impacting the Peace Bridge ITBCS test, it would have been very useful to have built institutional assessment into the fabric of that test.

A second observation, undoubtedly related to the first, is that we noticed a curious reluctance to fully participate in some of those we contacted for interviews. For a few, this manifested itself as a weak disclaimer that they had anything of value to contribute to our enterprise. Yet, in reports of other participants in the test, they were clearly described as active contributors and were recommended as people with whom we should talk. While most ultimately agreed to be interviewed, their comments were often rather antiseptic. When pressed for detail, it was not uncommon that they would admit that there had been some rough moments and/or disconnects between organizations during the test, but asserted that everyone had clearly learned from them and the problems would not arise again in future operational implementations of the ITBCS technology. Thus, few elaborations on the nature of the “problems” were offered.

In a few other interviews, this reluctance was conveyed by the delicacy and care with which interviewee comments were made. Here the impression conveyed was that the interviewee was “walking on eggshells” and the interviewer was being asked to read between the lines. Some of this is understandable when difficulties between levels in the same government agency are being discussed; or when policy/mission disconnects between different federal agencies/departments are implicated; or when “personalities” are seen as problematic (all of which clearly happened during the Peace Bridge test). When pervasive, however, it conveys a worrisome impression that there might have been more profound problems encountered or that there may have been flaws in the test procedures of which no one will speak.

A final observation concerns the viability of the actual test conducted at the Peace Bridge. Put simply, was the test a true proof of concept of the ITBCS system? Our impression after conducting our formal interviews and participating in numerous casual discussions with people connected to the Peace Bridge project is that it probably was not. Indeed, it could be argued that the desire to create the simulation models described in Parts II and III of this report and to use those models to explore the potential benefits of using the ITBCS system, is de facto evidence that the operational hardware test did not generate sufficient data to actually assess the full range of consequences that would ensue from a full-scale deployment of this technology.

Now, we should note that these conclusions should not be seen as barriers to a full implementation of the ITBCS system. The hardware technology used in the ITBCS system is not new and its use in transportation-related environments has been assessed on numerous other occasions. The various components of the ITBCS system work. The Peace Bridge effort, however, was to be an operational test of an integrated system that met the needs of a major set of institutional players at a border crossing. While the test did generate some flow data; confirmed that some of the hardware, software, database and communication components can work as anticipated; and uncovered a number of potential institutional barriers to the use of these systems; it did not generate the volume or types of data that were anticipated. Indeed, several of our interviewees expressed the opinion that the test was not successful precisely because such data expectations were not met.

Why did this happen? Given the lack of true real-time evaluation data and the reticence of some of our interviewees, we can only speculate. The data that does exist and our instincts, however, suggest strongly that institutional disconnects led to faulty prototype design and the lack of a true climate for evaluation. If we are correct, the following summary findings from our exploration of institutional barriers to ITBCS deployment deserves a careful reading.

9.7 The Complexity of the Institutional Environment

The ITBCS test at the Peace Bridge was conducted in a very complex institutional environment. The ITBCS Project steering committee is composed of twelve members each representing an organization with a significant interest in either how the border crossing is operated, or in the technology used at the crossing. However, well over 100 governmental units that have legislatively mandated regulatory concerns about commercial traffic across the border are not represented in the steering committee. A border crossing, therefore, is a specific location where multiple institutional missions converge and are enacted. In such an environment, it is likely that an action taken to optimize performance against one institutional mission will come into conflict with or sub-optimize another's mission.

The evidence is compelling that such mission conflict occurred during the Peace Bridge test. When it did so, it was not generally caused by "bad" people pursuing unfair advantage or unrealistic ends. Instead, it resulted from dedicated institutional representatives trying to live up to their job requirements. That, however, is the problem. If the essential character of an initiative is collaborative, it is not useful when individual players come to the table focused only or largely on their own needs. In such an environment, advocacy elongates problem solving and may frustrate effective action by those who must actually take action in the field, i.e., create the ITBCS system and test it.

Clearly these dynamics had a negative impact on the Calspan Corporation, the contractor retained to develop and test the ITBCS prototype. This was especially evident during the contracting phase when functionality requirements for the system were used by the contractor to develop a statement of work and assess costs. Each of the twelve key stakeholders who had input into the functional specifications tended, to greater or lesser degrees, to focus on their individual needs and were resistant (again, to greater or lesser degrees) to modify those requirements in service to system optimization (either in terms of functionality or cost). Thus, the contractor was forced to deal with requirements from different stakeholders that were at times contradictory. They were also placed in the unenviable position of mediating between stakeholders who placed different emphasis on cost versus functionality, and who simultaneously seemed resistant to entering into a dialogue with the contractor about how such cost-functionality trade-offs could be resolved.

The problematic nature of such mission-focused interaction is magnified if the players at the table do not have sufficient authority from their agency to change or deviate from standards to facilitate collaborative action-in this case designing an effective test of a new technology. This is a dual issue of flexibility and empowerment. When this is the case, they must use the chain of command to resolve issues. Should a situation arise where a given agency has not developed a well thought out policy position ‘on the initiative under test, then there can be disconnects between leadership statements from headquarters and test-related field needs. There is evidence that all of these things occurred during the Peace Bridge test. To oversimplify, it could be said that the ITBCS test was conducted without a clearly defined overall vision or “common need” for the technology that was accepted by all participants.

Examples of potential mission conflicts would include:

- Transportation agencies concerned with flow; Customs concerned with enforcement.
- Business stakeholders concerned with the cost of the system; Functional stakeholders concerned with operation/functionality.

9.2 When Conflicts Arise, Who Decides?

In a multiple stakeholder environment, where institutional missions may not overlap, how are the conflicts that inevitably arise resolved? Such conflicts can be of two types: operational/tactical and strategic/policy. The former type can often be resolved by field leaders at the site who have a track record of working together and have developed mutual trust and respect. Clearly this happened often during the Peace Bridge test. Indeed, so noteworthy was this behavior during this test that several interviewees suggested that interpersonal relationships between field leaders from different agencies in a multi-agency environment are critical to implementation success. It goes without saying that leaders with “rigid” or “authoritarian” personality tendencies, or those who lack the interpersonal skill necessary for collaborative problem-solving can severely disrupt such an effort. There is some indication that, unfortunately, this also cropped up during the Peace Bridge test.

But what about conflicts in different agencies that involve fundamental issues of policy? What is the mechanism by which such conflicts are resolved in an efficient and timely manner so that implementation can proceed? The ITBCS Steering Committee created for the Peace Bridge test was a coordination body that was not sufficiently empowered to operate at an inter-agency policy level. Some interviewees have suggested that if free-trade and “seamless borders” are the goal, more thought must be given to how national agencies within the same country will collaboratively work together to set policy and resolve policy conflicts. Hierarchical escalation and then negotiation at the highest level between agencies is both inefficient and subtly reinforces the ethnocentric tendencies of most agencies. Perhaps, it has been suggested, a forum that represents the border must be created to resolve such issues.

9.3 Treating a Test Installation as an Operational Sys tern

There is some evidence that frustrations occurred during the Peace Bridge ITBCS test because some stakeholders insisted upon using rigorous operational standards in a test environment. This is not an uncommon problem when new concepts are being examined in a “regulatory” context. It does, however, make it difficult to create a proper test environment. For example, in the Peace Bridge test, the requirement to handle customs clearance procedures using both the new automated system and the old paper system may have been a disincentive for commercial carriers and customs brokers to participate in the ITBCS test. It may also have impacted the attitudes and ultimately the behavior of those participating in the test in ways that distorted test results.

Another manifestation of this issue may have occurred during the system definition phase leading up to the design of the Peace Bridge installation. As we understand it, the accuracy requirements put forth by U.S. Customs were extremely rigorous. In response, some technical personnel questioned whether any system could perform to such standards. Others asked whether the current system operated at the specified level of accuracy. The real issue, however, is whether operational “aspirations” should be used as a non-negotiable baseline to determine the feasibility of a new concept.

9.4 Who Controls the Data?

A theme that has appeared throughout our interviews concerns data security. ITBCS is an automated system that facilitates communication between vehicles crossing a border, regulatory personnel at the border and various regulatory data bases located at the crossing site and at other sites in the relevant nations. Data base design is critical to the performance of the ITBCS system. For a completely integrated border crossing system to be developed, the agencies operating at the crossing would have to agree on the creation of a comprehensive data base that could be interrogated to support all regulatory requirements. The experience of the Peace Bridge ITBCS test, however, suggests that regulatory agencies are reluctant to cede control of their data base out of concern for data integrity. At issue are such things as who maintains a data base, who can access it, where is it located and, ultimately, questions of sovereignty and national security. While the design of such an integrated trade data base in the U.S. is slowly being addressed by an agency within the U.S. Treasury Department (ITDS), it would appear that concern about data control was an institutional barrier confronted numerous times during the Peace Bridge ITBCS test.

9.5 Intra-Agency Communication and Coordination

In a complex, multi-agency environment, where collaboration is required even as participants are learning how to collaborate, alignment of different levels within a given agency is very important. Collaboration between agencies with very different missions is difficult enough, without mixed messages being sent because of a lack of internal coordination within an agency. The Peace Bridge ITBCS test experienced some of these dynamics. We have heard of disconnects between Washington headquarters and Buffalo field personnel in the three major Federal institutions involved in the test: the Federal Highway Administration, the Customs Service and Immigration and Naturalization Service. This, however, is one of the issues that our interviewees seemed most reticent to discuss, so we cannot say how serious such disconnects actually were. We can only say that such internal communication/coordination issues appear to have caused some frustration in relations with Calspan, the system contractor, and to have impacted relations between the Federal Highway Administration and the U.S. Customs Service.

9.6 Regulatory Culture

Organizations develop internal cultures that can profoundly influence the behavior of those who work in them. Such cultures are about values, expectations, assumptions, standards-in short, they are a picture of how a little piece of the world works and how we are supposed to be if we work in that piece of the world.

Many of the government agencies that participated in the Peace Bridge ITBCS test exist to regulate or oversee something. They were created, when all is said and done, to enforce legally-defined standards. Day to day work in such organizations involves overseeing or policing some activity or product to assure that the right things are being done and, most importantly, that the wrong things are not being done.

If regulation always involves standards, the application of those standards is designed to protect us from ourselves, to encourage us to do what is in the best interests of our society. Regulatory activity that occurs at an international border, however, can take on a somewhat more potent character. An international border is a boundary between our society and another that is, to greater or lesser degree, different from ours. Thus, regulatory activity at a border has a strong component of protecting us from others. Those involved in such regulatory activity may develop a heightened awareness of themselves as “safeguarders” of our society, our nation, our sovereignty. Such awareness is likely to result in strong feelings of pride in mission and dedication to task.

One of the strongest themes in our interviews is that a regulatory culture can be a significant barrier to the smooth implementation of ITBCS technology. From a transportation perspective, such technology facilitates flow across the border. Historically, transportation agencies, when confronted with capacity problems, sought relief through capital investment in additional infrastructure. Now, intelligent transportation systems are positioned as a less costly alternative to such infrastructural investment to facilitate flow.

Flow, however, is not a central concern to those with a regulatory mission. Enforcement, often accomplished through face-to-face interaction with individuals and/or through direct inspection of documents, vehicles, products, etc. is at the traditional core of regulatory work. It goes without saying that both face-to-face interaction and direct inspection work against flow. Certain regulatory agencies (especially the U.S. Customs Service) involved in the Peace Bridge ITBCS test appear, in our interviews, to be so captured by this enforcement world view that they have had a difficult time honoring seamless flow across the border as an objective that is important.

If effective inter-agency cooperation at the border is to be fostered, a great deal more attention must be paid to the impact of culture on behavior. This is not a matter of "ordering" employees to behave differently, or sanctioning them if they do not. This is not an issue of individual "goodness" or "badness". Representatives of agencies, regulatory or otherwise, simply enact values that have led to success in the past and which make eminent sense to them. Indeed, they may not be aware of how those values were derived from a set of environmental stimuli in the past. Thus, when confronted with new environmental conditions requiring a new response, they simply apply old values and associated behaviors and expect success.

If the changing geo-political environment means that national borders will have a new meaning, then those who work at the border will have different jobs. The need for regulation will not go away--but it will be manifest differently. Introducing ITBCS systems to facilitate flow and cross-border transactions is less a technical issue, than it is an issue of work redesign. It must be handled as such, and cultural change is at the core of that enterprise.

CHAPTER 10

Summary and Conclusions

10. 1 Summary

In 1993, the North American Free Trade Agreement (NAFTA) committed the United States, Canada and Mexico to facilitate movements of people and goods among the three member countries. In a subsequent agreement in February, 1995, Canada and the United States agreed to establish the Accord on Our Shared Border. The Accord commits both governments to promoting international trade by permitting commercial goods to flow easily between the two countries and to facilitating the movement of people by eliminating unnecessary impediments to cross-border travel. The strategy adopted in the Accord includes the following major elements (Accord on Our Shared Border, Executive Summary, 1996): streamline commercial and traveler procedures to make them friendlier and faster; use freed-up resources to improve service and concentrate enforcement efforts on high-risk areas; eliminate archaic paper-based processes that add little or no value; use technology as a strategic tool; and rethink the way we do business to do it better and at less cost.

Several projects, including the North American Trade Automation Prototype (NATAP) program and the Advanced Technology for International and Intermodal Ports of Entry (ATIPE) project, have focused on developing improved technology for sensing, inspection, and communication that could reduce delays to commercial traffic (trucks and trains) crossing the U.S.-Mexican and U.S.-Canadian borders.

One of the NATAP pilot studies was conducted at the Peace Bridge, a major border crossing facility joining Buffalo, New York and Fort Erie, Ontario. The project at the Peace Bridge is often referred to as the Intelligent Transportation Border Crossing System (ITBCS) prototype project, and that nomenclature is used extensively in this report.

The results presented here are derived from a study that was an adjunct to the ITBCS effort. Using simulation, we evaluated the impacts that might occur if the ITBCS technology were deployed permanently and on a pervasive basis. We also conducted an investigation of the institutional issues that arose during the prototype implementation and those that would have to be overcome to achieve permanent deployment.

Simulation is the main impact assessment tool. The simulation models focus on how trucks and automobiles are and would be processed through the various customs and toll activities. Since buses are a very small percentage of the total traffic, we did not model their operation.

Performance indicators generated by the models include overall time in system (from first arrival to final departure), processing time in primary and secondary inspection, the percentage of vehicles sent to secondary inspection, and the utilization of system resources, such as primary and secondary customs inspectors and vehicle storage space in secondary inspection.

The U.S. and Canadian models were developed in a similar way. Site visits and interviews provided information about the processing logic and physical layout. Data collection in 1998 allowed development of all model parameters, especially the service time distributions for all major activities. Of special interest were processing times for primary and secondary inspection, as well as toll collection, broken down by appropriate vehicle classifications. The resulting model was checked for validity (processing logic) and then calibrated for existing operating conditions. Three days, June 26, August 19, and August 28, 1997, were used for analysis purposes because they typified moderate to heavy traffic conditions for both trucks and autos.

Following calibration and validation, adjustments were made to the models to create various ITBCS scenarios so the range of impacts that might result could be investigated. Trends among these scenarios were compared and contrasted to gain a sense of the impacts to be expected.

10. 1.1 U.S. Operations Evaluation Two types of investigations were conducted with the U.S. side model. The first looks at impacts as a function of ITBCS performance, such as the reliability of the antennas. The second looks at trends in impacts of the ITBCS technology as a function of participation levels among cars and trucks.

Vehicles are categorized based on customs processing and toll collection. For trucks, the customs categories *are Line Release, Monthly/In-Transit/Empty, ITBCS,* and *General* and the toll categories *are Electronic Toll Collection (ETC), Charge* and *Cash.* Line Release (or C4) trucks constitute about 48% of the truck traffic and require an average of 55.4 seconds for primary inspection. Monthly, In-Transit, and Empty trucks are grouped together; they constitute about 18% of the total truck traffic, and average 45.9 seconds for primary inspection. Trucks in the General category are 34% of the traffic, have an average primary inspection time of 56.8 seconds, and are sent to secondary inspection about 89% of the time. These trucks make up most of the traffic in the secondary inspection area. ITBCS is a customs category for trucks making use of the ITBCS technology. Trucks in the Charge category require an average of 15 seconds for toll payment, and Cash, 26 seconds. ETC refers to use of the ITBCS for toll payment and is assumed to have an average processing time of about 1 second.

Autos fall into three customs categories *(AutoPass, Designated Commuter Lane (DCL)* and *Other)* and three toll categories *(Electronic Toll Collection, Coin/Token and Cash).* Among the customs categories, AutoPass is the program currently in place whereby drivers and vehicles are “pre-cleared” for entry because they make trips frequently. About 20% of the autos are enrolled in AutoPass and they have an average primary inspection time of 7.2 seconds. DCL is the equivalent of AutoPass for ITBCS. The Other category is all other autos (80%) and it has an average primary inspection time of 25.7 seconds.

This first U.S. side investigation focused on trends in impacts related to variations in ITBCS quality, especially antenna reliability and communications times. All participating trucks (20% of the total traffic stream) are assumed to come from the General category. (This means the potential reduction in primary inspection time is maximized as well as the likelihood that a secondary inspection will be eliminated.)

Plausible, conservative assumptions pertain to the “high” and “low” performance systems. The high performance system is assumed to have a faster turn-around time from the remote Customs computer. 17 seconds in all cases (the length of time it takes trucks to pull-up into the primary inspection booth), instead of 20 seconds if the advance antenna reads the truck tag successfully or 30 seconds if it does not. A 10% failure rate is assumed for the advance antenna and 1% for the decision antenna. These failure rates are quite high compared with typical installations, and produce conservative estimates of the impacts. It is assumed that the inspector takes 5-15 seconds to process the truck, that 2% of the trucks for which information is displayed (decision antenna worked) are sent to secondary inspection and 100% of those for which no information is displayed (decision antenna failed).

Table 10-l. Variations in System Performance

	Servicing Times by Scenario				Vehicles to
Scenarto	Sys-90	Sys-Avg	Pli-90	Pri-Avg	Secondary
tiase	2217 0	810 1	511.1	278 5	98
Low	613.0	300:9	418.0	218:5	30
Htgh	392.3	353.8	280.7	160.9	31

Table ES-l shows how truck times are affected. For the low performance system, the average time in system drops 52%, from 8 10 seconds to 389. For the high performance scenario, an even lower average of 354 seconds is obtained. This is a reduction of 56% from the base case. More dramatically, the 90th percentile time in system drops 72%, from 2217 seconds to 613, for the low performance system and 82%, to 392 seconds, for the high performance system.

The reduction in the 90” percentile values, representing the “tail” of the distribution of times, is largely because the number of trucks sent to secondary inspection drops significantly. About 400 trucks arrive during the three-hour period of interest, and in the base case there are about 136 (34%) trucks in the General category. Of these, 89% (about 120) are referred to the warehouse and in the run data recorded, 98 have been cleared by the end of the period and have their times recorded. In the simulations for the low and high performance scenarios, 20% (about 80) of the total trucks are diverted from the General category to the ITBCS category, and only about 3% of these trucks (2% sampled randomly and 1% due to decision antenna failure) are referred to the warehouse. This reduces the number of trucks sent to secondary by about 70 over the three-hour period, and in fact in the simulation data recorded, the number of trucks referred dropped to about 30.

10.1.2 – Participation Investigation The second U.S. side investigation explored the impacts of different ITBCS penetration levels.

The change in system performance for eastbound trucks is quite dramatic, as shown in Table IO-2. From scenario S 1 (the base case, representing current conditions) to scenario S32 (50% ITBCS participation) we see a 66% decrease in the average time in system, and a 78% decrease in the 90th percentile time.

Table 10-2. Time in System for Eastbound Trucks

Scenario	Avg	90%
S1	932	3005
S21	563	1715
S22	530	1650
S31	338	786
S32	321	677

In part, this is due to major changes in secondary inspection. The number of trucks sent to secondary inspection drops 64% from 90 to 33, and the times in secondary inspection fall similarly. The average drops 34% from 2873 seconds to 1838, and the 90" percentile time drops 3 1% from 4829 seconds to 3362.

Primary processing times also fall dramatically. The average time in primary inspection drops 64% from 225 seconds to 8 1, and the 90th percentile time falls 68% from 407 to 129.

The change in system performance for eastbound autos is also dramatic, as shown in Table 1 O-3. From Scenario S 1 to S32, average time in system drops 35% from 166 seconds to 108. The 90th percentile time drops even more, 48% from 295 seconds to 155. Moreover, there are significant differences between S21 and S22. In S21, there is one designated ITBCS lane, while in S22 there are two. That extra lane produces a 21% drop in average time in system. and a 28% decline in the 90" percentile time in system. Considering that this benefit accrues to all system users, primarily due to a decrease in time in queue waiting to reach primary inspection, the benefits should be carefully weighed against the costs of providing the second ITBCS booth.

Table 10-3. Eastbound Auto Time in System

Scenario	Avg	90%
S1	166	295
S21	152	263
S22	120	190
S31	108	155
S32	108	15s

For westbound trucks and autos, the effects of ITBCS implementation are not as dramatic. The only activity for westbound vehicles is toll collection. Implementation of ITBCS technology reduces the delay for toll collection, but most of the time required to move through the system westbound is delay at the traffic light at the end of the ramp from I-190, and the ITBCS system cannot affect that portion of the delay.

10.1.3 Canadian Operations Evaluation The Canadian side investigation focuses on impact trends due to participation rates among both autos and cars.

Significant differences in philosophy and data processing exist between U.S. and Canadian Customs in the ITBCS prototype implementation. The U.S. system requires access to a remote Customs computer (in Washington, DC) after the decision antenna has identified the truck entering the primary inspection booth. The Canadian system, on the other hand, downloads a decision recommendation to the local Border Crossing Computer (BCC) long before the vehicle reaches the bridge. These operational differences have resulted in significant differences between the U.S. side and the Canadian side in observed inter-event times in the data recorded during the prototype experiment.

Trucks and autos are classified on the basis of their treatment by Canada Customs. For trucks, there are three categories, Y-28, ITBCS, and ROL. For autos there are two, ITBCS and Regular. Y-28 is the designation for trucks sent to secondary inspection by the primary inspector. About 28% of the trucks fall into this category. The ROL category is for all trucks released on-line under existing conditions. ITBCS is for the ITBCS participants. For autos, all vehicles currently fall under the Regular category. ITBCS is for the ITBCS participants.

To explore the trends in impacts, a range of scenarios is explored, from existing conditions to high penetration and deployment. For trucks, scenarios Sl 1 and S12 are identical (no ITBCS), and the same pertains to S31 and S32 (50% ITBCS), so we can focus on them as single scenarios.

Trends regarding time in system are shown in Table 10-4. The numbers presented are the results for average time in system, and the 90th percentile time in system, averaged across the three case study days. From scenarios Sl l/S12 to S3 l/S32 we see a 40% decrease in the average time and a 34% reduction in the 90th percentile of the distribution. In part, this can be traced to a reduction in the number of trucks sent to secondary inspection. This number shrinks from about 100 in Scenario S 1 l/S 12 to about 50 in S3 1/S32, a 50% reduction.

Table 10-4. Time in System for Westbound Trucks

Scenario	Avg	90%
S11	1166	3480
S12	1172	3532
S2	970	3081
S31	695	2210
S32	730	2442

Primary processing times also fall substantially. The average time in primary inspection drops 14% from 199 seconds to 173, and the 90th percentile time falls 15% from 253 to 2 14.

The most important findings for westbound autos entering Canada are that: 1) at a 35% participation rate for autos, a dedicated ITBCS lane is warranted; and 2) at a 50% participation rate, two dedicated lanes are necessary to maintain an adequate level of service over the range of traffic volumes present at the bridge.

10.2 Institutional Issues

Implementation of advanced information technology at a border crossing presents many institutional challenges as well as technical ones. A border crossing is a complex institutional environment because there are many different agencies from both countries that have significant stakes in the operations. These agencies have different fundamental missions, different internal cultures, and varying viewpoints on any substantial change in operational procedures at the border. Chapter 9 of this report explores the institutional experience from the ITBCS project at the Peace Bridge in an effort to identify important issues that need to be addressed to create successful implementations of similar information systems in the future.

This component of the evaluation effort was largely accomplished through interviews with representatives of many of the organizations-government agencies in Canada and the United States and private and quasi-public organizations- with a stake in the Peace Bridge test. Such interviews required participants to describe their experiences during the test and to share their observations about and evaluation of the institutional environment during the test. While distinctly subjective in nature, when conducted well and with a diverse group of cooperative informants, interviews can provide a rich and surprisingly accurate picture of organizational life. Seventeen interviews were conducted for this study, ranging in length from one to two hours. In addition, interview data was augmented with documentary information associated with the Peace Bridge test and from evaluations of similar technology in other locations.

An important observation from these interviews concerns the viability of the actual test conducted at the Peace Bridge. Put simply, was the test a true proof of concept of the ITBCS system? Our impression after conducting our formal interviews and participating in numerous casual discussions with people connected to the Peace Bridge project is that it probably was not. While the test did generate some flow data; confirmed that some of the hardware, software, database and communication components can work as anticipated; and uncovered a number of potential institutional barriers to the use of these systems; it did not generate the volume or types of data that were anticipated. Indeed, several of our interviewees expressed the opinion that the test was not successful precisely because such data expectations were not met.

Why did this happen? The data we have, and our instincts, suggest that institutional disconnects led to faulty prototype design and the lack of a true climate for evaluation.

First, the ITBCS test at the Peace Bridge was conducted in a very complex institutional environment. In such an environment, it is likely that an action taken to optimize performance against one institutional mission will come into conflict with or sub-optimize another’s mission. There is compelling evidence that this mission conflict existed during the Peace Bridge test. When it did so, it was not generally caused by “bad” people pursuing unfair advantage or unrealistic ends. Instead, it resulted from dedicated institutional representatives trying to live up to their job requirements. To oversimplify, it could be said that the ITBCS test was conducted without a clearly defined overall vision or "common need" for the technology that was accepted by all participants.

Strategic/policy conflicts need institutional coordination. The ITBCS Steering Committee served that role for the Peace Bridge test but it was not sufficiently empowered to operate at an inter-agency policy level. Some interviewees suggested that if free-trade and "seamless borders" are the goal, more thought must be given to how national agencies within the same country will collaboratively work together to set policy and resolve policy conflicts. Hierarchical escalation and then negotiation at the highest level between agencies is both inefficient and subtly reinforces the ethnocentric tendencies of most agencies. Perhaps, it has been suggested, a forum that represents the border must be created to resolve such issues.

There is some evidence that frustrations occurred during the Peace Bridge ITBCS test because some stakeholders insisted upon using rigorous operational standards in a test environment. For example, the requirement to handle customs clearance procedures using both the new automated system and the old paper system may have been a disincentive for commercial carriers and customs brokers to participate in the ITBCS test. It may also have impacted the attitudes and ultimately the behavior of those participating in the test in ways that distorted test results.

Another manifestation of this issue may have occurred during the system definition phase leading up to the design of the Peace Bridge installation. As we understand it, the accuracy requirements put forth by U.S. Customs were extremely rigorous. In response, some technical personnel questioned whether any system could perform to such standards. Others asked whether the current system operated at the specified level of accuracy. The real issue, however, is whether operational "aspirations" should be used as a non-negotiable baseline to determine the feasibility of a new concept.

A theme that appeared throughout the interviews relates to data security. For a completely integrated border crossing system to be developed, the agencies have to agree on the creation of a comprehensive database that can be interrogated to support all regulatory requirements. The experience of the Peace Bridge ITBCS test, however, suggests that regulatory agencies are reluctant to cede control of their database out of concern for data integrity. At issue are such things as who maintains a database, who can access it, where is it located and, ultimately, questions of sovereignty and national security. It is obvious that this issue needs significant attention.

Many of the government agencies that participated in the Peace Bridge ITBCS test exist to regulate or oversee something. They were created, when all is said and done, to enforce legally defined standards. Day to day work in such organizations involves overseeing or policing some activity or product to assure that the right things are being done and, most importantly, that the wrong things are not being done.

One of the strongest themes in our interviews is that a regulatory culture can be a significant barrier to the smooth implementation of ITBCS technology. Expediting flow is not a central concern to those with a regulatory mission. Enforcement, often accomplished through face-to-face interaction with individuals and/or through direct inspection of documents, vehicles, products, etc. is at the traditional core of regulatory work. Certain regulatory agencies (especially the U.S. Customs Service) involved in the Peace Bridge ITBCS test appear, in our interviews, to be so captured by this enforcement world view that they have had a difficult time honoring seamless flow across the border as an objective that is important.

If effective inter-agency cooperation at the border is to be fostered, a great deal more attention must be paid to the impact of culture on behavior. This is not a matter of "ordering" employees to behave differently, or sanctioning them if they do not. This is not an issue of individual "goodness" or "badness". Representatives of agencies, regulatory or otherwise, simply enact values that have led to success in the past and which make eminent sense to them. Indeed, they may not be aware of how those values were derived from a set of environmental stimuli in the past. Thus, when confronted with new environmental conditions requiring a new response, they simply apply old values and associated behaviors and expect success.

If the changing geo-political environment means that national borders will have a new meaning, then those who work at the border will have different jobs. The need for regulation will not go away, but it will be manifest differently. Introducing ITBCS systems to facilitate flow and cross-border transactions is less a technical issue, than it is an issue of work redesign. It must be handled as such, and cultural change is at the core of that enterprise.

10.3 Conclusions

In conclusion, it appears that the introduction of ITBCS technology can have a major impact on productivity at the Peace Bridge. Reductions in time in system ranging up to 50% seem possible even if the technological standards for the system are not made extremely high. Benefits are more substantial for the inbound than for the outbound flows because of the customs processing, and the U.S. side of the bridge stands to benefit more than the Canadian side because of operational efficiencies already introduced in Canada.

To achieve these impacts, however, significant institutional hurdles must be overcome. It is apparent that inter-agency collaboration and cooperation is needed, and that the facilitation of flow needs to become a more central objective. If regulatory policing continues to be a dominant theme, then expeditious processing is likely to remain a significant challenge. Careful scrutiny of participants, ex-post-facto compliance inspections, and a broader definition of the border to include point of loading to point of delivery, may help disconnect the conflicts in goals that seem to have dampened the success actually achieved during the experiment.

It is clear the technology is available, and that if applied, it can produce significant beneficial impacts. The challenge for the future is to make it possible for those benefits to accrue.

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APPENDIX A

Tag Data Analysis

This appendix presents an analysis of the tag data collected as part of the ITBCS prototype experiment. About 14,000 events were recorded across a 10 month timeframe from May 1997 through February 1998. The events recorded include readings of both ITBCS prototype experiment participants as well as trucks equipped with EZ-pass tags. The resulting database reflects about 1,100 eastbound trips and approximately the same number of westbound trips. Each record contains a Trip ID (for the ITBCS prototype participants), tag number (likewise), date and time of the event (to the nearest second), trip type, event type, and log number. For the trucks in the data set that were not participating in the ITBCS prototype experiment, only certain types of events are recorded (i.e., there are no customs clearance-related events.) Of primary interest are the relative frequencies with which individual events are recorded, and the time interval between those events. The latter gives us insight into the way the ITBCS prototype technology might perform if permanently deployed.

A.1 Placement of the Tag Readers

Tag readers of three main types are installed at the Peace Bridge. Figure A-l shows where they are placed on the U.S. side. Advance antennas are located upstream of the facility in both directions to detect oncoming trucks. Decision antennas are positioned at the primary inspection booths for eastbound traffic (see the bottom right-hand portion of the figure), and immediately upstream of the toll booths for westbound traffic (left-hand side of the figure). Exit antennas detect trucks leaving the facility. Eastbound they are on the I-190 ramp (upper right-hand comer of the figure) and on Baird Drive (upper left-hand comer of the figure). Westbound there is one, downstream of the toll booths. In addition, there is an override antenna above the primary inspection booth (right-hand side of the figure), so that the decision reached by the primary inspector can be displayed in the truck cab.

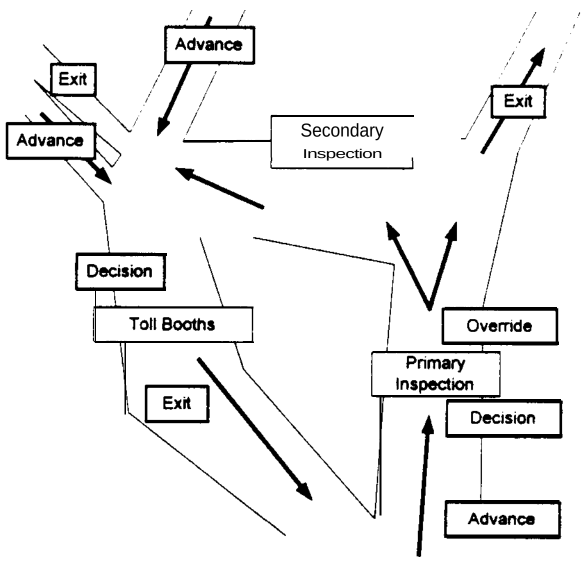

Figure A-l. Antenna Placement on the U.S. Side

Figure A-2 shows the placement of the tag readers on the Canadian side of the bridge. Westbound, there are three detectors. The advance detector is at the entrance to the primary inspection booth. This antenna is not further upstream because the records for arriving trucks are downloaded to the local server well in advance of a truck's arrival. The decision antenna is at the exit side of the primary inspection booth and the exit antenna is along the exit from the facility. Westbound, there are just two detectors since no processing takes place: a decision antenna to identify arriving trucks and an exit antenna to detect trucks leaving Canada for the U.S.

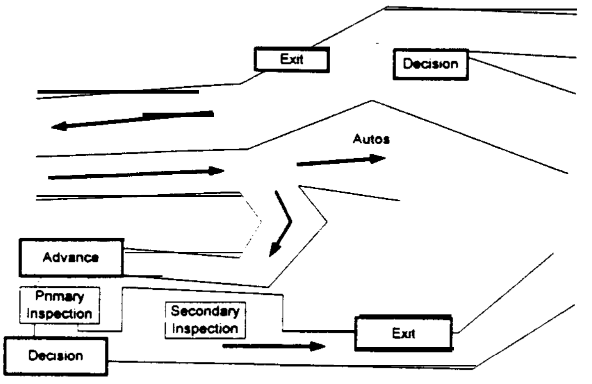

Figure A-2. Antenna Placement on the Canadian Side

A.2 Event Records and Event Sequences

Figure A-3 presents a general diagram of the ITBCS system. The advance antenna is the first system element to see an arriving truck. Located above the toll booth (for eastbound trucks

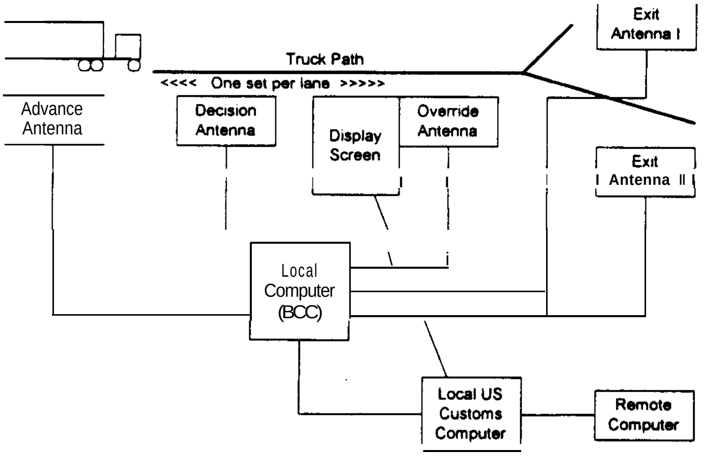

Figure A-3. ITBCS System Block Diagram

entering the U.S.), and upstream of the customs inspection booth, the advance antenna queries the truck's tag and sends to the BCC the Trip ID it reads. That ID identifies not only the arriving truck, but also its load and driver. The BCC in turn sends the ID information to the remote computer through the local Customs network. The remote computer then accesses the record in its database corresponding to the Trip ID and processes it to determine what, if any, special U.S. Customs treatment will be required (e.g., random cargo inspection of arriving shipments).

The next series of events is triggered by the decision antenna. The decision antenna is located at the primary inspection booth, so it can read the tag of the truck that is entering the booth. When it detects a truck, it forwards the Trip ID from the truck's tag to the BCC, and the BCC transmits it through the local Customs network to the remote computer. The remote computer responds by sending back the data record belonging to the Trip ID. (Also, if this is the first time the tag has been read, the remote computer does the preliminary processing described before.)

When the local Customs computer receives the Trip ID record from the remote computer, it sends information about the arriving truck to the display screen in the primary inspection booth. (This includes any special treatment identified by the remote computer in preprocessing the Trip ID record.) The Customs inspector uses this information to decide whether the truck should be cleared for entry or sent to secondary inspection. When a decision is made, the Customs inspector enters the decision to the local Customs computer, which then notifies the BCC. The BCC activates the override antenna and sends a signal to the truck tag indicating to the driver whether the truck has been cleared for entry or not. The local Customs computer notifies the remote site of the decision.

When the truck has been cleared for entry, it exits the system via either the ramp to I-190 or Baird Drive. In both cases, the truck passes by an exit antenna. The exit antenna reads the truck's tag for the Trip ID. That information is sent by the BCC to the local Customs computer, and then on to the remote computer. The record belonging to that Trip ID is found and the disposition of the truck identified at the remote site. Once that disposition is determined, a signal is sent back by the remote computer to the local Customs network, and then to the BCC. The BCC activates the exit antenna to notify the tag in the truck, indicating whether the truck has been cleared for entry (green) or not (red). If red is displayed, the truck is expected to return to the customs warehouse for further processing.

The eight types of events recorded in the file and used in our analysis are:

- *AdvArriv:* truck tag is seen by the advance antenna and the Trip ID is read
- *AdvNot:* advance data packet is sent by the BCC to the remote site (via the local Customs network)
- *DecArriv:* truck tag is seen by the decision antenna and the Trip ID is read
- *DecNot:* decision data packet is sent by the BCC to the remote site (via the local Customs network)
- *DecRes:* the BCC receives the decision status from the Customs local network based on the inspector's action
- *ExitArrv:* truck tag is seen by the exit antenna and the Trip ID is read
- *ExitNot:* exit data packet is sent by the BCC to the remote computer (via the local Customs network)
- *ExitRes:* exit antenna sends exit status to truck based on remote site response.

On the U.S. side, there are also *OverArrv* events recorded as the truck is recorded by the override antenna as it leaves the primary inspection booth, but we have not used those records for estimating processing intervals. There is no comparable event on the Canadian side.

A.3 Analysis Methodology

From the Peace Bridge we obtained an MS-Access database (MDB) containing tag events recorded between May 1997 and February 1998. A QA/QC analysis of the data identified many records that were unusable for analysis purposes. For example, the database contained events for tags that were used for testing purposes. Such tags were often carried from one location to another to see if the detection antennas were working correctly. We sorted the database by tag number and deleted the records for these tags.

We took the remaining database and sorted it into order by time stamp as well as tag number. This meant that for each individual -tag, we could see the sequence of events that had transpired. Ideally, we expected to see that every event was recorded. For example, for a truck starting in Canada and making a round trip to the U.S., we expected to see a *DecNot* followed by a *DecRes* and *an ExitArrv,* all on the Canadian side; followed by *an AdvArrv, AdvNot, DecArrv, DecNot, DecRes, OverArrv, ExitArrv, ExitNot,* and *ExitRes,* all on the U.S. side. If the truck cycled back from the U.S. into Canada, we expected to see *an AdvArrv, AdvNot, DecArrv, DecNot, DecRes, ExitArrv, ExitNot, ExitRes* sequence on the U.S. side followed by *an AdvArrv, AdvNot, DecArrv, DecNot, DecRes, ExitArrv, ExitNot,* and *ExitRes* sequence, all on the Canadian side.

We discovered that complete sequences were quite uncommon. The database had missing events and time stamp inconsistencies between the U.S. and Canadian data sets. For records related to processing events (e.g., *DecNot* and *DecRes),* where the tag number was not explicitly read, the tag number and trip ID were not entered into the records. Those fields were blank. We added the data by hand. Also, it was obvious that the participating carriers were not updating the trip ID’s on a consistent basis. A single Trip ID might be used for many trips. Hence, by hand, new Trip ID’s were added to each record so that actual east and westbound bridge crossings could be identified. Moreover, we discovered that the computer clocks on the U.S. and Canadian sides were unsynchronized twice during the timeframe being studied. This was apparent because there were record sequences in which it took the tag say 5 hours to cross the bridge, from the last recorded event on one side until the next event on the other. These time stamps were judiciously corrected, again by hand.

We also discovered a few more tags that must have been used for testing purposes, because the event sequences were illogical. Finally, we deleted some tags that had very few (less than 10) event records in the database. They were deleted because otherwise it would have required great effort to make them meaningful.

In the end, a database containing about 14,000 useful records was obtained. It reflects about 1,100 eastbound trips and a similar number of westbound trips. It is these trips upon which the findings presented below are based.

Just prior to beginning the analyses, the 14,000 records were split into 4 separate databases, by country and direction. Thus we produced data sets for: 1) Canadian exports, 2) U.S. imports, 3) U.S. exports, and 4) Canadian imports. The findings are presented in this context below.

For each database we proceeded as follows. First, we ascertained how many times each type of event had been recorded. Second, we determined how many times a given event sequence was recorded, *as* in *an AdvArrv* followed by *an AdvNot.* We did this both for the case where event "A" was followed immediately by event "C", with no other intervening event and then also for the case where there were intervening events. In the latter case, we used the event-to-event intervals to learn more about the system's performance.

A.4 Analysis and Findings

Separate sections are presented here for each country and direction.

A.41 U.S.Imports The database for U.S. imports contains 5,159 event records related to 1,159 trips. The following types of events are recorded: *AdvArrv, AdvNot, DecArrv, DecNot, DecRes, OverArrv, ExitArrv, ExitNot, and ExitRes.* As Table A-l shows, the event that occurs most frequently is the override event, which is recorded for 79% of the trips. Arrival events are next most prevalent: 842 for *ExitArrv, 803* for *AdvArrv,* and *687* for *DecArrv.* A sense of the number of ITBCS prototype-related trips captured by the database can be gained by reviewing the "notification" events. *AdvNot* records occur 219 times, *DecNot,* 185, and *ExitNot,* 148. Therefore. there appear to be a little more than 200 ITBCS-equipped truck crossings in the data set. Of some disappointment is the fact that less than half of these (82) contain *DecRes* events. This means that only *82 DecNot-DecRes* event pairs can exist, assuming that every *DecNot* event has a corresponding *DecRes* event

Table A-l. Observation Frequencies - U.S. Imports

Event	# Obs	% Obs
advarr	803	6 9 %
advnot	219	19%
decarrv	687	59%
decnot	185	16%
decres	82	7%
overarrv	918	79%
exitartv	842	73%
exitnot	148	13%
exitres	78	7%
total trips	1159	

Table A-2. Unique Pairwise Event Combinations - U.S. Imports

from\to	advarrv	advnot	decarrv	decnot	decres	overarrv	exitarrv	exitnot	exitres
advarrv		214	470			74	15		
advnot			188			17	7		
decarrv				185		450	27		
decnot					81	96	4		
decres						64	12		
overarrv							673		
exitarrv								148	
exitnot									78

Table A-2 shows how many times each unique sequence of events occurs in the dataset. For example, of the 803 *AdvArrv* events that appear in the database, *2 14* have *an AdvNot* as their next event, *470* have a *DecArrv* next, *74* have *an OverArrv,* and 15 have an *ExitArrv.* The abundance of arrive-to-arrive event pairs reflect, in part, the fact that there were events in the database for trucks that were not participating in the ITBCS prototype experiment. As a first-order estimate, there must be about 450 of these trucks based on the *DecArrv* to *ExitArrv* event pairs.

For *DecNot* events, there are 81 instances where the next event is a *DecRes.* This means that only one of the *DecRes* observations is missing a corresponding *DecNot* preceding event. However, of the 185 *DecNot* events (see Table A-l), 96 have no *DecRes* event, 4 have an *ExitArrv* as the next event, and four have no succeeding event.

In Table A-3, the number in each cell indicates the number of times a specific event-to-event interval could be computed, even if intervening events were recorded. Notice that the *DecNot* to *DecRes* value is 81, corresponding to our earlier comments.

Table A-3. Pairwise Event Combinations - U.S. imports

from\to	advarrv	advnot	decarrv	decnot	decres	overarrv	exitarrv	exitnot	exitres
advarrv		214	653	180	78	678	565	131	72
advnot			188	185	81	180	141	135	75
decarrv				185	81	610	507	121	67
decnot					81	160	125	120	67
decres						64	60	58	58
overarrv							673	117	61
exitarrv								148	78
exitnot									78

Table A-4 presents informative statistics about each of these event pairs. It lists the 10th percentile value as well as the median, mean, and 90th percentile. We see that the arrival and notification events always occur simultaneously. We also notice that the 90th percentile times range up to 3.200 seconds (about 53 minutes) which is a considerable length of time for a truck that is expecting expedited treatment.

Table A-4. Event Interval Statistics - U.S. Imports

Category	10%	Median	Mean	90%
AdvArr-AdvNot	0	0	0	0
AdvArrv-DecArrv	30	69	81	144
AdvArrv-DecNot	37	73	84	162
AdvArrv-DecRes	121	323	410	653
AdvArrv-ExirArrv	78	161	702	2493
AdvArrv-ExitNot	209	1398	1590	3195
AdvArrv-ExltRes	373	1532	1605	3060
AdvNot-DecArrv	31	72	81	158
AdvNot-DecNot	31	72	61	158
AdvNot-DecRes	116	322	427	704
AdvNot-ExitArrv	209	1417	1630	3179
AdvNot-ExitNot	207	1397	1596	3185
AdvNot-ExitRes	364	1374	1615	3026
DecArrv-DecNot	0	0	0	0
DecArrv-DecRes	51	230	316	564
DeArrv-ExitArrv	34	71	779	2462
DecArrv-ExitNot	154	1325	1488	3068
DeArrv-ExitRes	91	344	855	2094
DecNot-DecRes	51	230	316	564
DecNot-ExitArrv	156	1386	1526	3044
DecNot-ExitNot	154	1325	1488	3068
DecNot-ExitRes	235	1237	1347	2688
DecRes-ExitArrv	117	1510	1298	2920
DecRes-ExitNot	71	1100	1235	2592
DecRes-ExitRes	74	1103	1239	2595
ExitArrv-ExitNot	0	0	0	0
ExitArrv-ExitRes	2	3	3	4
ExitNot-ExitRes	2	3	3	4

Table A-5 presents the mean values from Table A-4, arrayed as a matrix. Notice that the intervals starting with *AdvArrv* and *AdvNot* are nearly identical, as they should be given that the time between *AdvArrv* and *AdvNot* is zero. The only instance where a major difference arises is in the times to *ExitArrv* where the *AdvArrv* intervals project a mean of only 782 seconds whereas it is 1630 for *AdvNot.* This suggests it would have been helpful to have a database with more intervening events recorded.

Table A-5. Trends in the Average Intervals - U.S. Imports

	AdvNot	DecArrv	DecNot	DecRes	ExitArrv	ExitNot	ExitRes
AdvArrv	0	81	84	410	782	1590	1605
AdvNot		81	81	427	1630	1598	1615
DecArrv			0	316	779	1488	855
DecNot				316	1526	1488	1347
DecRes					1298	1235	1239
ExitArrv						0	3
‘ExItNot							3

We will focus on two of the pairwise intervals: *DecNot - DecRes,* and *DecArrv - ExitArrv.* In the first case. the motivation is to examine primary inspection phenomena: the response time of the remote site and the time that’transpires between a truck entering the primary inspection booth and being cleared from primary inspection. The interval between *DecArrv* and *ExitArrv* gives us a sense of how long trucks stay in the system from the beginning of primary inspection until they exit.

DecNot to *DecRes* is the time from entry of the truck into the primary inspection booth until the BCC logs the Customs Inspector's decision on disposition of the truck. Nominally, this should be an indication of service time in the booth for the ITBCS-equipped trucks. Figure A-4 plots an empirical cumulative distribution function for the observed values of this interval.

Clearly, this distribution is at odds with observed performance. In Figure A-4 we see that the 50th percentile (about the average) of the distribution is about 240 seconds (4 minutes), well in excess of the average processing time of about 41 seconds (57 – 17 seconds for pull-up time) observed in the field for trucks of all categories. (In fact, only 6 observations in the data set, out of 81, have a value of 40 seconds or less.)

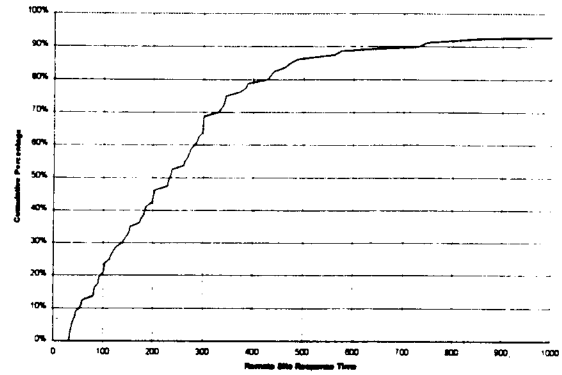

Figure A-3. ***DecNot*** **to** ***DecRes*** **Time Interval**

We have taken this result to imply that the dual processing (electronic plus paper) required for ITBCS-equipped trucks during the prototype experiment nullified any ability to use this data for estimating service time distributions that would be valid under full-scale implementation. Thus, we have constructed estimated service times by other means, as described in Chapter 4.

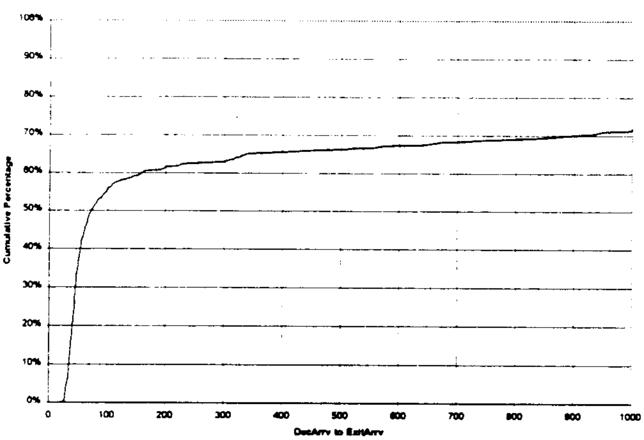

Figure A-4. DecArrv to ExitArrv Distribution

This conclusion is emphasized by examination of the *DecArrv* to *ExitArrv* intervals, as shown in Figure A-6. The data recorded in Figure A-6 include many trucks that have just EZ-Pass tags and have only arrival events recorded. The figure shows that 60% of all trucks recorded spend 200 seconds or less between *DecArrv* and *ExitArrv*. This is significantly less than the median time of the *DecNot* to *DecRes* time for the ITBCS-equipped trucks. Clearly, the service time data recorded for the ITBCS-equipped trucks is unusable for the simulation model.

A.42 U.S. Exports Time intervals for trucks moving westbound are shown in Table A-6. The table presents values for the 10th percentile, median, mean and 90th percentile. We immediately notice that all of the values are on the order of 3 minutes or less, based on the 90th percentile values, and the means are all under two minutes. These data reflect the time required to pass through the traffic signal and pay the bridge toll. We have done no further analysis of these data.

Table A-6. Interval Data - U.S. Exports

Combination	10%	Median	Mean	90%
AdvAn-AdvNot	0	0	0	0
AdvArrv-DecArrv	17	22	30	46
AdvArrv-DecNot	18	25	31	52
AdvArrv-DecRes	33	36	42	59
AdvArrv-ExitArrv	4.3	91	104	160
AdvArrv-ExltNot	54	92	103	191
AdvArrv-ExitRes	57	6.4	101	104
AdvNot-DecArrv	6	23	26	49
AdvNot-DecNot	6	23	26	49
AdvNot-DecRes	33	35	41	59
AdvNot-ExitArrv	55	87	100	175
AdvNot-ExitNot	55	07	119	175
AdvNot-ExltRes	59	64	99	179
DecArrv-DecNot	0	0	0	0
DecArrv-DecRes	12	14	16	27
DecArrv-ExitArrv	31	67	76	126
DecArrv-ExltNot	39	68	61	161
DecArrv-ExitRes	35	66	74	114
DecNot-DecRes	12	14	16	27
DecNot-ExitArrv	39	69	62	164
DecNot-ExitNot	39	69	62	164
DecNot-ExitRes	35	66	74	114
DecRes-ExitArrv	28	51	65	132
DecRes-ExitNot	28	51	65	132
DecRec-ExitRes	31	53	66	135
ExitArrv-ExitNot	0	0	0	0
ExitArrv-ExitRes	2	3	3	4
ExitNot-ExitRes	2	3	3	4

A.4.3 Canadian Imports A major contrast in the performance of the ITBCS prototype system on the U.S. side versus the Canadian side can be obtained by reviewing the tag data for the Canadian side operations, especially the time between *DecNot* and *DecRes* events. Time intervals for trucks moving westbound into Canada are shown in Table A-7. We immediately note that all of the values are on the order of 3 minutes or less, even based on the 90th percentile values, and the means are all under two minutes. These data reflect the fact that trip load information is downloaded to the local BCC by Canada Customs prior to entry of the truck, and that data is immediately available when the truck tag is read at the primary inspection booth. This is an encouragement to the U.S. participants that it is possible to find a procedural and technological solution in which the processing of trucks can be expedited.

A.4.4 Canadian Exports For Canadian exports, only three events are recorded: *DecNot*, *DecRes,* and *ExitArrv.* The statistics for all these intervals is effectively zero based on the data in the events database. This suggests that 1) the antennas were very close together (which is true), the time required to access the record for an exiting truck was short (also verifiable based on the Canadian import data discussed above), and that the vehicles were moving quickly between the two antennas (which also is consistent with what has been observed in the field). Therefore, the . conclusion to be drawn from the Canadian export observations is that these event sequences occur in a nearly simultaneous fashion, as should be expected from a moving traffic stream. There was no further analysis performed on this data.

Table A-7. Time Intervals - Canadian Imports

Cateaow	10%	Median	Mean	90%
AdvArr-AdvNot	0	0	0	0
AdvArrv-DecArrv	30	56	74	147
AdvArrv-DecNot	49	69	95	157
AdvArrv-DecRes	72	107	114	159
AdvArrv-ExitArrv	50	60	110	165
AdvArrv-ExitNot	67	121	126	201
AdvArrv-ExitRes	113	155	159	205
AdvNot-DecArrv	49	69	96	157
AdvNot-DecNot	49	69	96	157
AdvNot-DecRes	71	120	115	162
AdvNot-ExitArrv	67	121	129	201
AdvNot-ExitNot	67	120	126	202
AdvNot-ExltRes	113	155	152	192
DecArrv-DecNot	0	0	0	0
DecArrv-DecRes	0	0	0	1
Dearrv-ExitArrv	17	24	60	37
DecArrv-ExitNot	17	25	27	36
DeArrv-ExltRes	31	37	36	43
DecNot-DecRes	0	0	0	1
DecNot-ExltArrv	17	25	27	38
DecNot-ExitNot	17	25	26	36
DecNot-ExitRes	31	37	36	43
DecRes-ExitArrv	30	37	36	43
DecRes-ExitNot	30	37	36	43
DecRes-ExitRes	31	37	36	43
ExitArrv-ExltNot	0	0	0	0
ExitArrv-ExitRes	0	0	0	1
ExitNot-ExitRes	0	0	0	1