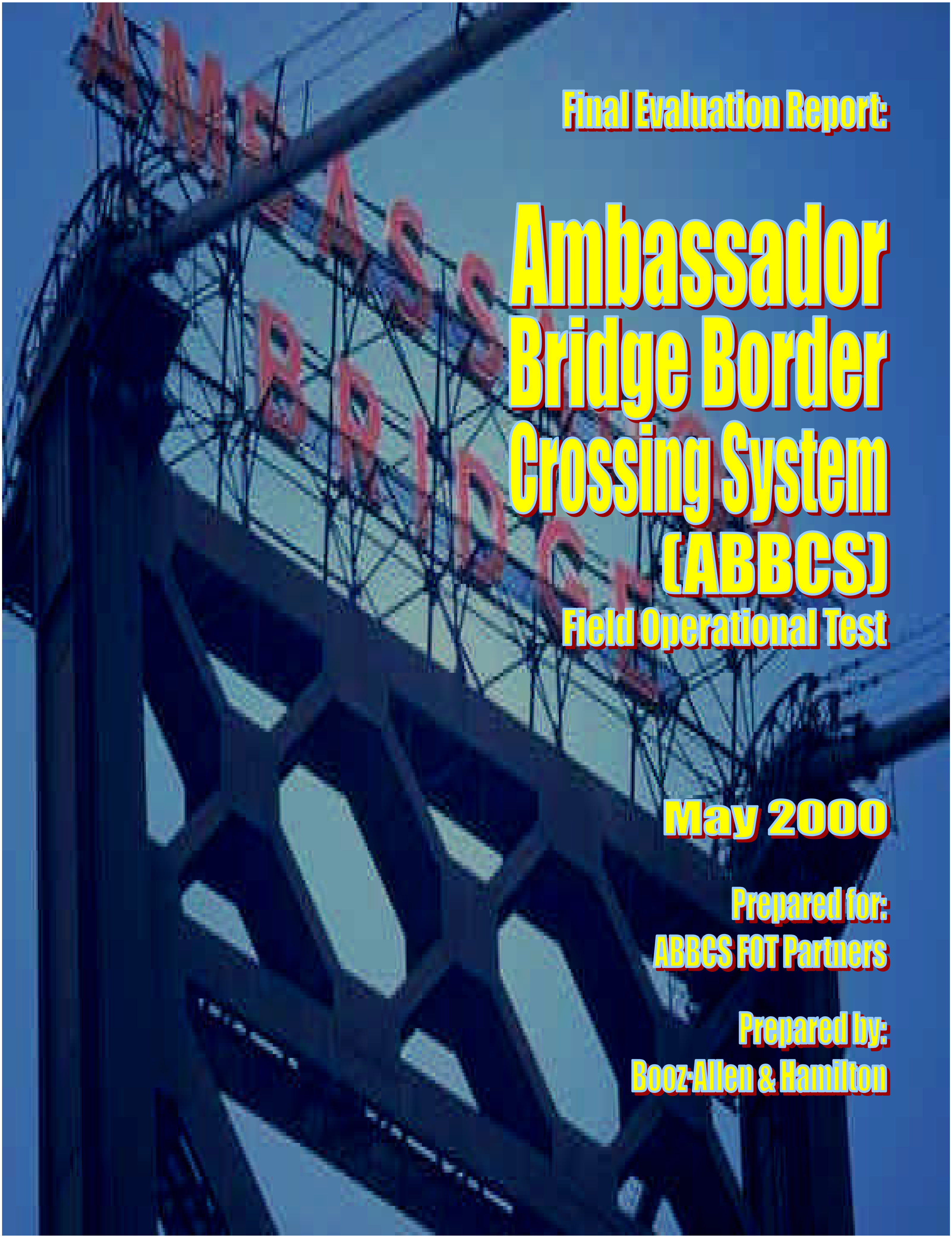

Final Evaluation Report:

Ambassador Bridge Border Crossing System (ABBCS)

Field Operational Test

May 2000

Prepared for:
ABBCS FOT Partners

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CONTENTS

EXECUTIVE SUMMARY

The US-Canada International Border Crossings (IBC) Project is a joint effort between the United States and Canada to provide a transparent, seamless border for expeditious crossing of people and goods through the application of Intelligent Transportation Systems (ITS) technologies at selected border crossing sites. Field operational tests were independently conducted at selected border crossing sites. This report details the evaluation of the field operational tests conducted at the Ambassador Bridge international border crossing site between Detroit, Michigan, USA and Windsor, Ontario, Canada.

The purpose of the Ambassador Bridge Border Crossing System (ABBCS) field operational test (FOT) was to demonstrate the ability of ITS technology to expedite safe and legal international border crossings for both commercial and commuter vehicles in an operational environment. The ABBCS project objective was to develop and demonstrate an integrated system that would allow pre-processed vehicles, trade goods, and commuters to pass through international border checkpoints with expedited customs, immigration, and toll collection processing. Through the application of new and emerging technologies, the ABBCS was intended to facilitate the positive identification of commercial vehicles, crews and cargo, and commuter vehicles, drivers and passengers, as well as to facilitate the electronic payment of bridge tolls.

The system operating concept was centered around the use of a system of in-vehicle transponders and roadside positive identification and classification equipment to gather pre-processed information for use in assessing the crossing status of a vehicle, its contents, and its occupants, and to collect tolls. This system provided the Detroit International Bridge Company (DIBC) with the ability to electronically collect tolls, and the US Customs Service (USCS), and Immigration and Naturalization Service (INS) to screen registered vehicles, cargo, and occupants upon entry into the US, utilizing a single vehicle-mounted transponder for both programs.

This report details the results of an independent evaluation of the ABBCS implementation. This evaluation was designed to address four goals:

1. Assess the *technical performance* capabilities of the technologies being used

2. Assess the *user acceptance* of the services and technologies being provided
3. Evaluate the potential *impacts* of the services and technologies to the transportation processes and interfaces at the international, federal, state and local levels
4. Document transportation institutional and technical *lessons learned*

Findings

These goals were developed to answer several questions, each of which is addressed here:

1) Will the level of functionality of the ABBCS components be sufficient to support the electronic processing and exchange of information necessary to conduct cross-border operations?
   a) The systems installed as part of the operational test demonstrated that the provision of expedited border processing was technically feasible, but that much is yet to be learned regarding the ability to efficiently process large numbers of participants, specifically:
      i) Dedicated short-range communications (DSRC) systems that rely on radio-frequency (RF) transmissions between roadside readers and vehicle-mounted transponders are capable of supporting trade processing decision support systems, such as the North American Trade Automation Prototype (NATAP)
      ii) The electronic card readers used for DCL processing suffered performance problems stemming, at least in part, from environmental effects. Minor modifications appeared to rectify these problems, but no long term data was available as of the completion of this report. Provided that no additional system modification is necessary, such readers, when used in conjunction with DSRC systems, may be an acceptable means to identify individual commuters for screening by the Secure Electronic Network for Travelers' Electronic Inspection / Dedicated Commuter Lane (SENTRI / DCL) deployed by the INS.
2) In what ways can the Detroit International Bridge Company, MDOT, Canada, shippers, carriers, receivers, brokers and commuters benefit from an ITS-based border crossing system?

   a) According to the results of a detailed simulation conducted by Mitretek Systems, the implementation of a system like the ABBCS, in combination with a carefully selected lane assignment scheme, has the potential to significantly reduce the length of vehicle queues during peak arrival periods:
      i) The time required for a participating commercial vehicle to progress from the point just before trucks enter the lane heading into the USCS compound, to the compound exit, can be reduced by 50 percent using ABBCS in a four-lane configuration where all lanes are mixed-use (a mixed-use lane is equipped with ABBCS technologies, and is open to all truck traffic)
      ii) However, a configuration in which all lanes are designated for mixed use is likely to negate some of the incentive for participation in the program, since any differential time savings for doing so would be eliminated
      iii) Benefits are more pronounced as the level of participation in the program increases.
3) What are the potential impacts of the implementation of ABBCS services and technologies on the transportation and traffic characteristics on and around the US side of the bridge?
   a) According to the simulation results, the SENTRI/DCL system also has the potential to positively effect traffic on the bridge:
      i) As with the ABBCS commercial vehicle processing, the combination of DCL and an all mixed-use lane configuration has the potential to measurably reduce queuing.
      ii) However, as was also the case with the commercial vehicle system, the elimination of lanes dedicated for participant use may serve as a disincentive to participation.
4) What are the challenges associated with operating an automated vehicle identification (AVI) system within the geographic context of an international border crossing?
   a) During the FOT, the DSRC AVI system exhibited no unique performance or reliability characteristics resulting from the environment at the bridge. None of the issues regarding antennae footprint overlap or transmission interference experienced at other border sites were evident.
   b) However, the transponder batteries did experience abnormally rapid discharging, apparently stemming from prolonged exposure to readers while in queue.

Due to the limited duration of the test, it is not known whether the replacement of batteries with longer-life units fully rectified this problem.

5) What technical and institutional lessons can be learned regarding the implementation and use of such systems?
   a) The most significant technical lessons pertained to transponder battery life, and DCL card reader environmental sensitivity
   b) Perhaps more significant was the finding from the simulation that reconfiguring the compound entry to accommodate two lanes of truck traffic would be likely to have a much more profound effect on traffic than the implementation of the ABBCS
   c) The most significant institutional issues can be characterized in one of three major categories: information management, inter-jurisdictional coordination, and sustainability
      i) Information management: the primary issue here stems from concern on the part of the carrier community regarding the collection, use, and protection of information not specifically required by law, and liability regarding inaccurate data. This issue is not unique to the border environment, and receives regular attention in most ITS for CVO forums.
      ii) Inter-jurisdictional coordination: the significant issues here involve the adoption and use of standards that promote interoperability, particularly with regard to DSRC, and the issues of sharing information across jurisdictions. These issues are significant, but they also enjoy considerable visibility among the stakeholders, and work to resolve them is well underway
      iii) Sustainability: this refers to the ability of the ABBCS and similar systems to provide incentives significant enough to attract users, and thus become a worthwhile investment of public and private funds. This continues to be a significant challenge.
6) What potential value can this system provide in the future improvement in the level of safety and regulatory compliance of international trade and commercial vehicles crossing into the US?
   a) At the most basic level, the program demonstrated that it is possible for law enforcement officials at or near the border to access information regarding specific vehicle, carrier, operator, and cargo data that was not previously available. As is typically the case with

regard to law enforcement, the more that is known about each of the components of an international shipment, the better equipped responsible enforcement officials are to make accurate decisions.

b) What remains to be demonstrated is the degree to which this information can be accessed and used without inducing additional delays for bridge users, or increasing the complexity of the enforcement tasks at hand.

7) Can utilizing ITS technologies at the Ambassador Bridge crossing allow the State of Michigan to better focus its enforcement resources on non-compliant carriers?
   a) There are legal limitations imposed on the Michigan State Police with regard to the selection of carriers and individual trucks for safety inspections. While this law currently prevents the targeting of specific companies and assets, it does not necessarily eliminate the possibility that the MSP can extract some utility from a system such as ABBCS. Such a system, when properly linked to an information source such as a registration database, could offer MSP the ability to immediately identify a vehicle that is not properly registered to operate in the state. Because Michigan is also a CVISN Pilot state, the potential exists for the establishment of a link to the state's developing commercial vehicle information exchange window (CVIEW).
8) What recommendations can be offered to the State of Michigan regarding the recruitment and enrollment of users, and the use of ITS technologies at other crossing sites? (See Recommendations below)

These questions, and the evaluation goals, were addressed during a series of interviews with border crossing and bridge stakeholders, a survey of commuters, and a simulation model of bridge operations under a number of bridge service configurations and technology deployment levels.

Conclusions

The system, as installed on the Ambassador Bridge, was successful at identifying individual vehicles and exchanging data with USCS and INS systems, though the timeliness and accuracy of these exchanges is uncertain. These findings suggest that the decision to use a transponder-based DSRC system was conceptually sound.

Due to the nature and duration of the operational test, it was expected that any benefits that would be likely to accrue to bridge users and other stakeholders would not necessarily be immediately apparent. Specifically, because import processing using ABBCS was conducted in parallel with, rather than in place of current processes, bridge users were more likely to experience additional workload and delay than any efficiency benefits. Based on user responses, this was, indeed, the case. Nonetheless, the hope that these benefits will eventually be realized remains among all stakeholder groups. However, until bridge users can be convinced that utilizing the ABBCS will benefit them, the bridge company will not realize the potential cost advantages of electronic border screening.

The Mitretek simulation, while being run with some figures that represent educated estimates, seems to indicate that the proper combination of system deployment and lane configuration can be expected to have a sizeable positive impact on traffic conditions on the bridge.

The results of the limited FOT provided very little evidence that the levels of safety and regulatory compliance of international trade and commercial vehicles entering the US could improve. This result is, without question, due at least partially to the narrow scope of this early operational test program. Nonetheless, the modest technical and operational successes experienced lend support to emerging compliance enforcement concepts that rely heavily on advanced electronic screening technologies.

Survey and interview findings clearly indicate that the willingness of bridge users to enroll in and use ABBCS and SENTRI/DCL systems is a direct function of the amount of direct benefit they expect to accrue. What is less clear is the magnitude of benefits necessary to draw them into these programs. In lieu of physical changes to the compound (such as the addition of a second primary inspection approach lane for commercial vehicles), ABBCS proponents may be forced to consider other means of attracting participants, such as financial incentives or preferential treatment.

In summary, while the ABBCS FOT has successfully served to begin bridging the gap between research and development and the deployment of field-ready solutions, much remains to be done both to comprehensively demonstrate the capabilities of the technologies and to assess the impacts of fully deployed systems. For instance, until a viable, sustainable link for making information available to state enforcement officials can be established, the utility of systems such as ABBCS will be limited to that of a conduit for the exchange of trade information and the enforcement of import restrictions. While these are certainly valuable functions, they fall short of the potential for border clearance systems with regard to vehicle and operator safety screening.

Recommendations

The following recommendations are offered for consideration:

The operational test partners should follow this FOT with additional efforts to incrementally develop and validate systems that provide the necessary functionality. Cooperative efforts to advance the International Border Clearance Safety System (IBCSS) concept offer a means to achieve this end.

This concept, which is intended to provide a means for state commercial vehicle safety organizations to assess the risks associated with vehicles, drivers and cargo entering the US, relies heavily on the reliable, accurate determination and relay of key identification parameters. Because the FOT was brief, and the IBCSS was not yet developed, it is unclear if the systems currently deployed on the bridge would satisfactorily support a fully deployed system. To this end, the public agencies and private organizations that constitute the Ambassador Bridge stakeholders should support ongoing efforts to develop and test a prototype of the IBCSS at the Ambassador Bridge by extending cooperative relationships established during the FOT. This includes partnering with the FHWA in technology and infrastructure investments on and around the bridge.

The second recommendation is that an in-depth market assessment that takes into consideration the planned construction of an additional span be completed prior to incurring the substantial costs associated with the implementation of border screening systems. Because limited information is currently available regarding such issues as willingness to pay for services that have yet to reach maturity, the completion of such an assessment appears to be a prudent investment.

Any such assessment should be constructed to incorporate anticipated growth in regional and international trade, existing and developing job markets, population growth projections, current and planned infrastructure, and evolving business models.

Finally, the simulation results suggest that serious consideration should be given to altering the compound entry geometry to allow for two lanes of commercial vehicles from the end of the bridge to the lane divide just prior to the primary inspection facility. This is regardless of whether a system such as ABBCS is deployed. Should such a system be deployed, the simulation results also indicate that particular attention should be paid to determining the lane configuration that results in the maximum overall benefit to commercial bridge users.

PROJECT BACKGROUND

Purpose and Scope

The purpose of the Ambassador Bridge Border Crossing System FOT was to demonstrate the ability of Intelligent Transportation Systems technology to expedite both commercial vehicle and commuter international border crossings in an operational environment. The ABBCS project objective was to develop and demonstrate an integrated system that would allow pre-processed vehicles, trade goods, and commuters to pass through international border checkpoints with expedited customs, immigration, and toll collection processing. Through the application of new and emerging technologies, the ABBCS was intended to facilitate the positive identification of commercial vehicles, crews and cargo, and commuter vehicles, drivers and passengers, and to facilitate the electronic payment of bridge tolls.

"The ABBCS project objective was to develop and demonstrate an integrated system that would allow pre-processed vehicles, trade goods, and commuters to pass through international border checkpoints with expedited customs, immigration and toll collection processing."

To adequately address this objective, this evaluation was formulated to address four goals:

1. Assess the *technical performance* capabilities of the technologies being used
2. Assess the *user acceptance* of the services and technologies being provided
3. Evaluate the potential *impacts* of the services and technologies to the transportation processes and interfaces at the international, federal, state and local levels
4. Document transportation institutional and technical *lessons learned*

In the simplest of terms, these four goals spoke to how well the system worked, whether its use had any effect, how users felt about it, and what it took to get such a system up and running.

Simulation modeling techniques were utilized to offer a method for evaluating potential benefits derived through enhancements in information technologies. The model focused on evaluating ITS technologies that demonstrated time savings, increased throughput efficiencies, and safety improvements that could be achieved through investments in information technology.

A detailed evaluation plan provided the strategy and methodology that was observed as the technical evaluation was performed. It provided the goals and objectives of the evaluation, and the measures by which they would be addressed. It specified the individual data elements to be collected and the analytical techniques to be used. It defined the specific tasks to be accomplished, assigned roles and responsibilities to the test participants, and delineated the schedule and resource requirements for completion of the evaluation.

The data needed to address each of the test objectives was gathered through a cooperative effort between the evaluator, the project partners, representatives from the participating federal and state agencies, and motor carrier and commuter volunteers recruited to participate in the operational test. A combination of research, surveys, and interviews served as the mechanisms for the collection of the necessary information.

History

The US-Canada International Border Crossings Project is a joint effort between the United States and Canada to provide a transparent, seamless border for expeditious crossing of people and goods by the application of Intelligent Transportation Systems (ITS) technologies at selected border crossing sites. Field operational tests were independently conducted at selected border crossing sites. This report details the evaluation of the field operational tests conducted at the Ambassador Bridge international border crossing site between Detroit, Michigan, USA and Windsor, Ontario, Canada.

"The ABBCS operational test directly addresses the national goals of enhancing the efficiency and the level of customer service provided by the nation's transportation system…"

The ABBCS operational test directly addresses the national goals of enhancing the efficiency and the level of customer service provided by the nation's transportation system by implementing systems aimed at increasing the throughput, and hence, reducing the time required to travel safely and legally through international border crossings. It was anticipated that the improved level of service at the border would result in cost and operational benefits to the agencies, commuters, and trade community constituents that conduct international business. The high level of stakeholder interest and support for the ABBCS implementation was evidence of the potential for these benefits. This evaluation was designed to address the ability of the ABBCS technologies and services to advance these national goals and objectives.

One of the most critical elements for a successful operational test and subsequent evaluation was the definition of the roles of all partners and the organization. This FOT of Intelligent Transportation Systems technology was cooperatively funded by the Federal Highway Administration (FHWA), Revenue Canada, Canadian INS, the Michigan Department of Transportation (MDOT), and The Detroit International Bridge Company. The ABBCS program was a joint effort being conducted by the FHWA, MDOT, the US Treasury Department, the USCS, and the US INS, with the support of the DIBC and the Michigan State Police. The ABBCS components were installed and integrated by TransCore. The evaluation was being conducted by Booz·Allen & Hamilton, with modeling support provided by Mitretek Systems. Exhibit 1 lists the principal partners and illustrates areas of involvement.

EXHIBIT 1 - Partners and Roles

Organization	Role
Michigan Department of Transportation	Program Manager
TransCore	Prime Systems Contractor
Mitretek Systems	Simulation Modeling
Booz·Allen & Hamilton	Evaluation Contractor
Detroit International Bridge Company	Private Bridge Owner
US Treasury	North American Trade Automation Prototype
US Customs	System Use
Michigan State Police	Enforcement Issues
US Immigration & Naturalization Service	Dedicated Commuter Lane
US Federal Highway Administration	Program Funding and Oversight
Revenue Canada	Program Funding and Oversight
Canada INS	Program Funding and Oversight

The ABBCS FOT was comprised of a combination of public and private organizations. Program management was provided by the Michigan Department of Transportation. The FHWA was the Contracting Agency for the evaluator, Booz·Allen & Hamilton. This project was conducted in parallel with the US Treasury's North American Trade Automation Prototype project, which is discussed in detail later in this report.

System Description

"The ABBCS Operational Test was designed to provide the trade community, commuters and state and federal regulatory agencies with services and technologies that would demonstrate electronic enhancements to current border crossing and commercial vehicle safety and security processes."

The ABBCS Operational Test was designed to provide the trade community, commuters, and state and federal regulatory agencies with services and technologies that would demonstrate electronic enhancements to current border crossing and commercial vehicle safety and security processes. Each stakeholder in the border clearance process required that data be collected or information be exchanged in a way that was unique to their portion of the process. Thus, the ABBCS services and technologies offered were varied and tailored to the data collection and information exchange environment of the stakeholders being served.

In this evaluation, the primary environments for which technologies were developed were the international border crossing facilities, the carrier or customs broker facilities, and the commercial and commuter vehicles. These environments provided the physical infrastructure that housed the demonstrated technologies.

The system operating concept was centered around the use of in-vehicle transponders and roadside identification and classification equipment to gather information for use in assessing the crossing status of a vehicle, its contents and occupants, and to collect tolls. This system provided the Detroit International Bridge Company with the ability to electronically collect tolls, and the USCS and INS to screen registered vehicles, cargo, and occupants upon entry into the US, utilizing a single vehicle-mounted transponder for both programs.

An electronic toll collection (ETC) participating vehicle approaching the span from the Canadian side first had its transponder polled for identification, allowing the bridge company to deduct the toll from a prepaid account. The account was debited based on the number of axles, which were determined automatically. After passing through the toll plaza, the vehicle crossed the bridge.

On the US end of the bridge, automobiles and commercial traffic were separated into different customs and immigration processing facilities. DCL participants utilized the dedicated commuter lane at the US Customs plaza, where user-specific electronic identification cards were read and the user data was compared against a dedicated immigration database. Provided the vehicle and its driver were determined by the database query to be in proper standing, the vehicle was allowed to pass.

Commercial vehicles were directed into the US trade processing compound, where their transponders were read by the first of three readers. This first, or advance, read provided USCS with notification that a specific border crossing transaction movement was in progress. An identification number corresponding to a specific customs declaration and a specific carrier was read from the transponder and forwarded to the NATAP system, which retrieved the corresponding records in preparation for the next transponder read. When the vehicle approached the USCS primary inspection point, the transponder was read again, and the records retrieved after the advance read were made available to the inspector at the customs booth. This read, called the decision read, resulted in the presentation of a set of vehicle, cargo, and crew pre-processing screening results to the inspector, who made a decision whether to allow the vehicle to pass or send it to secondary inspection. The driver was notified of his status by a red or green light, provided both on the transponder in the vehicle cab, and on a traffic signal adjacent to the primary inspection booth. Finally, once the shipment satisfied US Customs requirements, it was allowed to proceed from the compound, at which time its transponder was read for a third, and final, time. This final, or exit, read constituted the closing of a specific border crossing transaction.

Institutional Issues

On a daily basis, three separate and distinct agencies conduct operations at the Ambassador Bridge: US Customs, INS, and Ambassador Bridge staff. Each operates independently and follows its own internal processes. The agencies have various points of overlap and interface with each other to address the overlapping responsibilities.

Traffic on the bridge structure is controlled by Ambassador Bridge staff. Traffic outside the bridge structure is controlled by Michigan DOT and the City of Detroit on the US side. In an operational scenario such as this, it is expected that issues regarding information sharing and jurisdictional responsibilities will arise on occasion. This evaluation sought to capture those issues that resulted from, or were relative to, the implementation of the ABBCS.

Key Assumptions

The success of this evaluation was dependent on several factors involving the expected levels of effort and timing of activities on the part of its participants. A number of assumptions were made about each participant's ability and willingness to assist in the collection of the data necessary to perform the analyses cited above. These assumptions were:

- Participants will agree to be subjected to survey and interview questions
- Participants will be thorough, complete, and forthright in completing any data collection instruments and in answering interview questions
- System records will be available and will contain the data necessary to conduct the assessments described in the plan
- Data needed to finalize and validate the Mitretek model will be able to be collected
- The number of participating carriers will yield a representative sample size.

Once the evaluation was underway, some of these assumptions proved less than completely accurate. For instance, one motor carrier that had initially agreed to participate in evaluation activities was unwilling to do so once data collection began. Additionally, system records were not available for review and, had they been available, input from users indicated that they would have contained very little data. Finally, because only three carriers participating in the FOT agreed to respond to interviews, no conclusions can be made regarding the degree to which they represent the larger commercial vehicle bridge user population.

Key Limitations

There were a number of test and evaluation limitations that restricted a purely objective and statistically satisfactory evaluation of the ABBCS system. While these limitations were necessary within the realistic scope of this test, their potential effects needed to be recognized and understood. The major constraints and limitations were:

- The limited number of crossings by participating carriers and commuters during the operational test

would likely preclude the evaluator from performing a statistically viable study with a high level of confidence
- Much of the data to be evaluated would be output produced through extensive modeling of traffic volumes and various congestion conditions projected to occur on the bridge
- Many of the inputs to this model would represent estimates on the part of the participants and the evaluator.

Evaluation Activities

Prior to the development of the detailed evaluation plan, Booz·Allen & Hamilton prepared an evaluation strategy document. Included in this document was a set of preliminary goals and objectives. On April 21, 1998, a meeting between Booz·Allen and the other ABBCS participants resulted in the selection of four recommended goals to guide the evaluation. The goals and objectives provided in this report reflect the results of that meeting, and the subsequent coordination of stakeholder input into the plan.

Evaluation Goals

Goal 1: Assess the Technical Performance Capabilities of the Technologies Being Used

The purpose of this portion of the evaluation was to assess the ability of the dedicated short range communication (DSRC) equipment and the border crossing computer to effectively support the border crossing process.

Goal 2: Assess the User Acceptance of the Services and Technologies Being Provided

The purpose of this portion of the evaluation was to assess the extent to which the ABBCS system satisfies the requirements and suits the preferences of its users. Structured surveys and interviews with motor carrier personnel, commuters, Detroit International Bridge Company personnel, and governmental agency personnel responsible for border crossing administration and public safety were used to collect the information necessary.

Goal 3: Evaluate the Potential Impacts of the Services and Technologies to the Transportation

Processes and Interfaces at the International, Federal, State, and Local Levels

The purpose of this portion of the evaluation was to evaluate the potential impacts the ABBCS will have on Detroit International Bridge Company, MDOT, Canada, shippers, carriers, receivers and commuters. Data gathered through research, observation, surveys and interviews with stakeholders, and the results of the modeling effort were used to address these objectives.

Goal 4: Document Transportation Institutional Issues and Lessons Learned

The purpose of this portion of the evaluation was primarily to document the institutional issues and lessons learned that arose during the operational test, and the development and operation of the ABBCS system. It was also intended to serve as a means to provide some insights into the potential impact these issues and lessons, and the solutions employed during the operational test, may have on the deployment of such a system. Interviews with participants and research of records were used to address the objectives.

These goals and the objectives provided were developed to address the following questions:

- Will the level of functionality of the ABBCS components be sufficient to support the electronic processing and exchange of information necessary to conduct cross-border operations?
- In what ways can the Detroit International Bridge Company, MDOT, Canada, shippers, carriers, receivers, brokers, and commuters benefit from an ITS-based border crossing system?
- What are the potential impacts of the implementation of ABBCS services and technologies on the transportation and traffic characteristics on and around the US side of the bridge?
- What are the challenges associated with operating an automated vehicle identification system within the geographic context of an international border crossing?
- What technical and institutional lessons can be learned regarding the implementation and use of such systems?

- What potential value can this system provide in the future improvement in the level of safety and regulatory compliance of international trade and commercial vehicles crossing into the US?
- Can utilizing ITS technologies at the Ambassador Bridge crossing allow the State of Michigan to better focus its enforcement resources on non-compliant carriers?
- What recommendations can be offered to the State of Michigan regarding the recruitment and enrollment of users, and the use of ITS technologies at other crossing sites?

Evaluation Technical Approach

System Performance

The system performance assessment of the Ambassador Bridge Border Crossing System focused on the success of communication events among the ABBCS system, the transponder-equipped vehicles of the test participants, and the NATAP and SENTRI/DCL systems. For the purposes of this evaluation, the two federal database systems (NATAP and SENTRI) were considered as black boxes. In other words, this evaluation was not concerned about the functionality or accuracy of data contained in either federal system but examined the ability of the ABBCS to receive and transmit information reliably, quickly, and accurately. It evaluated the communication links and hardware and software functions that enabled data derived from the two federal systems to update the ABBCS system which then informed the driver via on-board and roadside signaling as to how to proceed within the border crossing environment. An assessment of the user-observed time variance between read/write transmissions focused on the functionality of the system's capabilities to process data quickly.

The data was amassed through the utilization of interviews and surveys, document gathering, and configuration review. The assessment of technical performance capabilities was intended to be ascertained by performing a detailed review and comparison of federal system records and ABBCS system records. This was aimed at documenting the rate of successful transmissions between the federal databases and the border crossing system. As discussed previously, this data was not made available to the evaluator.

User Acceptance

User acceptance can be characterized as the ability of the ABBCS system to meet the functionality and user friendliness demands of border crossing participants, measured in terms of ease of use, willingness to pay for equipment and services, acceptability of observed performance, and usefulness of the system. The evaluator conducted a combination of surveys and structured interviews with the test participants to obtain opinions regarding the acceptability of the system, and to ascertain where users see potential opportunities for improvement.

By definition, information obtained through interviews is qualitative in nature. While the results of this data collection and analysis were characterized numerically, it is important to note that they were based solely on the perceptions of a small number of system users and were highly dependent on the features and level of functionality offered by the ABBCS system.

Where the format of the data allows, responses to questions were aggregated and presented in tabular and graphical format for analysis. Anecdotal responses were reviewed and, where possible, condensed to aid in the analysis of the tabular and graphical data.

Potential Impacts

The evaluation of potential impacts of the services and technologies to transportation processes and interfaces were assessed by identifying the potential value of the systems, the safety and volume impacts, and the conditions under which such a system represents a viable and responsible investment.

The assessment of the potential value of the systems to both public agency and private sector users was based upon user responses to structured queries. The queries included questions regarding public and private sector costs, improvements in the quantity and quality of data, reductions in administrative burdens and traffic delays, and changes in the approach to commercial vehicle compliance monitoring.

During the interview and survey process, users were asked their perceptions regarding the conditions that would need to exist to generate increased participation in the border crossing automated system.

The user-projected impacts were supplemented using a functional modeling of the border crossing environment. The simulation model was created and calibrated by Mitretek, using a modified version of its WESTA weigh station model. Booz·Allen & Hamilton collected the data necessary to complete the configuration and validation of the model prior to using the simulation to project the possible impacts of a system like ABBCS on the border crossing environment.

The simulation was used to model "what if" scenarios and border crossing system configuration changes that could conceivably occur. These changes were representative of those that might occur due to changes in market penetration or congestion, or system installation configuration. Data generated from the model was used to evaluate the current and projected conditions from the toll exit point on the Canadian side of the bridge to and over the US side of the bridge to the point where traffic emerges onto Detroit streets. The resulting data was analyzed, and the results were incorporated into the final report.

The test also examined the use of the unique identifier for commercial vehicles and the viability of the concept to ITS projects interfacing with the border crossing, such as safety enforcement efforts conducted by the Michigan State Police (MSP). Interviews were conducted with MSP and FHWA personnel to identify and assess options for the utilization of international border crossing systems as extensions of proposed state screening systems.

Institutional Issues

Institutional issues play a vital role in the evolution from concept to deployment of any international border crossing system. Institutional issues include the functional, operational, legislative, and statutory demands and constraints within which the system must operate, and the relationships that exist among stakeholders. Putting in place a functional system that aims to address the needs and limitations of a number of jurisdictions and user groups invariably requires the cooperative efforts of those involved.

The specific issues encountered from one border crossing site to another, and the solutions developed to address them, are likely to vary substantially, depending on the agencies and individuals involved. In many cases, however, there exists an underlying commonality among the participants that lends itself well to the sharing of experiences.

Hence, there is value to be gained by documenting and passing along these experiences, particularly in those instances where the solutions were unusual or innovative.

During this evaluation, information regarding the institutional issues encountered and the resolutions reached was collected using a combination of the documentation provided by, and interviews with, project participants. Because the evaluation was not started until long after systems were installed, the evaluator was not able to attend project meetings, which are often a rich source of information regarding institutional issues.

Based on the issues encountered during this operational test, the possible impacts on a deployed system were postulated by transposing the issues to a context that more closely reflects that which would exist in full deployment. For instance, issues that were resolved through temporary agreements, which would only remain in effect for the operational test period, were reexamined with an eye towards understanding the likelihood such an arrangement would be viable long-term.

Current Conditions

The privately-owned Ambassador Bridge was completed in 1929. At the time, it was the longest suspension bridge in the world with a total length from entrance to exit of 9,200 feet. In 1992, the Ambassador Bridge surpassed the Peace Bridge, which connects Fort Erie, Ontario, and Buffalo, New York, as the busiest international land border crossing in North America. The United States and Canada are the world's largest trading partners. The value of trade between the US and Canada is approximately $600 million per day. Fully 27 percent of all merchandise trade between the US and Canada crosses the Ambassador Bridge.

"In 1992, the Ambassador Bridge surpassed the Peace Bridge, which connects Fort Erie, Ontario, and Buffalo, New York, as the busiest international border crossing in North America."

In 1995, more than 10 million vehicles crossed the Ambassador Bridge, reaffirming its status as the premier international gateway in North America. During the last quarter of 1998, the daily volume of commercial traffic averaged about 5,800 commercial vehicles each way and the 6,000-vehicle milestone was achieved multiple times during the period. The bridge can handle up to 5,000 vehicles per hour and now carries 2,500 to 2,600 during peak hours. The Ambassador Bridge international border crossing continues to be utilized by ever-increasing numbers of both private and commercial vehicular traffic.

The Ambassador Bridge Company is preparing to build a second span by 2012, when traffic on the bridge is estimated to reach capacity. A growing regional economy and international trade boom are expected to double bridge traffic between Detroit and Canada as early as 2012. The company expects to spend $300 - $400 million to build the second span, probably with 6 to 8 lanes. Design work is under way, as is property acquisition around the bridge in Detroit and Windsor. Plans call for putting the new bridge just west of the current span.

"A growing regional economy and international trade boom are expected to double bridge traffic between Detroit and Canada by as early as 2012."

In a sometimes confusing route, travelers entering and leaving the bridge in Detroit must cross city streets that separate the bridge from I-75 and I-96. A $100 million Michigan Department of Transportation initiative, the Gateway project, to connect the bridge to the interstates is currently in development. The project objective was enhanced in 1998 when Congress voted to allow Michigan to use federal funds to connect the privately owned Ambassador Bridge to nearby interstates. The Gateway project includes: reconstructing more than a mile of the I-75 and I-96 freeways from just west of West Grand Boulevard to north of the Michigan Avenue overpass; reconstructing about a mile of Fort Street, from 18th Street west to Clark Street; building a pedestrian bridge off Bagley Avenue; building ramps off I-75 to Vernor; building access ramps over I-75, south of Bagley Avenue, to the Ambassador Bridge.

The Ambassador Bridge Company will expand its tollbooth and duty-free plaza between West Fort Street and Lafayette Street. The state expects to complete preliminary engineering on the Gateway project by early 1999. After receiving public comments about the project, the state will complete design work and, in 2000, start buying property. Construction is estimated to take three or four years.

ABBCS Project Intent

The primary intent of the Ambassador Bridge Border Crossing System was to demonstrate the ability of ITS technology to expedite both commercial vehicle and commuter traffic in an operational environment. The goal of all stakeholders at the bridge is to achieve an increase in volume throughput while maintaining the high level of safety and security measures in place. The ABBCS system was intended to facilitate the positive identification of commercial vehicles, crews and cargo, and commuter vehicles, drivers and passengers, and to facilitate the electronic payment of bridge tolls. The system was composed of three distinct ITS initiatives: the North American Trade Automation Prototype; the Secure Electronic Network for Traveler Rapid Inspection system used within Dedicated Commuter Lanes; and the Electronic Toll Collection system.

NATAP

The NATAP system was designed for the US Treasury to test the feasibility of an automated system to capture trade data, and provide border agents the ability to perform a more efficient, more thorough review of declaration documentation. An effort that grew out of the National Performance Review, it was intended as a means to prove the concept and identify technical and operational issues.

In 1994 the Information Exchange and Automation Working Group (IEAWG), a trilateral forum aimed at identifying and resolving technical and institutional issues regarding the exchange of information among North American trading partners, established a requirement for interoperability of Dedicated Short-Range Communications technology at both the US/Mexico border and the US/Canada border. Interoperability, in the context of NATAP, is defined as the ability of each DSRC system deployed at each NATAP port to function identically with any transponder issued as part of the NATAP effort, regardless of manufacturer or issuing organization. From the user's standpoint, interoperability means that a NATAP participant will experience seamless border crossings at both the northern and southern ports, regardless of the type of transponder used. From the governments' standpoint, interoperability means that NATAP in-transit shipments between Mexico and Canada via truck are possible, and that the technology is not bound to a particular equipment manufacturer.

To address these concerns, the IEAWG formed a trilateral team to conduct an in-depth test and analysis of the DSRC systems at two sites, including the Ambassador Bridge in Detroit. The team tested the DSRC systems at both sides of the border and simulated an in-transit shipment. The primary purpose of this test was to demonstrate and verify the interoperability of the NATAP DSRC systems.

SENTRI / DCL

The INS is responsible for enforcing the laws regulating the admission of foreign-born persons (i.e., aliens) to the United States and for administering various immigration benefits, including the naturalization of resident aliens. The Secure Electronic Network for Travelers' Rapid Inspection (SENTRI) system, an INS sponsored program, significantly changes border inspection processes. SENTRI enables inspectors to use advanced technology to rapidly screen frequent vehicular border commuters. The system is aimed at minimizing delays without compromising border security. SENTRI is intended to benefit businesses and individuals that frequently cross the border by improving the efficiency of border inspection processes.

SENTRI is composed of two key components: the Global Enrollment System (GES) and the validation system. The GES stores information about applicants, including fingerprints, photos, and biographical data and screens it against INS databases. Once an individual is authorized, a SENTRI card is issued and a transponder is installed on the car. When a driver stops at the inspection booth, the pertinent data—e.g., license number, digitized photographs of the driver and passengers, and make, model and color of the vehicle—are displayed on a computer screen in the inspector's booth. The information is used by the inspector to quickly identify the vehicle and its passengers.

ETC

Electronic Toll Collection is the use of various technologies to allow the manual in-lane toll collection process to be automated in such a way that customers do not have to stop and pay cash at a tollbooth. With ETC, an actual toll plaza is not even a requirement to collect tolls. The ETC equipment can be mounted on overhead gantries and / or in the pavement, which allows tolls to be assessed while vehicles proceed at highway speeds.

ETC is intended to allow the Ambassador Bridge Company to improve customer service and satisfaction by speeding the trip through the toll plaza, removing the need for the customer to stop, fumble for change, or roll down a window. Customers pre-register with credit cards and have their credit card account automatically charged when their toll account dips below a predefined level, thereby eliminating the customer's concern over funds for toll payment. In addition, customers can receive monthly statements detailing their toll usage and do not have to ask for receipts. Commercial customers have the added benefit of no longer being required to send drivers out with cash or some form of ticket which has the potential of being misused.

The Ambassador Bridge Company also benefits from Electronic Toll Collection. Bridge volume capacity can be increased without the need to build additional infrastructure (such as more tollbooths) and the amount of staff dedicated to the toll collection process can also be reduced. Even the general public may realize clean air benefits from ETC since fewer cars and trucks will be idling at a toll plaza, which will result in less exhaust being discharged into the air.

FINDINGS

The sections that follow detail the data captured and findings developed during the evaluation data collection and analysis. Findings are presented as answers to the questions identified in the project background section of this report.

Will the level of functionality of the ABBCS components be sufficient to support the electronic processing and exchange of information necessary to conduct cross-border operations?

The ability to deliver the level of service necessary to expedite the processing of commercial goods movements and commuters depends on the technical capabilities of the systems installed on the Ambassador Bridge. The primary functions of the systems installed on the bridge are the exchange and management of information. Hence, the measure of technical success for such systems is the degree to which information is accurately and efficiently collected and transmitted among the system's components.

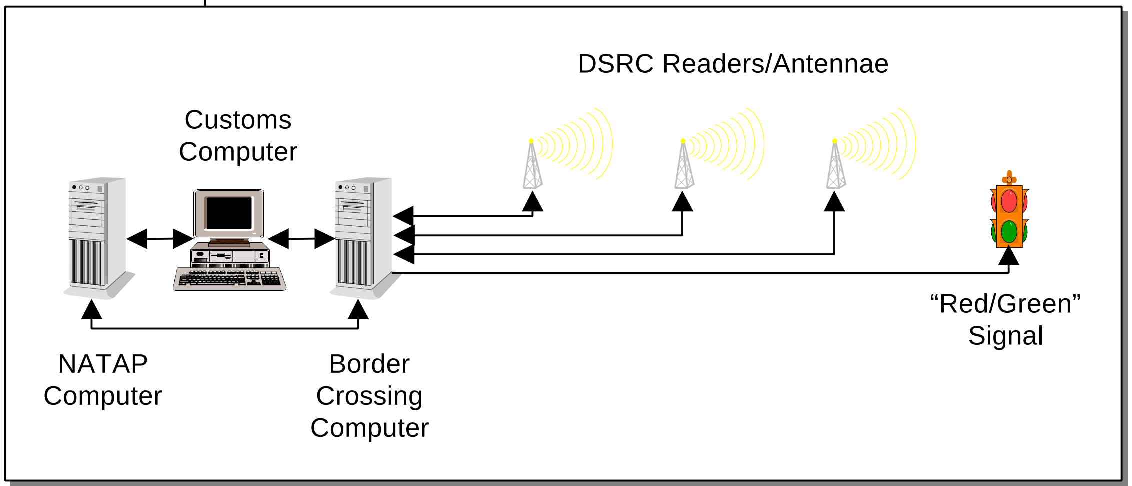
At the time the evaluation was being planned, it was anticipated that some system-recorded technical records would be available for review. This was unfortunately not the case. Actual system usage was very sparse, and the commercial vehicle processing test terminated prior to the initiation of the evaluation, making it impossible for testers to accommodate the data collection necessary for a comprehensive assessment of the technical performance of ABBCS. Nonetheless, interviews with implementers and users offered the opportunity to gather information from an experiential perspective.

At this point, it is useful to note that much of the technology deployed as part of the ABBCS commercial vehicle screening system comes from proven, off-the-shelf componentry. One example of such componentry is dedicated short-range communications, in the form of vehicle-mounted transponders read by a system of roadside readers and antennae. Similar systems have been used successfully for years, and their reliability and accuracy in identifying specific vehicles is well established. From this perspective, the need for technical assessment is limited to the ability of these components to effectively support overall system functionality in the unique operating environment on the bridge. Dissecting the ABBCS into its component parts, so as to isolate those features unique to this installation, facilitates this type of assessment.

The illustration in Exhibit 2 offers a simplified representation of the ABBCS commercial vehicle (CV) installation. At the right of the figure are the three DSRC antennae / reader installations, and the "red / green" traffic signal. These components are connected to, and controlled by, the border crossing computer. This computer gathers information from and distributes responses to the readers, and controls the traffic signal. It is also responsible for passing transponder reads to the NATAP system, and relaying NATAP screening results to the US Customs computer at the primary inspection booth, and to the vehicle transponders. Neither the NATAP system nor the US Customs computer are considered part of ABBCS, and are therefore not included in the assessment.

One of the fundamental questions regarding the DSRC component centered on the ability to individually complete three separate exchanges of information—the advance, decision, and exit "reads"—in an environment that is more geographically condensed and constrained than is typical in other DSRC applications, such as weigh station bypass operations. This has been a significant concern at some border crossing sites, where space is typically at a premium, and properly tuning antennae to avoid erroneous and duplicate reads has been a challenge.

EXHIBIT 2 – Basic ABBCS Architecture



The specific information to be exchanged consisted of a trip / load number (T / LN). The T / LN is an alphanumeric string, encoded into the transponder memory, that is used to identify a specific shipment, including the cargo being moved, and the vehicle and driver transporting it. This unique identifier is assigned to the shipment at the time the requisite trade documentation is filed with the responsible government agencies—in this case, the US Customs and the Immigration and Naturalization Service.

No problems that could be attributed to the sequential installation of antennae or readers for ABBCS were reported by any of the test participants. The spacing and orientation of the individual system elements resulted in no reported instances of overlapping or interference among any of the antennae footprints, as has occurred in installations at other locations. However, problems were reported regarding the transponders. Apparently, the extended periods transponder-equipped vehicles spent queued at the primary inspection booth resulted in prolonged exposure of transponders to the readers, causing the transponder batteries to prematurely lose charge, rendering them inoperable. The transponders were equipped with longer-life batteries, which appeared to solve the problem. No problems were reported regarding the relay of NATAP responses to either the vehicle transponders, or the red / green signal. These findings suggest that the functionality of the ABBCS DSRC as a separate component was acceptable.

The other major technical measure of screening system performance is the ability of the ABBCS to effectively communicate with external systems—in this case, the NATAP system and its components. Because all red / green decisions are made by the NATAP system, the ABBCS is required only to be capable of providing accurate transponder reads to NATAP, and accurately relaying NATAP decisions to the transponders and red / green signal. According to TransCore technical staff, the only problem that occurred with this interface was with the ITDS response time to a tag notification message sent from the ABBCS border crossing computer (BCC). The time to obtain a decision response was often too slow to be able to write to the transponder to trigger its light-emitting diodes (LEDs) before the truck cleared the antenna zone at the import exit location. While the reason for this was not specifically identified, there were occasional timing problems with the Treasury network in communicating between Ambassador Bridge and Washington, D.C.

Obviously, the very small number of actual commercial vehicle border crossing events by NATAP-participant trucks precludes the formation of definitive conclusions regarding system performance. Nonetheless, anecdotal evidence suggests that a screening system that relies on sequential DSRC reads is both technically viable, and operationally satisfactory under the limited use conditions experienced, and the configuration used on the Ambassador Bridge. What remains to be assessed is the ability of such a system to support increasing volumes of transponder-equipped vehicles.

> ***"…anecdotal evidence suggests that a screening system that relies on sequential DSRC reads is both technically viable, and operationally satisfactory under the limited use conditions experienced, and the configuration used on the Ambassador Bridge."***

The functionality of the INS SENTRI system was examined through surveys of system users, and discussions with Detroit International Bridge Company personnel. The system is designed to permit expedited processing of personally owned vehicles (POVs) through primary inspection with the use of a swipe card distributed to bridge users that choose to subscribe to the service. Users apply to the INS for enrollment in the system, which provides a dedicated commuter lane at the primary inspection facility.

Shortly after the system became operational in Spring 1999, surveys were mailed to motorists who had enrolled in the program, asking their opinions of the functionality, usefulness, and value of the system. The evaluator had hoped to delay survey distribution until after users had been given several months to use the system. Unfortunately, system implementation delays, coupled with a fixed evaluation contract end date, effectively shortened the period of exposure. The unwillingness of system administrators to provide the evaluator with names and addresses of enrollees forced the distribution to be incorporated with a Bridge Company mailing, and precluded an independent mailing after prolonged exposure.

Nonetheless, surveys were sent to 385 DCL program enrollees. As of the middle of June, 1999, 122 responses were received by the evaluator, a 31.7 percent response rate. Of the 122 respondents, 115 (77 percent) use the Ambassador Bridge at least five times per week, while 22 (15 percent) use it 10 or more times per week. Fully 81 percent of the respondents use the bridge to commute to and from work. Interestingly, only 84 of the 122 respondents (56 percent) claim to actually use the DCL. The brief nature of the survey did not permit the collection of data regarding reasons for non-use.

Fifty-eight (39 percent) of the bridge users that responded to the survey indicated they had used the DCL more than 15 times. Slightly more than one-fourth (28 percent) of the respondents indicated they experienced difficulty using the system, while 56 (38 percent) had not, and 15 (10 percent) were uncertain. The relatively large percentage of users reporting difficulties appears consistent with reports from bridge operators regarding difficulties they witnessed users having.

While INS reported a couple of problems with the card reader, in fact in only a few instances was the problem internal to the card reader itself. Site testing of the reader showed that over time the unit would reflect intermittent reads resulting in the need for users to swipe their cards multiple times to obtain a successful read. The problem was determined to be the result of grit and grime build-up on the reading heads. TransCore provided cleaning kits to the Detroit INS staff to periodically clean the readers.

Other problems that were believed to be reader problems were in fact related to an internal fiber optics transceiver component that was manufactured by Telebits. The external transformer, which has a 12-volt AC electrical connection, experienced some arcing problems. Apparently this is a common problem with the serial device (RS485) with transceiver cables. A redesign of the electrical connection sheath resolved the problem. Finally the card reader has been modified to incorporate an internal heating element to eliminate condensation problems caused by humid or freezing conditions.

As was the case with the commercial vehicle screening system, the level of testing does not support the ability to fully assess the functionality or reliability of the DCL system. Nonetheless, anecdotal evidence gathered from users and bridge staff suggests that, given the nature of the climate on the bridge, both environmental and operational, other options should at least be explored. For example, the use of contact-less cards and readers offers one potential solution.

In what ways can the Detroit International Bridge Company, MDOT, US Federal agencies, shippers, carriers, receivers, brokers and commuters benefit from an ITS-based border crossing system?

The classical definition of "benefit" is the realization of an advantage or a gain. Given the diverse sets of international border crossing stakeholders, these advantages and gains could take a number of different forms with regard to the Ambassador Bridge crossing. For the Bridge Company, they may be characterized by improvements in the speed with which bridge users can cross from one country to the other, making the Ambassador Bridge an attractive alternative to other crossings. For Michigan DOT, less congestion and smoother traffic flow will hopefully reduce the frequency and severity of accidents. Bridge users, whether commercial or commuter, may realize time savings that reduce lost productivity and stress levels associated with congestion. Trading partners may benefit through improved transaction accuracy and speed, and the ability to monitor shipment progress.

Despite the diversity of interests, a common thread binds together the goals of the stakeholder groups: the application of technology to improve the speed and accuracy of transactions necessary to cross an international border. With information technology (IT) investments, typically the expectation is that the efficiency and effectiveness of processes will be enhanced in a measurable way. For businesses, these improvements translate into increased profitability. For government agencies, they render reductions in operating costs, improved customer service, and greater compliance with laws. For individuals, reductions in costs, both financial and psychological, result.

With this commonality in mind, the potential impacts the use of ABBCS may have on public agency and private users was examined. The approach used for this analysis consisted of two parts. First, users were interviewed to gain an understanding of their expectations for such a system, and the conditions that would have to exist for them to consider it beneficial. Once this was characterized, the results of the bridge modeling effort were examined to gain an understanding of the potential to meet user expectations, and the conditions under which they would occur.

Public Agency Users

Three basic public agency stakeholder groups were involved during the Ambassador Bridge operational test: federal trade and immigration agencies, specifically US Customs and the INS; federal transportation agencies, in the form of the FHWA; and state transportation and public safety agencies, i.e., the Michigan DOT and State Patrol. In order to understand the perceptions that users offer regarding benefits, we must first consider the missions of these organizations.

USCS and INS

The US Customs Service is primarily charged with ensuring that goods imported into and exported from the US are moved in compliance with laws regarding trade. It also has the responsibility to act as an on-site representative for a number of other US government agencies, including the Department of Agriculture (USDA), and the Food and Drug

Administration (FDA), to name but a few. The USCS agents at the border must exercise their judgement and expertise to prevent the movement of contraband into the US, and to prevent the illegal export of protected commodities, such as certain technology products. It is these functions, among others, that an expedited border crossing system must accommodate to be considered useful.

An interview was conducted with Mr. Ben Anderson, the Chief USCS Inspector on site at the Ambassador Bridge to gain insight regarding the potential benefits of a system like the ABBCS. As with all stakeholder interviews, Mr. Anderson was asked his opinion of both the ABBCS, and the current method of operations on the bridge.

Mr. Anderson believes that the current process used for screening international goods movements entering the US is not easy to complete, but is completed quite quickly. He indicated that US Customs oversees the processing of an average of 28,000 import movements per week. Dependent upon the type of import load involved, he reports the process takes between 10 seconds and 86 seconds to complete. Anderson strongly believes that the process is completed in an acceptable period of time and also feels that the process produces accurate and reliable results. He also finds that the level of maintenance required to keep the system functional is acceptable.

Mr. Anderson, who has been a USCS inspector for 22 years, learned his job responsibilities from scratch and learned the proper procedures while performing the job tasks or when interfacing with NATAP and programs. His staff receives training sessions on the use of their systems and processes. They also received NATAP training, but due to the low participation volume of the NATAP program and the length of time between the training session and program activity, most learning was lost. US Customs has a set of support documents that the staff uses to guide their actions while utilizing the system. Mr. Anderson is satisfied with the level and quality of information available to him under the current processes and systems. He is, however, somewhat unsatisfied with the level of compliance monitoring among users of the Ambassador Bridge. US Customs has a goal of 95% compliance, yet, according to Mr. Anderson, they are only achieving 75% compliance at the Detroit facility.

As for the effects of ABBCS implementation, he did not foresee any impacts to the processes US Customs uses to conduct its operations since he did not feel ABBCS volumes were high enough at this stage of the implementation. Mr. Anderson agrees that the ABBCS program represents a significant change from normal operational parameters, but somewhat disagrees that the ABBCS/NATAP program was easier to use than the system currently employed. He strongly feels that the time necessary to complete his responsibilities would not change as a result of the ABBCS system or processes, but nonetheless believes that an ABBCS system would be a wise investment for US Customs.

Mr. Anderson was confident that the ABBCS is sufficient to complete the tasks assigned to his agency, but, curiously, he indicated that the resulting information received from the system is not of much use to his agency. He feels the primary benefit that would result from use of a system such as ABBCS is the reduction of costs associated with completing the tasks he is responsible for by reducing the volume of paperwork. He also feels that the use of such a system will result in improvements in the quantity and quality of data regarding vehicles and cargo if the screen information matches what is shown on the paperwork, but it is really dependent on the system used. He also contends that the level of compliance monitoring should also increase because if data is transmitted accurately, then compliance rates should be higher.

"[Mr. Anderson] feels the primary benefit that would result from use of a system such as ABBCS is the reduction of costs associated with completing the tasks he is responsible for by reducing the volume of paperwork."

The INS' fundamental responsibilities with respect to the movement of goods or people across the border are: to ensure that identified US citizens are able to enter the country as expeditiously as possible; to examine non-US citizens and allow those that qualify to enter without significant delay; and to deny entry to those individuals that do not qualify.

Mr. Norm Byron, Port Director at the Ambassador Bridge crossing site, manages staff that use a variety of modern and archaic processes to accomplish the agency's mission. Mr. Byron strongly believes that the current process used for international goods movement is easy to complete. According to Mr. Byron, the INS oversees approximately 140,000 car inspections, averaging 2 persons per car, each week, with seasonal frequency changes for holidays, school year summer vacations and special events such as hockey games. The length of time necessary to complete the process is dependent upon the type of crossing and number of persons per vehicle. During typical morning and evening peak traffic periods, clearing a vehicle with one occupant takes just a few seconds to complete. Mr. Byron strongly believes that the process is completed in an acceptable period of time and is reliable and accurate as long as proper inspection staffing levels are maintained.

From a technical perspective, however, Mr. Byron feels strongly that the level of maintenance required to keep the current system functional is not acceptable because it is outdated and obsolete. He is satisfied with the level and quality of information available to him under the current processes and systems, and is also satisfied with the costs associated with completing the tasks. He is, however, somewhat unsatisfied with the level of compliance monitoring among users of the Ambassador Bridge.

Mr. Byron indicated he was relatively familiar with the ABBCS, and that he foresees significant negative impacts to the processes INS uses to conduct its operations, primarily because he believes it will consume resources that INS cannot afford to dedicate to the program. He agreed somewhat that the ABBCS was easy to use, but felt strongly that the program created significantly more paperwork than current systems. He also contends it will not speed up the process because INS will inspect the same number of vehicles, and the inspection process will not be any shorter than it is presently.

Mr. Byron believes that INS would incur high costs to operate the program and that the current "no charge" policy for SENTRI/DCL will not cover the costs of the program. As a result, he does not believe that an ABBCS system would be a wise investment for US Customs. He does not see any advantage to the program because it opens up the process to all participants instead of being a tool to assist officers in the inspection process. While he considers the ABBCS system to be reliable, he feels there is no comparison to current systems, since DCL participants are pre-screened, processing requirements cannot compared to those necessary for the unscreened users in the other lanes.

Mr. Byron feels that ABBCS is sufficient to complete his assigned tasks, and the resulting information received from the system is of use to his agency. However, he does not think that use of a system such as ABBCS will result in the reduction of costs associated with completing the tasks he is responsible for because the program is not charging a fee, and current staffing will have to be split between the two processes. He does feel that the system is a wise investment for INS provided that they allocate the necessary resources without impacting current resources. This is despite his contention that the use of such a system will not result in improvements to the level and quality of data regarding vehicles, cargo or individuals entering and/or exiting the US. He feels that the level of compliance monitoring will not change since the emphasis is not on improving security and enforcement, but on facilitating the border crossing activity with a minimum of security inspections.

FHWA

While the US DOT has responsibility for ensuring that automobile parts entering the country meet regulatory requirements, the Federal Highway Administration technically has no specific responsibilities in processing border crossing movements. It does, however, have the responsibility to facilitate the implementation of solutions that can assist state transportation agencies and other federal agencies in accomplishing their missions. In the case of the ABBCS, the FHWA invested significant funds to implement DSRC to assist both the USCS and Michigan DOT efforts to expedite crossings at the bridge.

During the operational test, the FHWA's primary role was to coordinate with the USCS to ensure that technical and institutional challenges were addressed, allowing the implementation of the DSRC, and the associated systems. Since the FOT was completed, the FHWA has continued to lead the development of transportation safety-related systems. These include an International Border Clearance Safety System, which will interface with the International Trade Data System (ITDS), and with state enforcement systems.

"…the consensus among FHWA representatives contacted during the evaluation was that systems such as that installed and planned for the Ambassador Bridge represent a very valuable investment…"

Because this system remains under development as of this writing, it was determined that in-depth interviews with FHWA personnel regarding the ABBCS would be of limited value. Nonetheless, the consensus among FHWA representatives contacted during the evaluation was that systems such as that installed and planned for the Ambassador Bridge represent a very valuable investment—both for their ability to expedite the processing of vehicles at the border, and their potential as a critically important information gathering point for state transportation safety agencies.

MDOT

The Michigan Department of Transportation's primary responsibility with respect to cross-border transportation is to provide funding for the construction and maintenance of infrastructure and systems to facilitate the safe movement of people and goods.

Dr. Kunwar Rajendra, Engineer of Intelligent Transportation Systems, Michigan Department of Transportation, and Mr. Ross Bremer, Supervising Engineer for MDOT, were interviewed to gain insight into the perspective of a state transportation agency regarding expedited border crossing systems. Dr. Rajendra's primary role at MDOT is coordinating, initiating and directing the application of technology efforts. Mr. Bremer's primary role at MDOT is leading the Out-State ITS Unit in its role of facilitation of programs promoting the development, deployment, and support of ITS in Michigan.

MDOT is not directly involved in the Ambassador Bridge Border Crossing System project. However, it does provide facilities, and is a stakeholder in the overall process. As the state agency lead for the evaluation, it expects the results to contribute to determining the future of ITS applications in the state.

The staff at MDOT recognizes that current procedures for processing international goods movements are cumbersome and somewhat inconvenient. As for the specific impacts expected from the ABBCS, Dr. Rajendra is uncertain whether there will be a reduction in costs associated with tasks that fall under his responsibility. He has chosen to await the completion of this evaluation prior to passing judgement as to whether the implementation of a system such as ABBCS would be a wise investment. He expects to have further data upon which to make a decision once he reviews this completed report.

Mr. Bremer believes that a system like ABBCS will promote efficient crossings, improve safety, and enhance the overall commercial trade climate. He is confident that such systems will allow for better safety compliance monitoring, which will enable enforcement organizations to concentrate on non-compliant carriers.

MSP

From a transportation safety perspective, the Michigan State Police stands to realize the most significant impact from ABBCS, from a public agency perspective. The MSP's primary responsibility with respect to the movement of goods or people across the border involves ensuring that all applicable safety laws and administrative regulations are observed by commercial and private vehicle owners and operators. These include vehicle size and weight restrictions, operator hours of service, vehicle condition, motor vehicle operator laws, and the possession of proper credentials and permits.

Lt. Lisa Irwin, State Support Commander, Michigan State Police, was interviewed for this evaluation. Lt. Irwin's primary role for MSP is managing safety related state programs including hazardous materials and fatal accident teams. She also is responsible for the Division's management information systems, grant application management, and an investigative staff located in fifteen MSP districts.

According to Lt. Irwin, MSP processes have changed over time due to the evolution of ITS, and the growing emphasis on automation and IT strengths. In Lt. Irwin's opinion, while Department of State Police is moderately automated, her division is highly automated.

The Michigan State Police is not directly involved in the Ambassador Bridge Border Crossing System project but is responsible for the enforcement of safety and regulatory laws of the State of Michigan. It is, however, a stakeholder in the overall process. Lt. Irwin believes that if a safety link is established through the ABBCS, a reduction of costs associated with tasks that fall under her responsibility should occur. She also feels that the implementation of a system such as ABBCS would be a wise investment for MSP, provided the goals of the program are consistent with the safety goals of the enforcement community. She is neutral towards automation unless it contains a direct tie-in to enforcement activities.

"[Lt. Irwin] feels that the implementation of a system such as ABBCS would be a wise investment for MSP, provided the goals of the program are consistent with the safety goals of the enforcement community."

Lt. Irwin reflects that an ABBCS system will result in improvements to the level and quality of data, if that data is input with a minimum number of keystrokes in as few steps as possible to ensure a high degree of accuracy. Commercial vehicle compliance monitoring should also increase if vehicle participation is mandatory, and should result in an incremental increase in the actual level of vehicle compliance due to the knowledge that "big brother" is watching the process.

Private Users

Two fundamental private stakeholder groups were involved during the Ambassador Bridge operational test: those involved in commercial goods movement, and private individuals that use the crossing to access jobs, tourism, and other commerce. Again, in order to understand the perceptions that users offer regarding benefits, we must consider their reasons for using the bridge. We can then examine whether the improvements promised by the ABBCS offer real benefits.

Commuters

The Ambassador Bridge is a very popular commuter facility. Among those that participated in the DCL survey, 62 percent choose to use the bridge because it is the most convenient to their destination. Nearly as popular reasons are because it has electronic toll collection, and it is considered a faster alternative to other border crossings border. The presence of the DCL was also a significant drawing point for some commuters.

What these reasons have in common is the underlying appeal of reducing total travel time from origin to destination. This is reinforced by the fact that 75 percent of respondents cited time savings as the primary purpose for enrolling in electronic toll and DCL programs. Based on survey responses, at least some of the program participants perceive some benefits from enrollment.

"...58 percent credit the DCL with travel time savings, with 44 percent claiming savings in excess of 3 minutes per trip."

Fifty-four percent of respondents agreed that electronic toll collection has reduced their travel time. Approximately 48 percent estimated travel time savings per crossing of between 1 and 5 minutes. In comparison, 58 percent credit the DCL with travel time savings, with 44 percent claiming savings in excess of 3 minutes per trip. More than 70 percent expect to continue to see travel time savings resulting from the two programs.

Within the same commuter population, however, just as many felt traffic conditions on the bridge had not improved since either electronic toll collection or DCL were added, as felt they had. Some respondents cited ongoing construction projects as the source of continued traffic problems, while others indicated that too few commuters use electronic toll collection and DCL to make a significant difference. Fully 60 percent of the respondents expect that traffic conditions will eventually improve because of the addition of the DCL.

Perhaps the most difficult item to assess is the willingness to pay for services. This is traditionally an elusive measure, with respondents often answering such questions in a manner typically aimed more at influencing pricing policy, than truthfully relating a cost threshold. That phenomenon in mind, 55 percent indicated they would not be willing to pay for the service, and 17 percent would pay no more than $.25 per crossing.

While these results seem to indicate support for the contention that the DCL does offer benefits to commuters, it must be understood that the population surveyed was not selected randomly. As such, it is not necessarily representative of the population of bridge users as a whole. Hence, caution should be exercised when drawing conclusions regarding the valuation of DCL services. Nonetheless, that 62 percent of respondents indicated a willingness to continue to use DCL after initial testing is completed speaks well for the future of the service.

Motor Carriers

The Ambassador Bridge is, without exception, the busiest US land border port. In 1998, more than 1.5 million import truck movements were made over the bridge. Fully 27 percent of the annual trade volume between Canada and the US passes through this port. Between 1993 and 1997, truck traffic across the bridge increased by 50 percent. This tremendous rate of growth is anticipated to continue for the foreseeable future.

In spite of the favorable trading status that exists between the US and Canada, it is not surprising that the volume of goods movement through the port exacts a toll on the infrastructure and organizations charged with processing these shipments. This workload has obvious implications for the motor carriers that use the crossing to deliver customers' goods between the trading nations.

Significant traffic backups are not uncommon during peak commercial goods movement periods during the day.

These periods, which typically occur around midday, often see trucks backed up out of the US Customs processing facility, onto the bridge span. These delays are most often the result of demand that exceeds the processing capacity of the US Customs primary inspection facility—a condition that is usually remedied by USCS staffing additional primary inspection booths.

Not surprisingly, the elimination of such traffic delay is one potential ABBCS benefit in which motor carriers are particularly interested. Nowhere is the concept that time is money more graphically illustrated than in the motor carrier industry. Opinions offered by motor carriers that participated in the ABBCS FOT reinforce this priority.

Representatives from three motor carriers that transport a significant volume of goods across the Ambassador Bridge were interviewed as part of the evaluation. Due to a prior agreement not to disclose the names of the carriers, or the representatives that submitted to interviews, the carriers will be referred to in generic terms as Carrier 1, Carrier 2, and Carrier 3. A fourth carrier had agreed to participate in the FOT, but was unwilling to respond to repeated requests for an interview.

Carrier 1

Carrier 1 is based in Ontario, Canada, and has a fleet consisting of 380 tractors and 1,850 trailers that it uses to transport bulk paper products across the border. Approximately 25 percent of its international goods movement activity was processed using ABBCS. The representative from Carrier 1 credited the firm's overall level of automation with rendering the current processes relatively simple. The same carrier official also believes the processes are completed in an acceptable period of time, and that the results are accurate. He did not perceive any significant reduction of time or inconvenience when using ABBCS, and felt that the functions and features offered by the ABBCS were awkward to work with, and lacked integration with the satellite-based systems currently used by the carrier.

"The Carrier 1 representative was neutral as to the ability of a system such as ABBCS to reduce either the time required or the inconvenience associated with moving goods across the border."

The Carrier 1 representative was neutral as to the ability of a system such as ABBCS to reduce either the time required or the inconvenience associated with moving goods across the border. He also felt overall savings of no less than one hour would be necessary for such programs to be considered successful.

Not surprisingly, this carrier participant predicted minimal benefit from the ABBCS and similar systems, and as a result, considered investment in such systems unwise.

Carrier 2

Carrier 2, also based in Ontario, has 450 tractors and 1,300 trailers that it uses to transport automotive products between Canada and the US. About 30 percent of their international shipments were processed through the ABBCS. The Carrier 2 representative indicated that current processes for the movement of goods across the US/Canada border were not easy to complete. He also felt strongly that the costs associated with completing international goods movement are unacceptably high.

While use of the ABBCS system did not represent a significant change to existing Carrier 2 processes, he felt that the ABBCS system was somewhat easy to use but not necessarily easier to use than his current system. He indicated that Carrier 2 would incur additional time pressures if it was necessary to complete his responsibilities using the ABBCS system as it existed during the demonstration.

His experience with the system has created the feeling that the ABBCS system was not reliable because Carrier 2 did not receive any successful transmissions during the test. Further, he did not feel that the ABBCS produced accurate results and was not as accurate as current Carrier 2 systems.

The Carrier 2 representative did not perceive any reduction of time or inconvenience when using the ABBCS, and felt that the system needed to be linked to available satellite systems. He was, however, of the belief that a system such as ABBCS could reduce costs associated with moving goods across the border, but felt that at least 20 minutes less time spent at the border would be necessary for the program to be successful.

"The Carrier 2 representative… does believe that a system such as ABBCS would eventually be a wise investment on the part of his firm…"

If a system similar to ABBCS were adopted and deployed at the Ambassador Bridge, the Carrier 2 representative did not feel that it would be a wise investment for his firm until more technology is in place and the Ambassador Bridge lane configuration is improved to reduce congestion. He does believe that a system such as

ABBCS would eventually be a wise investment on the part of his firm and should increase the level of both vehicle compliance monitoring and driver screening activities. He also believes that the use of the ABBCS system will reduce traffic congestion on the roadways surrounding the bridge once market penetration is high enough.

Carrier 3

Carrier 3, also from Ontario, has 12 tractors that is uses to export its own products, and those of a major automobile manufacturer. Approximately 30 percent of its shipments were processed through the ABBCS. The Carrier 3 representative concurred with the opinion of Carrier 2 regarding the difficulty associated with the completion of current border crossing processes. He also agreed that the costs associated with completing international goods movement are unacceptably high.

A smaller carrier than the others, Carrier 3 has a relatively limited level of process automation. Hence, the introduction of the ABBCS into their operations represented a significant change. Despite this change, the Carrier 3 representative felt the ABBCS was easy to use once staff had become familiar with its operation. He also considered the system fairly reliable and accurate.

The Carrier 3 participant had overwhelmingly positive perceptions regarding the potential benefits of ABBCS. He was confident that the ABBCS was better suited to complete the tasks necessary to move goods across the border than current systems, and that ABBCS could reduce the time and inconvenience associated with cross-border goods movement. In fact, he felt the use of such a system has the potential to reduce transaction preparation time by as much as a few hours per week, primarily through the elimination of non-value-added labor.

"The Carrier 3 participant had overwhelmingly positive perceptions regarding the potential benefits of ABBCS."

The Carrier 3 representative also projected significant improvements in traffic conditions on the bridge and on the roadways surrounding it, which would result in substantial improvements in safety. Not surprisingly, he considered the implementation of such a system a wise investment for his firm, and for the motor carrier industry as a whole.

The DIBC

As a provider of facilities that are intended to allow users access to goods, services, employers, and customers on both sides of the US/Canadian border, the ability to provide quick, easy access to both countries is a competitive necessity for the Detroit International Bridge Company. The implementation of systems and services that promise to expedite crossing offers the DIBC the means to improve its competitive stance as the crossing of choice.

Mr. Joe Polak, Superintendent of Operations at DIBC asserts that the bridge company's primary responsibility with respect to the movement of goods and people across the border is to move traffic, goods, and people safely, efficiently, and without delays or hassles.

Like many other stakeholders, Mr. Polak believes the processes currently used for cross-border goods movement are complex. The Ambassador Bridge accommodates approximately 30,000 crossings per day for all traffic, much of which is commercial vehicles transporting automobile parts and finished vehicles between the two countries. Despite the complexity of processing and the level of traffic on the bridge, he estimates that trucks complete the import crossing in an average of between 6 and 7 minutes, and cars are processed across in an average of between 3 and 4 minutes.

Mr. Polak foresees positive impacts to the processes the bridge company uses to conduct its operations because he believes the ABBCS will produce across the board improvements. He strongly agrees that the ABBCS program is easy to use because the current system involves handling cash and change, issuing receipts and requires heavy staff involvement. He believes that the bridge company would incur initial deployment costs for such a system, but after implementation, all operating costs should be lower and that execution of the program will create more time for him to concentrate on improving and modifying program processes.

"Mr. Polak strongly believes that an ABBCS system would be a wise investment for the Detroit International Bridge Company because it will improve business operations."

Mr. Polak strongly believes that an ABBCS system would be a wise investment for the Detroit International Bridge Company because it will improve business operations. He considers the ABBCS system to be more reliable and accurate than his current systems and processes. He also believes that use of a system such as ABBCS will result in the reduction of costs associated with completing the tasks that fall under his responsibility. He indicated that the functions and features offered by the ABBCS are efficient, cost effective and will be a major improvement in operations. Further, he believes that the use of such a system will result in improvements to the level and quality of data and a reduction of associated costs since it will reduce manpower commitments and lessen “backroom” processing impacts.

Mr. Polak believes that both the level of compliance monitoring and the actual number of compliant vehicles will increase as a result of the ABBCS. Further, he asserts that the use of a system such as ABBCS is likely to reduce, by one-third, the time required to move goods across the border, as well as reduce the inconvenience factor by one-half. Mr. Polak believes the ABBCS will improve traffic flow by reducing congestion and speeding up the crossing process. Overall, he feels that there is tremendous market potential of commercial vehicle enrollment in similar technologies if incentives are tied to minimizing toll payments and crossing times.

What are the potential impacts of the implementation of ABBCS services and technologies on the transportation and traffic characteristics on and around the US side of the bridge?

System proponents and bridge users alike, point to two specific potential benefits from the implementation of a system such as ABBCS, and the US Customs, INS, and transportation safety systems it is intended to support. The first is the acceleration of processing at import primary inspection facilities. This is, in fact, one of the fundamental aims of the deployment of systems by USCS, INS, and the US Treasury Department.

The second potential benefit is actually a by-product of the first, but is by no means of less importance to stakeholders. Bridge users, owners, and state and federal transportation agencies are keenly aware of the potential for expedited processing to impact the traffic characteristics on and around the bridge. The benefits to bridge users are obvious—less time tied up in traffic getting across the bridge, and a potential reduction in the likelihood of being involved in congestion related accidents. For the bridge company, faster-moving traffic and less congestion make the bridge a more attractive border crossing option. For transportation officials, the potential exists to positively effect the safety and efficiency of a critical link in the local transportation network.

The question is then, to what extent, and under what conditions, can we expect the implementation of such systems to impact current traffic conditions? To gain some insight into this issue, it was determined that the most effective approach to predicting these impacts was the use of a computer simulation.

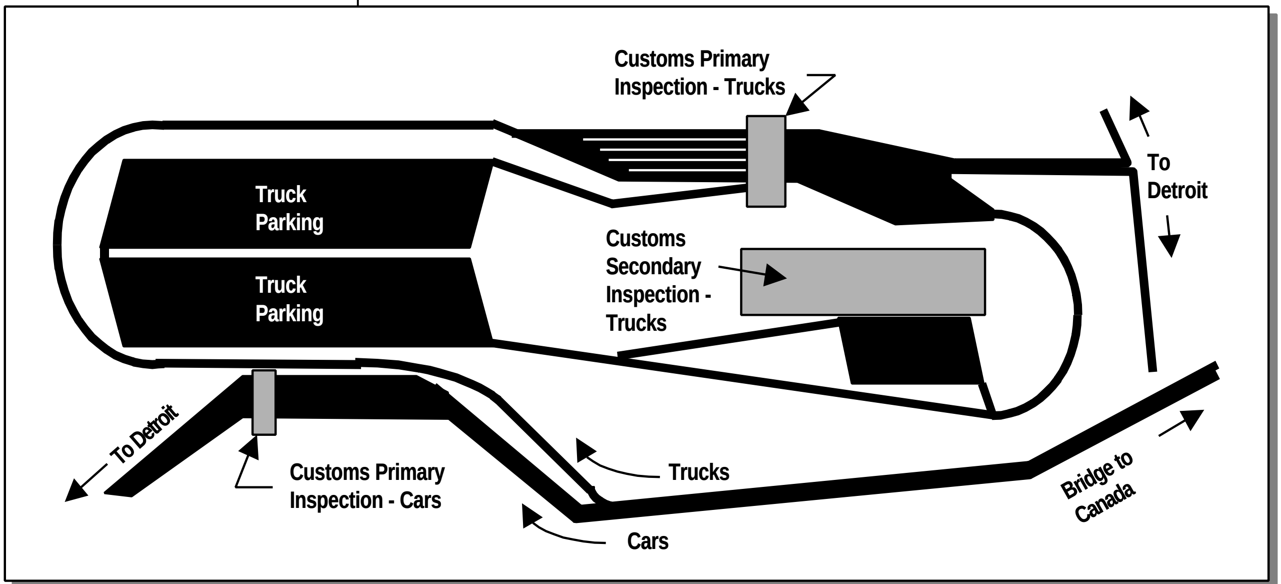
Working under an existing contract with the ITS Joint Program Office, with the technical cooperation of Booz·Allen & Hamilton, Mitretek Systems was tasked with developing a model of the US import side of the bridge, and executing a matrix of "what-if?" scenarios. These scenarios were based on potential operating conditions and system deployment levels, using a combination of measured and estimated performance parameters. Technical details are provided in the full text of the Mitretek final report, which is included in the Appendix. Some of the more significant findings are presented here.

The model used by Mitretek was an adaptation of the WESTA (Weigh Station) model it has used previously to model the effects of technology implementations at weigh station facilities. For this evaluation, it was configured to replicate the geometric and operational characteristics of the bridge between the toll exit and the US Customs facility exits for cars and trucks on the US import side of the bridge. Vehicle operating characteristics were modeled after results obtained from various previous studies, and site specific characteristics, such as vehicle mix, clearance processing speeds, and vehicle inter-arrival rate, were measured directly, or estimated based on data available from multiple sources.

The "what-if?" configurations and scenarios developed jointly by Mitretek and Booz·Allen staff were designed to offer a comprehensive set of combinations and permutations representative of the conditions likely to be encountered. Parameters for which effects were examined included the number of open primary inspection lanes, and the percentage of vehicles, whether cars or trucks, participating in the DCL and NATAP programs. The intent of this exercise was to examine the impacts such factors might have on the traffic characteristics on the bridge, such as queue length and delay.

The figure in Exhibit 3 is a simplified representation of the US import facilities at the bridge. Cars and trucks traveling from Canada arrive at the US end of the span, which is located at the lower right of the figure. Trucks must move to the right lane, from which they access the entry into the Customs compound. Cars move to the left, and enter US Customs primary at the base of the bridge.

EXHIBIT 3 – US Import Processing Facilities



Commercial Vehicles

Trucks must form a single line, and follow the roadway that encircles the parking area and leads to the primary inspection facility. Just prior to the inspection facility, the roadway widens into five lanes. Trucks that have their documentation in order, and meet the approval of the on-site Customs inspector are permitted to proceed into the US. Trucks containing goods that have not yet been processed for import are directed to the parking lot, where the operators park their vehicles and enter the building containing both the US Customs offices, and the offices of a number of customs brokers. Once processing is completed, these vehicles are also permitted to enter the US.

Should the US Customs inspector at the primary facility, or in the offices inside the inspection facility, determine that the driver, the vehicle, or its contents require further inspection, the driver is instructed to proceed to the secondary inspection facility at the center of the compound.

Currently, the most common operating configuration for commercial vehicle processing consists of a minimum of three primary inspection booths in operation at any given time, with additional lanes opened as dictated by truck volume. During the FOT, the leftmost lane was designated for use by NATAP-equipped trucks, yet any arriving truck was permitted to use the lane. None of the other lanes were equipped.

Four separate measures of system impact were identified for the simulation:

- *Percent of Peak Hour with Trucks Blocking Gore*—the amount of time that the queue of trucks awaiting primary inspection extends back to the bridge span
- *Number of Queued Trucks Awaiting Primary Inspection*—the total number of trucks in queue for primary inspection
- *Time Savings for ABBCS (NATAP) Trucks*—reduction in the average time necessary for participating trucks to traverse the entire simulation window
- *Overall Time Savings*—the reduction in the average time necessary for all trucks to traverse the entire simulation window.

The results of the simulation provide some very valuable insights into the likely effects of a system such as ABBCS under different operating scenarios, and varying levels of market penetration.

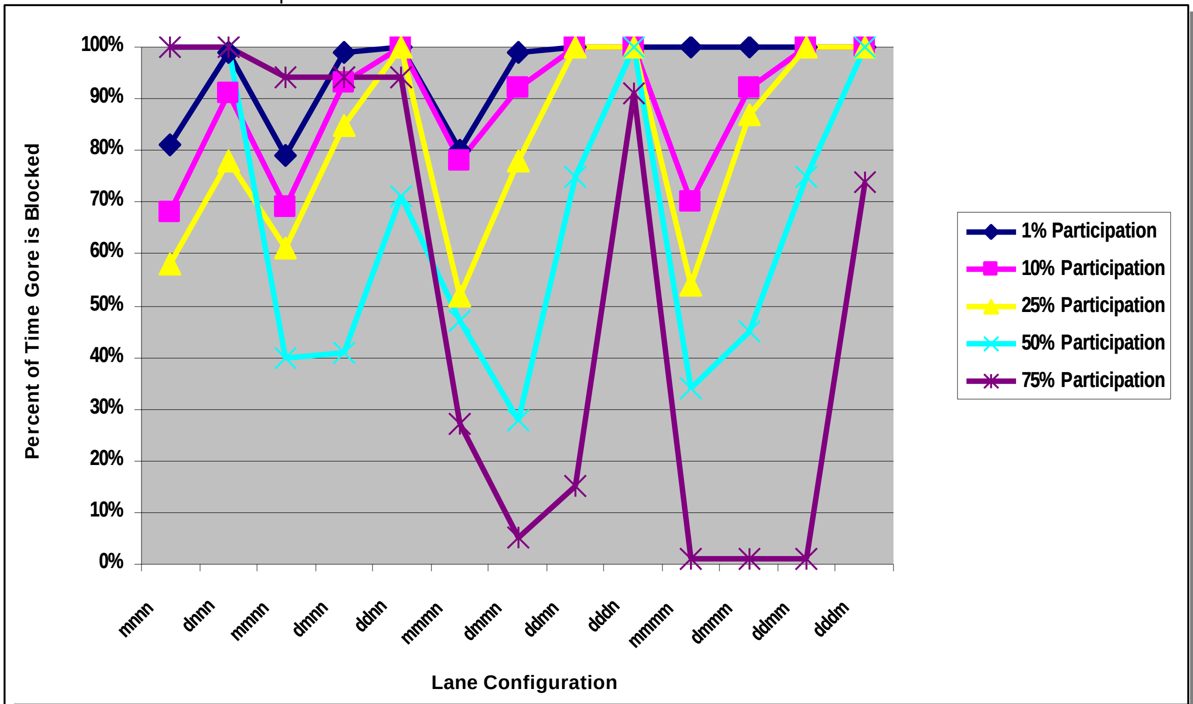
The most profound effects were apparent under conditions where the model was configured to have four truck processing lanes open. The graph in Exhibit 4 illustrates the effect that increasing ABBCS system use may have on the amount of time the trucks queued at primary inspection stretch back to the gore during peak traffic periods, which typically fall during the midday hours. The lane configuration schema on the figure is as follows:

- "d" = Lane *Dedicated* to ABBCS Participants Only
- "m" = Lane Open for *Mixed* Use
- "n" = Lane Open Only to *Non-ABBCS* Participants

What the figure clearly shows is that, under most lane use configurations, increasing ABBCS user density results in the reduction of the duration of gore blockage.

The few instances where higher gore blockage duration and high participation rates coincide are indicative of the effect that may result from not equipping enough lanes to support the demand from participating trucks. As can be seen on the figure, these points occur where two or more lanes are designated as non-equipped.

EXHIBIT 4 – ABBCS Effect on Gore Blockage (4-Lane Scenario)



Similarly dramatic results are evident when examining the number of trucks queued during the same period. As shown in Exhibit 5, the effects of participation and lane configuration on truck queue length are again quite apparent. These two figures, and the simulation data that supports them, indicate that gore blockage drops by 10 percent for each 10 percent increase in participation, a figure roughly equivalent to a reduction in average queue length of three trucks.

The anticipated time savings for participating trucks (vs. non-participants) as a function of participation rate and lane configuration is illustrated in Exhibit 6. At first glance, the results of the analysis regarding the amount of potential time savings that might be expected for participating trucks appear less encouraging than those for queue length and gore blockage. In fact, the data shows that as participation level increases, under certain lane configurations participating trucks actually spend more time moving through the system than do non-participating trucks. This is particularly the case where lane configurations include one or more non-equipped lanes. In most cases, however, according to the simulation results, participants can expect experience some time benefit compared to non-participants.

EXHIBIT 5 – ABBCS Effect on Queue Length (4-Lane Scenario)

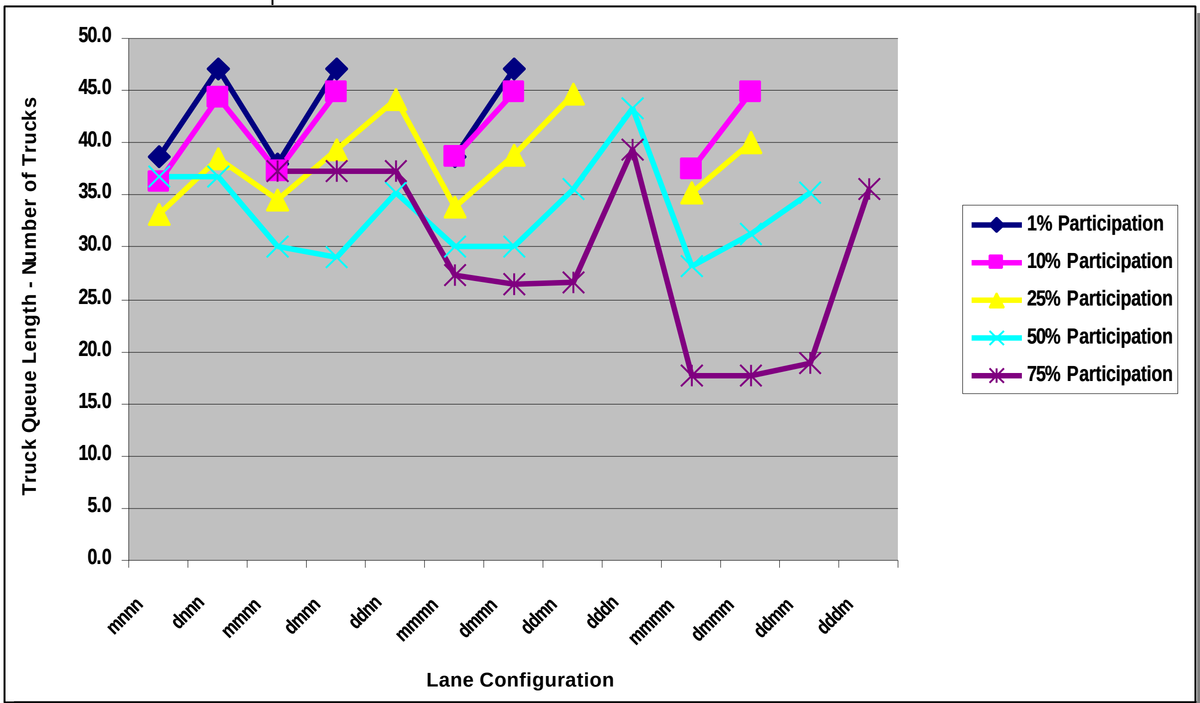
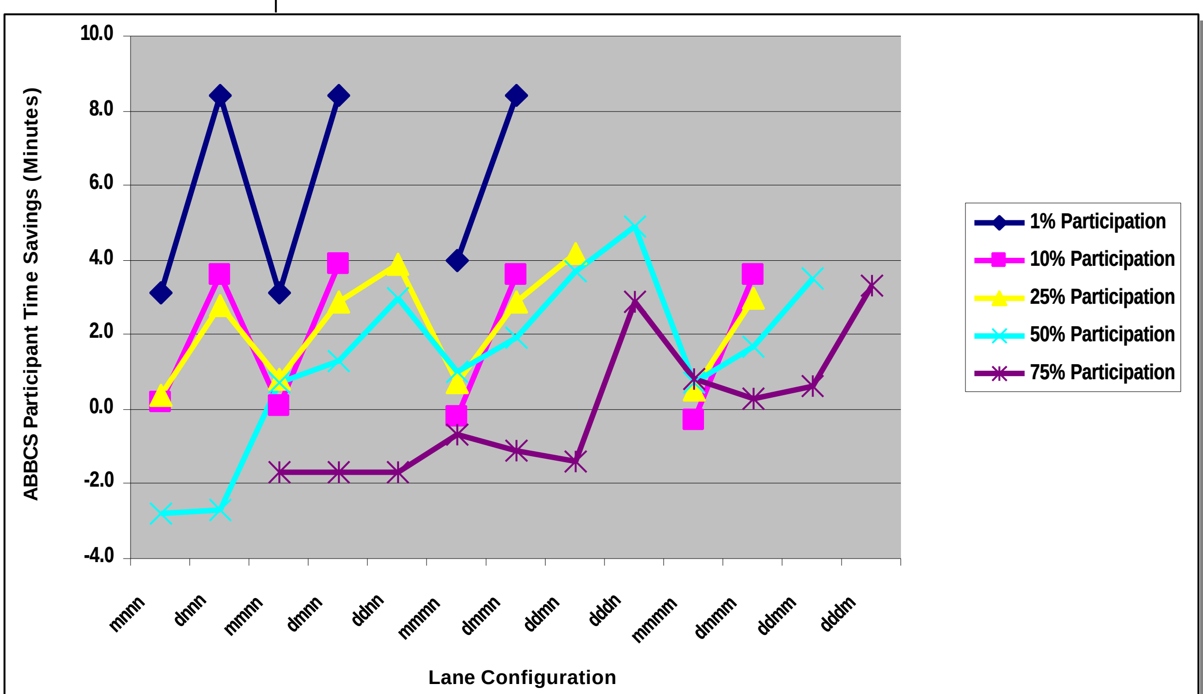


EXHIBIT 6 – ABBCS Effect on Participant Time in System (4-Lane Scenario)



These results suggest that, if the goal is to maximize participation in the program—thereby benefiting the entire truck population by reducing queues—provisions must be made to ensure that, at the very least, participants are not penalized. According to the data, the way to guarantee this is to equip every lane, and adjust the number of lanes dedicated for participants, while being careful not to significantly compromise the overall performance of the system.

Striking the appropriate balance will yield benefits for participants and non-participants alike. For example, simulation results indicate that for an all mixed lane configuration (i.e., mmmm), the average time required for participating trucks to traverse the system dropped from 12.6 minutes at 10 percent participation to 6 minutes at 75 percent participation—a reduction of more than 50 percent.

According to the simulation, trucks participating in a line release program will also benefit, with total time in the system declining from 12.8 minutes at 10 percent participation, to 6.8 minutes at 75 percent participation levels—a reduction of approximately 47 percent. Reviewing these effects across the range of participation levels reveals that the average overall time necessary to traverse the system is reduced by approximately 1 minute for each additional 10 percent growth in participation.

As indicated in the Mitretek report, the potential impact of ABBCS and NATAP technology implementations are tempered under three-lane and five-lane configurations. According to the model results, even at the highest participation levels, the truck arrival rate during peak periods far exceeds the ability of the system to quickly process them when only three lanes are used. Hence, under these conditions, gore blockage and long queues are likely to occur, regardless of the level of system deployment or use.

In light of the substantial likelihood that the volume of international goods movement will continue to increase for the foreseeable future, it would seem prudent to equip a minimum of four inbound primary processing lanes with the technology.

Under the five-lane scenarios examined using the simulation, positive results were observed, though to a lesser degree than was apparent under the four-lane scenario. This is primarily due to the fact that with five lanes open (particularly if all or most are for mixed use), very little gore blockage and queuing occur. Specific information regarding these results is available in the Mitretek report in the Appendix.

It should be noted at this point that, while specific "what-if?" scenarios were not run to quantify results, it is safe to assume that a significant portion of the delay and queuing experienced (both in the simulation and on the bridge) stems from the flow limits imposed by the single lane from the bridge span to the area just prior to the primary inspection booths. This single lane geometry forces participant trucks to wait in the same queue as non-participants, negating a portion of their differential benefit. It also prevents access to the rightmost lanes at times, further inhibiting overall system performance.

The roadway geometry at the exit of the Customs compound may also present some serious challenges in the future, particularly if the rate of primary inspection processing increases measurably. Specifically, though current traffic levels do not pose a problem, projected increases suggest that the volume of vehicles that must exit the compound may soon outstrip the capacity of the surface street intersection at the compound exit.

Privately Owned Vehicles

The route that cars must take to process through US Customs primary inspection is much more direct than that necessary for trucks. Cars can continue from any travel lane coming across the bridge span, directly to one of several primary inspection lanes. For the simulation, lanes dedicated for DCL subscribers were placed at the right end of the plaza, as opposed to the left-side orientation of the ABBCS for trucks. Once cars have been processed, they can proceed away from the bridge via two different exit routes.

The simulation was run at the peak arrival rate for cars of 800 cars per hour. This typically occurs during the morning rush hour as commuters are entering from Canada. Three separate measures of system impact on cars were identified for the simulation:

- *Percent of Peak Hour with Cars Backed Up Past Gore*—the amount of time that the queue of cars awaiting primary inspection extends back to the bridge span
- *Number of Queued Cars Awaiting Primary Inspection*—the total number of cars in queue for primary inspection

- *Time Savings for DCL Cars*—reduction in the average time necessary for participating cars to traverse the entire simulation window.

Lane configuration designations for cars were identical to those used for the trucks. The base case consisted of five lanes total, with only the rightmost lane equipped to process DCL enrollees. Under these conditions, the simulation estimated that, during the peak arrival period, approximately 51 cars would accumulate in the queue, resulting in gore blockage over 94 percent of the period.

As was the case with the truck simulation, a combination of increased DCL participation and appropriate lane configuration yielded promising results, for both participants and the commuter population as a whole. As shown in Exhibit 7, the combination of 25 percent DCL participation and one or more mixed use lanes virtually eliminates gore blockage.

Not surprisingly, such a combination results in significant reductions in the length of the queue at the automobile primary inspection facility, as shown in Exhibit 8.

These figures also demonstrate the adverse effects of not providing sufficient facilities as the participation rate climbs. This is graphically illustrated in both figures for the nnnnm lane configuration.

EXHIBIT 7 – DCL Effect on Gore Blockage

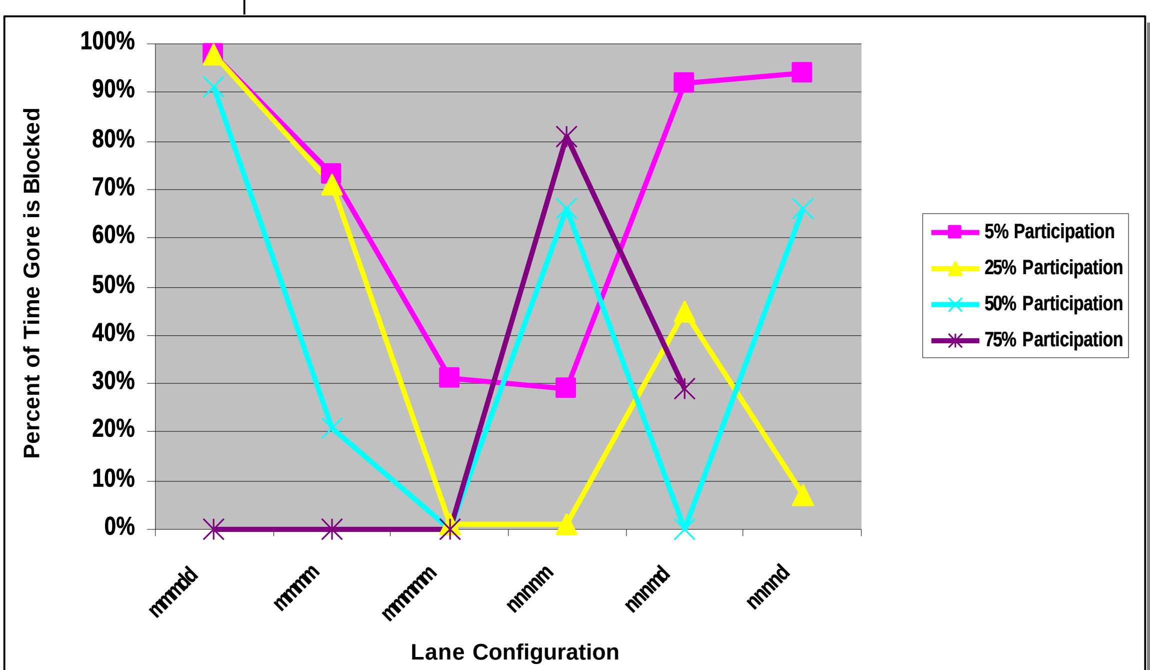
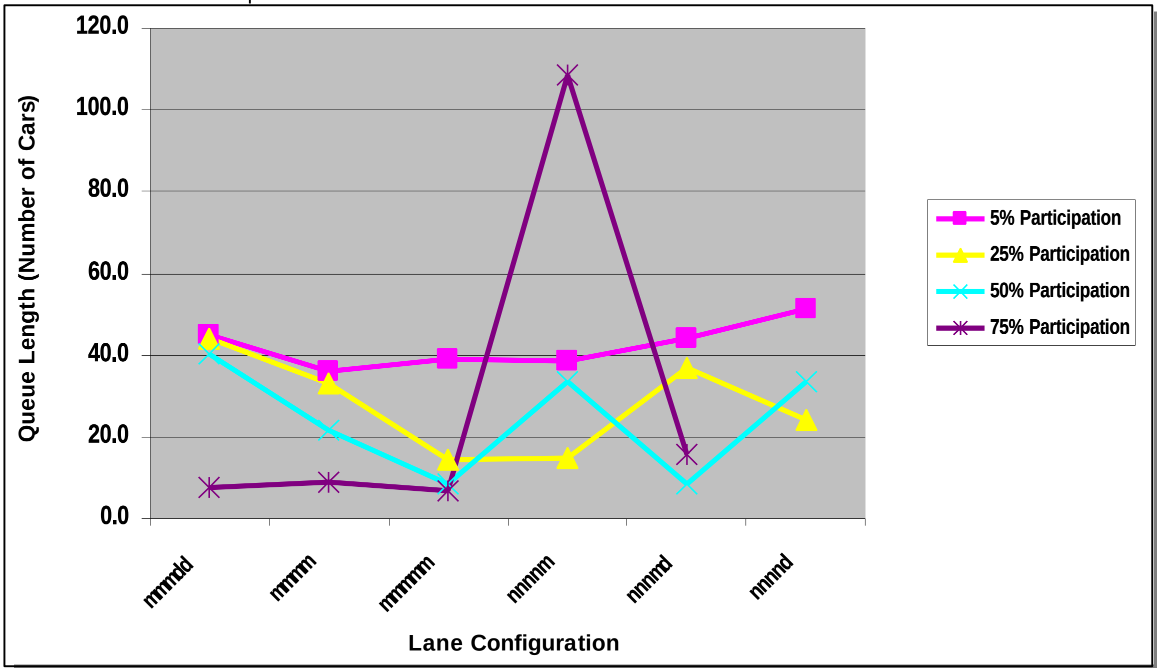
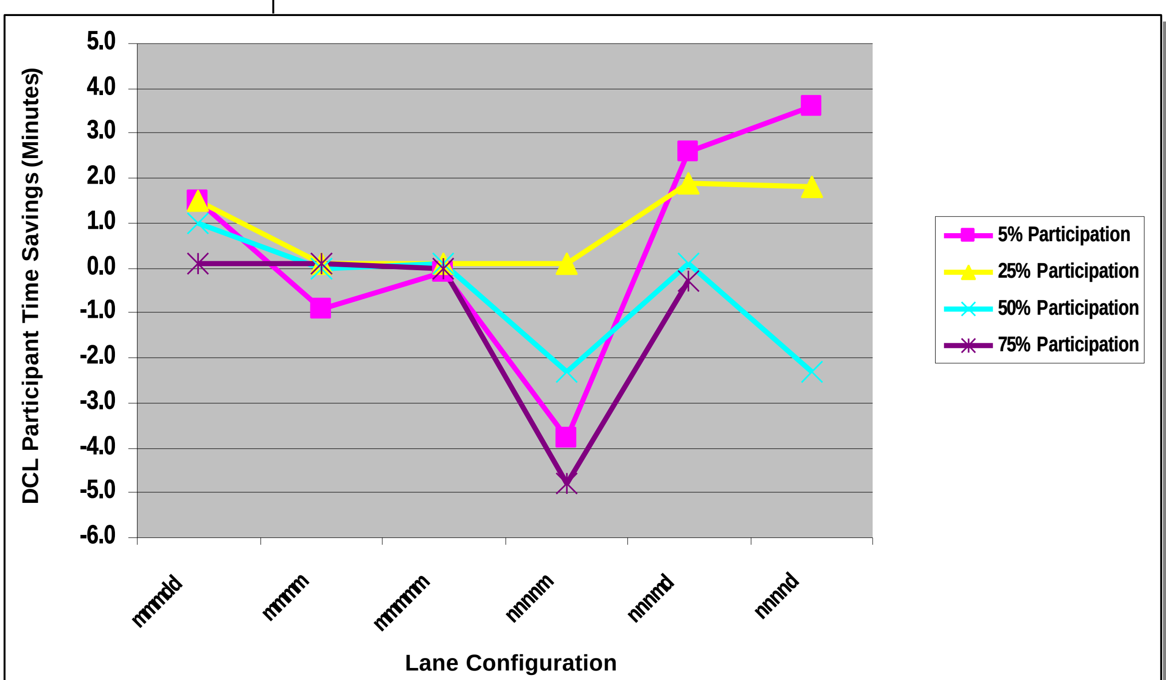


EXHIBIT 8 – DCL Effect on Queue Length



The data regarding time savings to be expected by DCL participants, as shown in Exhibit 9, is consistent with that shown for ABBCS truck participants. Namely, the configurations for which participants are likely to save time (i.e., those where one or more lanes are designated for participant use only) tend to degrade the overall system performance for all vehicles.

EXHIBIT 9 – DCL Participant Time Savings



Of course, this model assumes that all DCL participant vehicles will always choose to use the capability, regardless of the length of the queue in the DCL-equipped lane—an unlikely scenario. Nonetheless, it again illustrates the need to exercise caution in defining lane configurations, lest those very bridge users that enroll in such programs to save time end up being penalized for participation.

Overall Impacts

The Mitretek simulation results clearly indicate that systems such as ABBCS and DCL have the potential to positively impact the conditions on and around the US end of the bridge. They also provide evidence to warrant the reiteration of the importance of identifying the proper level of technology deployment and lane configuration. Each of these, along with projections for changes in the volume and composition of traffic entering the country must be taken into consideration in future deployment planning.

The simulation also shows that, as the percentage of commercial vehicle participants rises, the number of vehicles requiring a stop to work with customs brokers will necessarily decrease, resulting in less demand for parking facilities within the US Customs compound. Provided overall demand does not increase at a pace that would prevent a reduction in the size of the commercial vehicle parking lot, the potential exists to reclaim a portion of that area and convert into an additional travel lane. Such an additional lane has the potential to significantly impact the queuing and time savings benefits for participants.

Model Validation

The following information regarding the validation of the Ambassador Bridge simulation model was provided by Mitretek Systems:

"The WESTA model has been used recently to model truck inspection stations in Indiana, South Dakota, and Arkansas. In each implementation the station operators and supervisors confirmed that the model represented current operating conditions realistically and that projections for the "what if" scenarios were credible. They also confirmed that all major factors relevant to the specified present and future analysis scenarios had been incorporated into the model.

The WESTA representation of the Ambassador Bridge has been prepared with the best available data for vehicle arrival rate, processing time and operational policies as a function of truck type, and facility configuration. Section A.2.1 documents the input values selected. The model was calibrated to reproduce typical peak hour queue lengths as an output statistic. The available data did not support a systematic validation process over different operating conditions. Nevertheless, the model should realistically quantify variations in queue lengths and total waiting times between the base case scenario and alternate scenarios with different NATAP transponder percents, number of primary inspection booths, and lane usage policy. Knowledgeable parties with suggestions for relevant improvements to the model's fidelity are welcome to contact Mitretek Systems."

What are the challenges associated with operating an automatic vehicle identification system within the geographic context of an international border crossing?

As was highlighted earlier in this report, the ability of the DSRC system to effectively support overall system functionality in the unique operating environment on the bridge was the source of some concern among stakeholders. Specifically, it was determined that a better understanding of how these technologies would perform in the geographically constricted, extended exposure, highly congested environment that typifies international border processing facilities.

In particular, three primary questions were identified for examination:

- Will the DSRC be capable of being configured to identify individual trucks operating in close quarters?
- Can the DSRC readers and antennae be tuned so as to minimize or eliminate the likelihood of interference or signal overlap, without compromising system operational performance?
- Do the compound and the roadway leading to it provide sufficient space for the location of hardware in such a manner as to allow sufficient time for the system to query remote decision support systems?

The results of the FOT suggest that the answer to each of these questions is yes, provided key issues are considered and addressed. The ABBCS was capable of identifying individual trucks at multiple points within the compound. Though a statistically thorough analysis was not possible, it is reasonable to state that the advance, decision and exit readers were successful at capturing and relaying the necessary information. Specifically, when all systems were functioning, trip / load numbers and US Customs response indicators were exchanged at the appropriate time to be of use to the Customs officials, and the drivers of the equipped trucks.

Further, none of the difficulties with overlapping read zones and multiple reads experienced at other border crossing sites were evident at the Ambassador Bridge. This is likely due at least in part to a compound configuration that permitted adequate spatial and directional discretion during system installation.

Results from the FOT did, however, identify one potential problem—the effect of prolonged transponder exposure on power sources. As was evident during the FOT, such exposure may pose a problem for transponders with self-contained power sources. While the replacement of the transponder batteries appears to have addressed this issue, without prolonged study, there is no way to be certain that excessive power drainage will not remain a problem. This issue loses significance if transponders are wired to receive power directly from the vehicle battery.

Because the systems under test represented prototypes, it is not yet clear whether they will continue to function acceptably as import traffic increases. Workload sensitivity analyses should be conducted to determine the extent to which the communications and information processing capabilities of such systems are acceptable within an operational context—i.e., will system performance degrade to an unacceptable level under increased demand?

What technical and institutional lessons can be learned regarding the implementation and use of such systems?

A number of lessons, both technical and non-technical, were learned during the deployment and operation of the ABBCS and DCL systems on the Ambassador Bridge. Because the evaluation team was not brought under contract until some time after the bulk of the implementation and testing was completed, it is quite possible that those that participated in the evaluation interviews overlooked some lessons. Nonetheless, the evaluation team is confident that the more significant lessons have been captured.

Technical Lessons

In one form or another, the technical lessons learned have been discussed previously in this report. These lessons include: the effect of repeated reads on transponder batteries;

the effects the environment had on the ability of the DCL card readers to function properly; the limit to efficiency gains imposed by the geometric constraints of the Customs compound; and the criticality of system timing in capturing and delivering information to the users.

As was evidenced by the ability of the system developers and users to rectify each of the system functionality issues, it appears that none represents a potentially fatal flaw. Again, while the ability of these fixes to offer long-term solutions is unclear, the speed with which each was identified and implemented suggests that they do not represent insurmountable challenges.

"The impacts of the geometric constraints of the compound on the traffic characteristics are quite apparent in light of the results of the simulation."

The impacts of the geometric constraints of the compound on the traffic characteristics are quite apparent in light of the results of the simulation. Although the conceptual solution is relatively simple, reconfiguring the roadway to permit dual travel lanes to the primary inspection booth represents a substantial logistical and fiscal challenge.

Institutional Issues

As is most often the case with regard to the implementation and use of ITS for commercial vehicle operations, the most daunting challenges to full deployment of systems such as the ABBCS are not technical. These non-technical concerns, typically referred to as institutional issues, often present questions for which simple answers do not yet exist. Hence, many of the issues offered by the test participants are common to many ITS implementation efforts.

For ease of review, the issues identified during the evaluation interviews are grouped into one of three categories: Information Management, Inter-Jurisdictional Coordination, and Sustainability.

The focal point of concerns regarding information management is most often the issue of ownership and control of data. While this has been a long-standing concern of carriers wary of "big-brother" systems, only recently has it come to the fore within public agencies. Motor carriers, including those that participated in this evaluation, have repeatedly expressed reservations about allowing public agencies, particularly those responsible for enforcement, access to any information not specifically required by law. In spite of the adoption of policies restricting the amount of information collected, and the usage of the collected data within these agencies, many carriers remain unconvinced that more liberal practices will not be enacted.

Participants in the ABBCS evaluation also expressed concerns regarding the ability of agencies to adequately protect the security of potentially sensitive data. In the intensely competitive commercial freight industry, carriers vigilantly protect operational details. The ability to continue to protect this information in an increasingly active information exchange environment is a source of significant apprehension on the part of the carrier community.

The final major concern voiced by evaluation participants regarding information management stems from the uncertainty surrounding liability for inaccurate data. Specifically, one participating carrier raised the question, "Who is financially responsible for shipment delays due to [border crossing] system downtime?" Of equal concern was the impact that such delays may have on the credibility of the shipper and/or carrier.

Inter-jurisdictional coordination has long been a sizeable challenge with respect to the implementation of ITS technologies. In fact, the ITS/CVO program and the IBC Program continue to grapple with scores of specific issues under this heading. Among them are ongoing negotiations over technology standards, data sharing practices, and law enforcement jurisdictional authority.

"The preeminent standards issue appears to be the adoption of a universal DSRC standard for the exchange of information regarding individual cross-border shipments."

The preeminent standards issue appears to be the adoption of a universal DSRC standard for the exchange of information regarding individual cross-border shipments. Though this test and several others, not to mention fully deployed screening systems, have demonstrated the capabilities of existing information exchange protocols, discussion continues over the most appropriate standard for the future. Some stakeholders argue that a minimal amount of information should be stored on the transponder, while others support the storage of detailed carrier information. Disagreements also persist regarding whether the information should be perishable (i.e., trip/load numbers for each cross-border movement) or permanent.

That these issues have been brought to the fore highlights the differences in the jurisdictional responsibilities of the stakeholders. For instance, the nature of the responsibilities of the US Customs and INS dictate that each border crossing transaction be treated as a separate and distinct event, for which the risk of permitting the entry of the cargo and driver must be assessed. The US Treasury is also interested in shipment specific information because trade data must be collected. These requirements differ somewhat from those imposed by the responsibilities of state transportation agencies.

While state enforcement officials must also be concerned with the risk of permitting entry to the state, these concerns are not necessarily shipment specific. For example, if a given carrier's safety record indicates there is a significant likelihood that any of its vehicles entering the state will have safety violations, the state may want to ensure that the vehicle is directed to the nearest safety inspection facility, regardless of the contents of the shipment.

Fortunately, these issues enjoy considerable visibility among the stakeholders, and work to resolve them continues at the highest levels within state and federal agencies.

Finally, answering the question of how to encourage a level of participation sufficient to actualize some of the potential benefits illustrated by the simulation remains a sizeable challenge. History suggests that convincing carriers and commuters that participation will benefit the entire population of bridge users will yield limited results. For this reason, it would seem prudent to assume an approach that focuses on the benefits likely to accrue to participants.

"…in order to encourage bridge users to agree to equip themselves and/or their vehicles with ITS technologies, these benefits need to be enumerated in terms that focus on the relative merits of participation over non-participation."

This is not to suggest that an overall reduction in queue lengths and levels of congestion will not be perceived as benefits. Rather, it implies that in order to encourage bridge users to agree to equip themselves and / or their vehicles with ITS technologies, these benefits need to be enumerated in terms that focus on the relative merits of participation over non-participation. As electronic toll providers have repeatedly demonstrated, the perceived value of their systems is directly proportional to their ability to illustrate the impacts of enrollment.

This holds true for commercial carriers, as well. Until tangible evidence can be provided that demonstrates participation will, for instance, reduce the time necessary to process through primary inspection, market penetration will remain insignificantly small. In an industry where the bottom line effect of every technology investment is so thoroughly scrutinized, the identification of concrete benefits becomes an imperative.

The ability to attract and sustain interest in programs such as the ABBCS also has far-reaching implications with regard to future ITS implementation planning. For states such as Michigan, which participated in the Advantage CVO program, and is an ITS/CVO Pilot State, the ability to leverage ITS/CVO investments across multiple functions is essential to the realization of transportation investment goals.

What potential value can this system provide in the future improvement in the level of safety and regulatory compliance of international trade and commercial vehicles crossing into the US?

During the planning stage of the Ambassador Bridge Border Crossing FOT, the project partners envisioned a system that would provide a service to the border officials and agencies, the commercial fleet users, and trans-border commuters by:

- allowing more cost efficient allocation of enforcement resources, and enhanced inspection processes
- providing user services designed to enhance movement of trade goods and people
- reducing delay and congestion at border crossings.

The first of these three was focused on the border enforcement community, including the agencies responsible for enforcement of laws within the State of Michigan.

As has been discussed previously, a number of federal and state agencies bear responsibilities regarding the movement of commercial goods into the US via the Ambassador Bridge. There are two very distinct components of enforcement at the border: trade and transportation. To review, US Customs is responsible for ensuring the legality of the shipment itself, INS is responsible for approving the entry of individuals, and the US Treasury is tasked with capturing mandatory trade information, and verifying the payment of duties. These constitute the trade-related enforcement functions.

Transportation enforcement is the responsibility of the federal and state departments of transportation, which regulate operating authority, and the Michigan State Police, who is responsible for enforcing size, weight, safety, and traffic laws.

The value offered agencies by the ABBCS can then be expressed in terms of the ability of the system to facilitate the accomplishment of these roles. While the limited scope of the operational test precluded the likelihood that any impacts would be observed during its execution, it remains possible to draw some larger conclusion regarding the potential for these impacts to occur.

At the most basic level, the program demonstrated that it is possible for law enforcement officials at or near the border to access information regarding specific vehicle, carrier, operator, and cargo data that was not previously available. As is typically the case with regard to law enforcement, the more that is known about each of the components of an international shipment, the better equipped responsible enforcement officials are to make accurate decisions.

What remains to be demonstrated is the degree to which this information can be accessed and used without inducing additional delays for bridge users, or increasing the complexity of the enforcement tasks at hand. For instance, during the FOT, the inspectors manning the primary Customs facility were required to process every arriving shipment using established procedures. This was in addition to any procedures put in place to utilize the NATAP system. While it is expected that some efficiencies will be realized as confidence in the systems, and the databases that house the information used, increases, none were observed during the FOT.

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Because the ABBCS was not used in any way by federal or state transportation officials, conclusions regarding its value for vehicle enforcement purposes are very difficult to define. Nonetheless, if we rely on the conceptual similarities between ABBCS and the electronic screening systems widely deployed across the US, sufficient evidence exists to support the assertion that ABBCS will be of value in the enforcement of safety laws.

However, two significant issues will influence the degree to which this value will be attained. The first is that, to date, little or no data regarding non-US fleets is currently available for enforcement use. Because enforcement decisions are, by definition, only as accurate as the information used to make them, the quantity, quality, and availability of data are critically important.

The second issue stems from the fact that Michigan has a "probable cause" law that effectively limits the discretionary authority of the state police. In simple terms, this law restricts the police from targeting specific vehicles, carriers, or drivers for inspections. This law stands in direct conflict with the main premise of ITS for CVO—that it allows for targeted enforcement, directed at carriers, vehicles, and drivers that are more likely to be found out of compliance.

Can utilizing ITS technologies at the Ambassador Bridge crossing allow the State of Michigan to better focus its enforcement resources on non-compliant carriers?

As was discussed in the previous section, there are legal limitations imposed on the Michigan State Police with regard to the selection of carriers and individual trucks for safety inspections. While this law currently prevents the targeting of specific companies and assets, it does not necessarily eliminate the possibility that the MSP can extract some utility from a system such as ABBCS.

For example, such a system, when properly linked to an information source such as a registration database, could offer MSP the ability to immediately identify a vehicle that is not properly registered to operate in the state. Because Michigan is also a CVISN Pilot state, the potential exists for the establishment of a link to the state's developing commercial vehicle information exchange window (CVIEW), which would serve as a window into the International Registration Plan (IRP) and International Fuel Tax Agreement (IFTA) information clearinghouses currently under development. Using these tools, it is conceivable that, at the very least, MSP officials could spend less time verifying credentials, freeing up time to conduct more safety inspections.

Because none of these systems (i.e., IRP and IFTA Clearinghouses, CVIEW) currently exist, it is far too early to speculate as to the degree to which they will facilitate more focused enforcement. Nonetheless, no insurmountable technical or administrative barriers to the eventual realization of some efficiencies were uncovered during the operational test.

What recommendations can be offered to the State of Michigan regarding the recruitment and enrollment of users, and the use of ITS technologies at other crossing sites?

Among the more significant findings gathered from bridge users pertained to their perceptions regarding whether the benefits accrued during the operational test were sufficient to warrant a decision to continue participation, and at what cost.

Not surprisingly, the responses collected were similar to those often given regarding domestic electronic screening and toll road facilities. Generally speaking, bridge users polled during the evaluation gave some rather widely varying opinions regarding what they would consider acceptable conditions for continued participation. Common to nearly all participants, however, was the assertion that any service for which some expense is incurred should offer participants a measurable advantage over those that choose not to participate.

Commercial Carriers

Perhaps due to the equipment and training investments that would be required to equip vehicles and employees, commercial carrier representatives imposed higher expectations on system performance and benefits than did individual commuters. Recalling earlier data, one carrier indicated that a minimum of one hour of time savings per vehicle would be necessary before participation would be considered to offer sufficient value. A second carrier felt 20 minutes was the minimum acceptable time savings.

As discussed previously, these results are far from statistically valid. Nonetheless, they do suggest that, even given the demands imposed by just-in-time manufacturing, actual time savings will have to be consistently large to garner large scale industry support. Though the simulation results indicate that the anticipated maximum time savings are well below ten minutes, even under ideal circumstances, additional savings may be possible through modifications in roadway geometry leading to and inside the customs compound.

Despite the heightened expectations voiced by carrier participants, experience gained through domestic electronic screening programs suggests that carriers that have been able to justify participation in programs such as the Multi-jurisdictional Automated Pre-clearance System (MAPS) will likely find enrollment in expedited international border crossings attractive. The ability to implement systems that are interoperable with deployed and developing domestic

"The ability to implement systems that are interoperable with deployed and developing domestic screening and toll systems is also of fundamental importance to the sustainability of systems such as ABBCS."

screening and toll systems is also of fundamental importance to the sustainability of systems such as ABBCS. Such "bundling" of functionality makes the decision to adopt technologies and participate in programs a much easier one for motor carriers.

Commuters

On the whole, commuters insisted upon a lower standard than carrier representatives with regard to expectations for system benefits. Sixty percent of the survey respondents indicated they expected the DCL to eventually improve traffic conditions on the bridge, and 62 percent planned to continue using DCL.

Perhaps more revealing were the responses regarding willingness to pay. Again, caution must be exercised in drawing conclusions from data that is acknowledged to be statistically insignificant. Nonetheless, 26 percent of the respondents indicated a willingness to pay for participation in the DCL program. More than half (55 percent), however, were not willing to pay for the service. In fact, more than one motorist suggested that commuters should be charged less to cross than infrequent users.

These findings suggest that, once again, until tangible, repeatable benefits can be demonstrated to program participants, recruitment and retention of enrollees will remain a challenge. Some measures can, however, be taken in the interim to bolster the attractiveness of the program. Aside from configuring inspection lanes to eliminate as much queuing as possible for participants, program administrators may find it necessary to offer additional incentives, such as pricing guarantees and volume discount rates, to build enrollment. Toll road providers are likely to have suggestions for such programs.

"These findings suggest that, once again, until tangible, repeatable benefits can be demonstrated to program participants, recruitment and retention of enrollees will remain a challenge."

As for the implementation of systems similar to ABBCS at other border crossing sites, the results of this evaluation would seem to indicate that until a successful operating model can be defined at the Ambassador Bridge, more widespread deployment within the state is not advisable. Once the State of Michigan is able to define, develop, and implement a means to leverage the information gathered at the border to enhance enforcement operations, the potential exists for measurable benefits to accrue both for the lawabiding users of the crossing, and the agencies responsible for enforcement.

Much also remains to be learned regarding the integration of such systems with ongoing efforts along major trade corridors. As the technology, and the means to use it, continue to mature, the State of Michigan can expect to realize the advantages of having been a pioneer in the implementation of border crossing systems. The question that remains is, how long will the timeline be?

CONCLUSIONS

IN general, while the ABBCS FOT has successfully served to begin bridging the gap between research and development and the deployment of field-ready solutions, much remains to be done both to comprehensively demonstrate the capabilities of the technologies and to assess the impacts of fully deployed systems. For instance, until a viable, sustainable link for making information available to state enforcement officials can be established, the utility of systems such as ABBCS will be limited to that of a conduit for the exchange of trade information, and the enforcement of import restrictions. While these are certainly valuable functions, they fall short of the potential for border clearance systems.

Drawing definitive conclusions from numerically limited data is a very difficult task, at best. At worst, it represents a risk that the implications of evaluation findings could be misstated. Despite the narrow findings related in this report, several reasonably well-founded conclusions are possible. These conclusions, and their possible ramifications, are offered here for consideration.

ABBCS Functionality

Electronic screening systems that rely on DSRC are progressing out of their infancy and into the mainstream enforcement community. These technologies have been, and continue to be, installed in numerous sites along major highway corridors throughout the US. Their rising popularity is a testament to their perceived value within the commercial vehicle enforcement community. Devising a technical and operational environment within which these technologies could function as useful tools at international border crossings represented the next logical challenge.

Experiences at other border sites notwithstanding, the ABBCS operational test was able to demonstrate that DSRC is capable of supporting the exchange of information necessary to process cross-border movement of goods and commuters. The system, as installed on the Ambassador Bridge, was successful at identifying individual vehicles, and exchanging data with Customs and INS systems in a timely, accurate manner. These findings suggest that the decision to use a transponder-based DSRC system was conceptually sound.

There is, however, little information currently available regarding the degree to which such a system can be considered a sustainable solution. Very little is known or understood about how such a system will react to increases in processing loads likely to accompany increasing enrollment and bridge traffic.

Benefits

Due to the nature and duration of the operational test, it was expected that any benefits that would be likely to accrue to bridge users and other stakeholders would not necessarily be immediately apparent. For instance, since US Customs agents manning the primary inspection facilities were required to continue to process participating vehicles using existing methods, in addition to observing the operation of ABBCS and NATAP, users were not likely to experience any reduction in processing time. With this in mind, the evaluators expected that the program participants would still be able to offer their opinions regarding potential benefits. To some degree, this was the case.

Given their financial and institutional investments, public agency representatives were understandably optimistic regarding potential benefits of ABBCS and SENTRI / DCL. Without exception, the stakeholder agencies involved with the program are convinced that such systems will not only benefit bridge users, but will facilitate improved efficiency and effectiveness over the processes currently used to manage cross-border commercial and commuter traffic. To many, the modest successes demonstrated during the FOT served to reinforce the belief that such systems will eventually provide tangible benefits.

The bridge company was equally optimistic, though for slightly different reasons. As was alluded to earlier in the report, the prospect of having the ability to process more crossings, more quickly than is currently possible, without increasing staffing requirements, has great appeal to the bridge owner. The economic implications, particularly given the popularity of the Detroit / Windsor crossing region, are quite sizeable.

However, until bridge users can be convinced that utilizing the Ambassador Bridge will benefit them, the bridge company will not realize the potential cost advantages of electronic border screening. The users that took part in the evaluation have established a relatively lofty standard for measuring benefits—in the form of concrete time savings at little to no cost to users.

Traffic Impacts

Not only are these difficult targets to reach, they will be increasingly difficult to sustain as bridge traffic increases. As discussed earlier, a growing regional economy and an international trade boom are expected to double bridge traffic between Detroit and Canada by as early as 2012. Even with planning underway for the eventual addition of a second span, the bridge company and local and state law enforcement and transportation officials are concerned about the effects this may have on traffic conditions and safety on and around the bridge.

The Mitretek simulation, while being run with some figures that represent educated estimates, at best, seems to indicate that the proper combination of system deployment and lane configuration can be expected to have a sizeable positive impact on traffic conditions on the bridge. Although configurations can vary according to processing load, model results suggest that a combination of all mixed-use lanes—with a minimum of four for both the commercial vehicle and private vehicle primary inspection plazas—would serve to mitigate current congestion problems quite measurably.

Regulatory Compliance

The results of the limited FOT provided very little evidence that the levels of safety and regulatory compliance of international trade and commercial vehicles entering the US would be improved. This result is, without question, due at least partially to the narrow scope of this early operational test program. Nonetheless, the modest technical and operational successes experienced lend support to emerging compliance enforcement concepts that rely heavily on advanced electronic screening technologies.

One example is the International Border Clearance Safety System currently under development by FHWA. This concept relies heavily upon the ability to identify individual vehicles entering the US as a means to apply advanced safety screening processes that draw on data collected and stored in a centralized safety database through state-based systems. This database, termed Safety and Fitness Electronic Records (SAFER), is being developed and deployed on a national scale as part of the Commercial Vehicle Information Systems and

Networks (CVISN) program. The IBCSS is seen as a crucial link between domestic systems and international trading partners.

State Enforcement

One major impetus for the fielding of a system such as IBCSS is to make information gathered through other systems, like ABBCS, available to state enforcement officials. Though the implementation of such systems lies sometime in the future, once again, the ability of the ABBCS FOT to demonstrate the viability of essential components represents an important piece of the puzzle.

As stated previously, this did occur, albeit on a very limited scale. Because the prototype development of IBCSS was not complete as of this writing, the degree to which ABBCS advanced this concept is not clear. However, early indications are that technical and institutional lessons important to IBCSS were passed along.

Accordingly, state enforcement officials remain optimistic about the potential of such systems to offer improvements in operational efficiency and effectiveness. This is in spite of current laws limiting the discretionary authority of state inspectors.

User Acceptance

Survey and interview findings clearly indicate that the willingness of bridge users to enroll in and use ABBCS and SENTRI/DCL systems is a direct function of the amount of direct benefit they expect to accrue. What is less clear is the magnitude of benefits necessary to draw them into these programs. Neither the commercial freight nor commuter users appear inclined to agree to remit any additional payment to participate, based on their own current projections of benefits.

Adding to that challenge, careful examination of the results of the simulation indicate that many of the measures that result in overall system benefits actually mitigate benefits to enrollees. Since it is likely that implementers will prefer the improvement of overall efficiency, the promise of individual time savings as a recruiting tool becomes less powerful.

In lieu of physical changes to the compound (such as the addition of a second primary inspection approach lane for commercial vehicles), ABBCS proponents may be forced to consider other means of attracting participants, such as financial incentives or preferential treatment.

RECOMMENDATIONS

The following recommendations are offered for consideration:

The operational test partners should follow this FOT with additional efforts to incrementally develop and validate systems that provide the necessary functionality. Cooperative efforts to advance the International Border Clearance Safety System (IBCSS) concept offer a means to achieve this end.

This concept, which is intended to provide a means for state commercial vehicle safety organizations to assess the risks associated with vehicles, drivers and cargo entering the US, relies heavily on the reliable, accurate determination and relay of key identification parameters. Because the FOT was brief, and the IBCSS was not yet developed, it is unclear if the systems currently deployed on the bridge would satisfactorily support a fully deployed system. To this end, the public agencies and private organizations that constitute the Ambassador Bridge stakeholders should support ongoing efforts to develop and test a prototype of the IBCSS at the Ambassador Bridge by extending cooperative relationships established during the FOT. This includes partnering with the FHWA in technology and infrastructure investments on and around the bridge.

The second recommendation is that an in-depth market assessment that takes into consideration the planned construction of an additional span be completed prior to incurring the substantial costs associated with the implementation of border screening systems. Because limited information is currently available regarding such issues as willingness to pay for services that have yet to reach maturity, the completion of such an assessment appears to be a prudent investment.

Any such assessment should be constructed to incorporate anticipated growth in regional and international trade, existing and developing job markets, population growth projections, current and planned infrastructure, and evolving business models.

Finally, the simulation results suggest that serious consideration should be given to altering the compound entry geometry to allow for two lanes of commercial vehicles from the end of the bridge to the lane divide just prior to the primary inspection facility. This is regardless of whether a system such as ABBCS is deployed. Should such a system be deployed, the simulation results also indicate that particular attention should be paid to determining the lane configuration that results in the maximum overall benefit to commercial bridge users.

APPENDIX

Attached to this document is a copy of the final report Mitretek Systems prepared for the simulation of the Ambassador Bridge, as was described in the body of this report. With the exception of the addition of page numbers, the contents of the Mitretek report are offered in unedited form. Any questions regarding content should be directed to Mr. Richard Glassco of Mitretek Systems. Mr. Glassco can be reached at (202)488-5713.

Simulation and Analysis of North American Trade Automation Prototype (NATAP) Operations at the Ambassador Bridge

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McLean, Virginia

Executive Summary

This paper documents a study of the North American Trade Automation Prototype (NATAP) operations at the U.S. Customs facility at the Ambassador Bridge in Detroit, Michigan. Current operating policy and traffic levels result in frequent occasions where the queue of trucks backs up onto the bridge itself, creating long delays to both cars and trucks. Recently the customs facility at the Ambassador Bridge participated in a field operational test (FOT) of NATAP equipment designed to expedite customs processing for cars and trucks. The study simulates the deployment of NATAP equipment to cars, trucks, and custom inspection stations at levels greater than could be achieved during the FOT.

The study used the Westa (Weigh Station) simulation model to represent the current and alternate scenarios. Westa is a detailed simulation of truck, car, and other traffic around inspection stations. Model development and the current analysis were funded by the Federal Highways Administration (FHWA) Joint Program Office (JPO) for Intelligent Transportation Systems (ITS), with support from the FHWA Office of Motor Carriers (OMC) Size and Weight team.

Data defining the base (current) scenario were collected at the bridge by Booz·Allen & Hamilton (BAH) and by bridge operations authorities, and were provided to Mitretek. The measures of effectiveness for the base case scenario confirm congestion at the bridge. The arrival rate for trucks relative to the average rate for processing trucks through primary customs inspection causes the queue of trucks to fill up occasionally. Unless another customs inspection lane is opened, long backups develop on the bridge, restricting the access of cars to the car inspection facilities. Similarly, long backups for cars can occur during morning and evening peak commuting times.

Mitretek designed alternate scenarios based on recommendations from BAH. Mitretek ran multiple iterations of the base and alternate scenarios, using varying levels of cars and trucks equipped with electronic NATAP transponders.

Three sets of analyses were conducted for truck customs processing, corresponding to scenarios where there were three, four, or five lanes available for primary inspection. For each set, the proportion of trucks with NATAP transponders varied from 5 percent to 75 percent, and the policy for lane usage varied among (a) dedicated to NATAP trucks, (b) non-NATAP trucks only, and (c) mixed use allowing either type of truck. As expected, increasing NATAP participation results in shorter queues and reduced risk of gore blocking with judicious alteration in primary inspection lane configurations. At participation rates above 75% with four-lane configurations and at participation rates above 25% with five-lane configurations, the risk of truck queue growth beyond the gore is virtually eliminated even under peak truck arrival rates.

Similar analyses were conducted for cars, varying the proportion of cars in the registered commuter program with transponders, and the number and usage of Dedicated Commuter Lanes (DCL). Findings for the car inspection operations are similar to those for truck inspection. Increasing participation in the DCL program reduces overall queue size and risk of queues stretching back onto the bridge span past the gore diverge point. An increase to 25% participation from the current 5% level eliminates the risk of queue growth past the gore even at peak car arrival rates. Dedicated lanes have negative impacts on system performance until higher market penetrations can be reached. Travel time savings for DCL users is expected to be 1-2 minutes in these cases.

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Section 1

Description of the Westa Model

1.1 Overview of Westa

Westa (Weigh Station model) is a PC-based tool designed for modeling truck weigh stations on highways or any vehicle inspection or toll-collection station. It is a micro-level simulation program for evaluating operational performance under various traffic scenarios, inspection capabilities, and station configurations. It quantifies the effectiveness of advanced capabilities for (1) increasing enforcement of weight, safety, and customs regulations; (2) increasing vehicle throughput; and (3) reducing station queue lengths, delay to vehicles, and the time the entire station or components of the station are closed because of queue overflow. While Westa was originally developed to model trucks, it has been adapted to represent other vehicle types as well. Simulations run very quickly, producing animated graphics and writing statistics to permanent files. Westa is an object-oriented program written in the C++ computer language. The Westa System Description and User Guide is listed as Reference 1.

Westa simulates the behavior of each truck, car, or bus, from its creation at an origin, through each stage of its progress through the inspection or toll collection station and/or on the mainline, to the point where it leaves the simulation beyond the station. Vehicles may be routed depending on weight according to static or Weigh-in-Motion (WIM) scales or such user-defined characteristics as use of a pre-clearance transponder, preferred carrier or commuter status, safety status, or credential status.

Westa models inspection and toll collection facilities with a series of straight or curved one-lane links. Multiple lanes are modeled as parallel single lanes with defined rules for lane switching. Each vehicle moves along a series of links from an origin to a final destination. A link may branch forward to two others, allowing for multiple paths, and two links may merge into the same link. Upon arrival at a branching link, a vehicle is routed based upon its characteristics or the status of the links ahead. The user may define the combination of characteristics to be checked at each branch.

1.2 Vehicle Movement

Vehicle movement is calculated on the basis of a user-specified time-step value. Westa accepts time-step values as small as one-tenth of a second. Each vehicle moves according to its speed-dependent acceleration and deceleration abilities as well as those of the vehicles ahead of it. A vehicle's maximum acceleration rate decreases linearly with velocity, but its maximum deceleration rate is constant. Each vehicle attempts to accelerate to the maximum allowed speed for the link it is on, but decelerates for slower-moving vehicles ahead of it, a slower speed limit on the link ahead, or a required stop ahead. Vehicles will speed up or slow down as necessary for a merge.

Each vehicle has a maximum and a comfortable deceleration rate. If the user does not specify otherwise, Westa uses a default uniformly distributed maximum deceleration rate that ranges from 0.68g to 1.00g for cars and from 0.40g to 0.50g for trucks. Westa considers all simulated deceleration rates in excess of 0.30g for cars and 0.20g for trucks as hard braking, and reports this information as part of the traffic safety statistics. The comfortable deceleration rate defaults to 30 percent of the maximum value. The user may also specify maximum acceleration rates. The default maximum acceleration rate is generated from a uniform distribution with a range of 0.15g to 0.30g for cars and 0.06g to 0.12g for trucks.

When following another vehicle, a vehicle will keep a distance and speed such that if the vehicle ahead were to come to a stop at its maximum deceleration, the following vehicle would be able to stop with its preferred deceleration and avoid a collision. Only vehicles designated as being driven by aggressive drivers may exceed the speed limit on a link. No vehicle may move in reverse.

1.3 Vehicle Characteristics

When a vehicle is generated at an origin, the values of its characteristics or attributes are determined. Some characteristics are built into the model, but the user may define any other characteristics and the probability of occurrence as described below.

1.3.1 Vehicle Class

The first thing determined for a new vehicle is its vehicle class. Many other characteristics depend on the vehicle class. Westa recognizes the 13 vehicle classes defined by the FHWA. The following table defines the 13 classes. The proportion of vehicles of each class entering the simulation on each origin lane is defined in the input file (see section 2).

Class	**Description**
1	Motorcycles
2	Passenger Cars
3	2-axle 4-tire trucks (pickup trucks)
4	Buses
5	2-axle 6-tire single unit trucks
6	3-axle single unit trucks
7	4 or more axles, single unit trucks
8	4 or fewer axles, single trailer trucks
9	5 axles, single trailer trucks
10	6 or more axles, single trailer trucks
11	5 or fewer axles, multi-trailer trucks
12	6 axles, multi-trailer trucks
13	7 or more axles, multi-trailer trucks

Table 1-1. FHWA-Defined Vehicle Classes

1.3.2 Built-in Vehicle Characteristics

The following characteristics are specified in the input file for each vehicle class.

- **Weight.** Given its vehicle class, a vehicle's weight (in pounds) is picked randomly, given minimum and maximum values and the percentage of vehicles falling into ten equally spaced bands between the minimum and maximum. For example, figure 1-1 below shows the distribution of weights for vehicle class 9 (5-axle trucks with single trailers), obtained from data provided by Arkansas Highway and Transportation Department (AHTD). A different distribution is used for each class. Automobile weights are chosen the same way, using specified weight distributions for vehicle class 2.

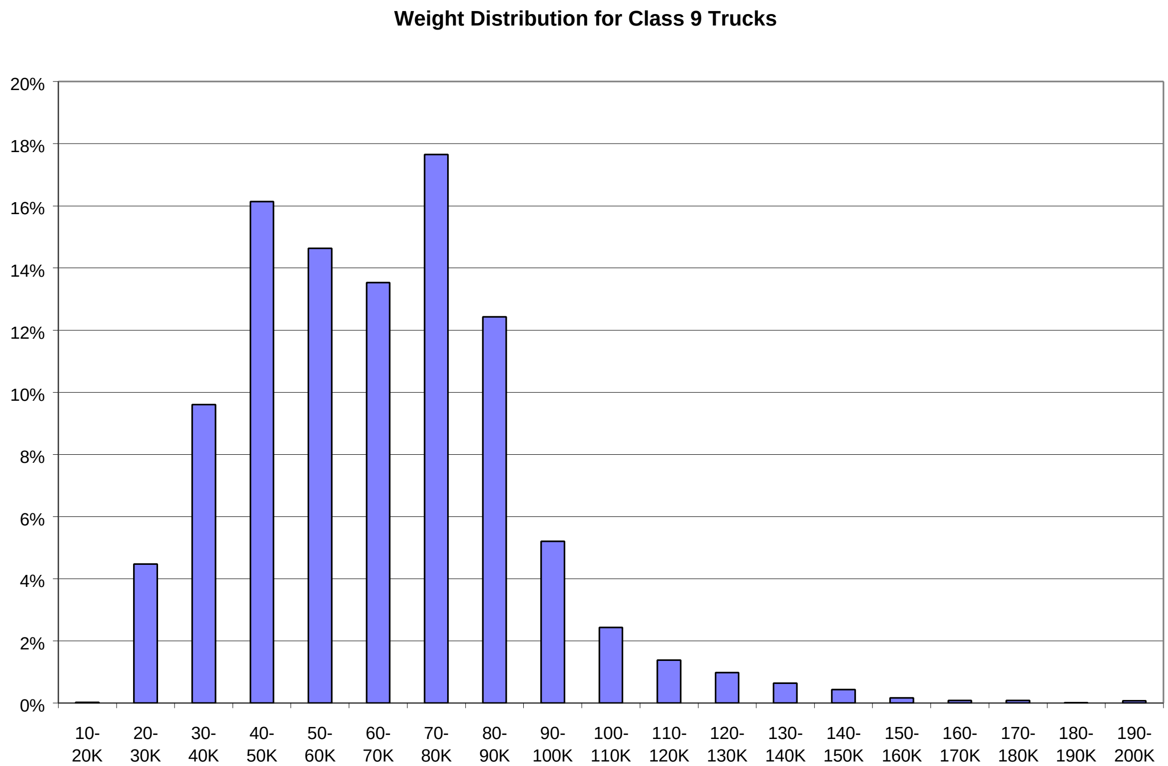

Figure 1-1. Distribution of Weight for Vehicle Class 9

- **Length**. Given its vehicle class, the length of a vehicle (in feet or meters) is picked randomly, given minimum and maximum values and the percentage of vehicles falling into ten equally spaced bands between the minimum and maximum. Automobile lengths are chosen the same way, using specified length distributions for vehicle class 2.

- **Maximum acceleration rate**. This rate (in feet/sec^2 or meters/sec^2) is randomly chosen from a uniform distribution between the specified minimum and maximum for the vehicle class. The default minimum is 0.15g for cars and 0.06g for trucks, and the default maximum of 0.30g for cars and 0.12g for trucks.

- **Maximum deceleration rate**. This rate (in feet/sec^2 or meters/sec^2) is randomly chosen from a uniform distribution between the specified minimum and maximum for the vehicle class. The default minimum is 0.68g for cars and 0.40g for trucks, and the default maximum is 1.00g for cars and 0.50g for trucks.

1.3.3 User-Specified Characteristics

The user may specify any characteristic relevant to the study. Examples are presence of transponder, safety status, carrier status, customs status, hazardous materials (HAZMAT) status, type of violation, and driver credential status. A characteristic could be defined solely to predetermine whether a vehicle will turn left or right at a certain branch point. The value of each user-defined characteristic is either true or false. The user specifies in the control file the probability that the characteristic will be true for each vehicle. That probability may depend on the value of previously defined characteristics.

For example, the user may specify the correlation between trucks over gross weight and trucks exceeding maximum axle weight, or may specify that trucks owned by a "preferred" carrier are less likely to be pulled over for inspection than other trucks. These characteristics form the basis for routing vehicles at branch points. The value of these characteristics may be set or reset as the result of tests performed at branch points during the simulation. The service time for a vehicle at a branch point may also depend on a specified combination of its characteristics.

The vehicle characteristics defined for the Ambassador Bridge model are described in Section 2. The Ambassador Bridge model also specifies a characteristic named "car" so that cars may be displayed on the screen with a different color than trucks.

1.4 Driver Characteristics

The driver-characteristics component of Westa provides a means of simulating variations in driver behavior, including speeding, aggression, and perception/reaction times. Simulation of these variations can help study traffic safety concerns such as the safety implications of merge and diverge maneuvers in the vicinity of the inspection facilities. Westa does not predict traffic crashes, but provides statistics on hard braking incidents that can be used as a surrogate for the level of risk exposure at inspection facilities. Westa's safety module is most relevant as a planning decision support system. The user can test the viability of different operational scenarios, and make a decision on the preferred scenario based on the relative magnitude of simulated risk exposure (i.e., hard braking incidents). Westa accepts two primary sets of input data on driver attributes: aggressiveness and perception-reaction time.

1.4.1 Driver Aggressiveness

Driver aggressiveness is a primary safety concern. Aggressive driving behaviors have been associated with a number of high-risk attributes, including the acceptance of short gaps or headway, sudden acceleration and deceleration, and/or speeding. In a Westa simulation, aggressive drivers travel up to 20% higher than the specified speed limit for each link. Aggressive drivers also require shorter headways when deciding whether to change lanes or decelerate for a slow-moving leader. That is because they anticipate that they and other drivers will decelerate at the maximum deceleration rate, while a normal driver will expect braking at a more comfortable deceleration rate. Westa's default value for the proportion of aggressive drivers is 20 percent. This percentage is the same across all vehicle classes.

1.4.2 Driver Perception-Reaction Time

Westa uses perception-reaction time (PRT) information in executing the vehicle-following logic described below. Westa uses a Weibull distribution to generate PRT values for individual drivers. The probability density function of the Weibull distribution is $f(x) = k\lambda^{-k}x^{k-1}\exp(-x/\lambda)^{-k}$; where k and λ are non-negative shape and scale parameters, respectively, the mean $\mu = \lambda/k\Gamma(1/k)$, and $\Gamma(k)$ = gamma function of k. The default values for λ and k parameters of the Weibull distribution are 1.35 seconds and 2.00 seconds, respectively. These parametric values of the Weibull distribution correspond to an average PRT value of 1.20 seconds. Figure 1-2 below illustrates the distribution of PRTs across drivers.

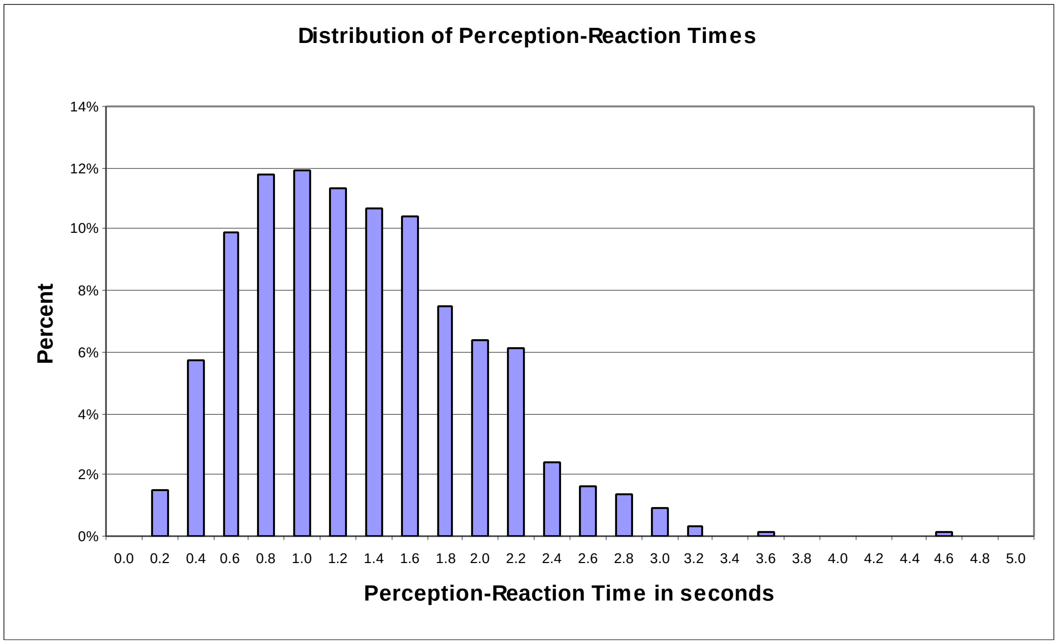

Figure 1-2. Distribution of Driver Perception-Reaction Times

1.4.3 Vehicle-Following Logic

Westa's vehicle-following logic governs drivers' decisions to change speed and to change lanes. The primary components of the logic include the gap acceptance principle of drivers during a merge or lane change maneuver and the spacing maintained between vehicles in the traffic stream. The size of the gap accepted during a merge or the spacing maintained in the traffic stream depends on whether a driver is aggressive or non-aggressive. A block diagram of the vehicle-following logic is shown in Figure 1-3.

Two safety regimes are assumed in the vehicle-following logic. The first safety regime, maximum acceleration for a merge or lane change maneuver and maximum deceleration for a stopping distance, is assumed for aggressive drivers. The second safety regime, comfortable acceleration for a merge and comfortable deceleration for a stopping distance, is assumed for non-aggressive drivers. The default values for maximum and minimum acceleration/deceleration rates for cars and trucks are documented in Section 2.2.

Driver Characteristics Determined when Vehicle is Generated

- Generate perception-reaction time (PRT) from Weibull probability distribution
- Use perception time (PT) as 25 percent of PRT and reaction time (RT) as 75 percent of PRT
- Determine whether driver is aggressive or non-aggressive
- Determine maximum acceleration and deceleration rates (low deceleration rate represents bad brakes)

Vehicle Movement, Evaluated Every 0.1 Second

- Has PT passed since previous acceleration / deceleration decision? If yes, make a new Acceleration / Deceleration Decision as described in the box below. If not, go directly to next step. This PT check allows alert drivers to respond to changes more quickly.
- Change velocity as determined by the acceleration / deceleration decision made RT seconds ago. Thus the action of pressing the brake or accelerator pedal lags to decision to do so by the driver's individual reaction time.
- Move vehicle along link according to its new velocity
- If vehicle has moved onto a new link, either by changing lanes or by passing the end of the previous link, update its link pointers.
- If vehicle has moved off the end of a destination link, it exits the simulation. Otherwise, repeat this process 0.1 seconds later.

Acceleration/Deceleration Decisions

- Does the vehicle need to stop or slow down because of
  - a red stop light ahead or the link ahead is a branch or scale requiring a stop
  - a slower speed limit on next link
  - need to maintain desired headway behind leading vehicle (aggressive drivers maintain shorter headway because greater deceleration ability is assumed)
  - yield to another vehicle at a merge coming up (aggressive drivers assume greater acceleration / deceleration values for self and competing vehicle)
- If yes to any of these, plan to implement required deceleration RT seconds from now, unless required deceleration is less than the minimum deceleration.
- If no, plan to accelerate up to the speed limit on the current link (120% of speed limit if aggressive)
- If (a) a parallel lane is defined, (b) the vehicle could go faster in the parallel lane, (c) it would not overrun its leader in the parallel lane, and (d) its follower in the parallel lane could decelerate so as not to overrun it (aggressive drivers force greater deceleration), switch to parallel lane and begin this set of acceleration / deceleration checks again.

Figure 1-3. Block Diagram of Vehicle-Following Logic

1.5 Link Types and Traffic Signals

Westa can model seven types of links: origin, transit, destination, scale, branch, parking lot, and building. The location and length of each link are determined by the x and y coordinates of its start and end points, specified in the input file. All links other than parking lots may be straight or curved. Westa can also represent two types of traffic signals: fixed timing plan and actuated. This section describes each link type and signal type.

1.5.1 Origin

Vehicles are created on an origin link. Characteristics pertaining to each vehicle, such as weight, length, presence of transponder, safety status, and credential status, are determined at the origin based on vehicle information data specified in the control file. Any number of origin links may be specified. If more than one origin is specified, the percentage of total traffic and the proportions of vehicle classes starting at each origin must be specified. An origin link has one next link and no previous links.

1.5.2 Transit

A transit link functions as a one-lane highway, ramp queue, or any other type of link that does not have multiple exits. Each transit link has one next link and one or two previous links. If there are two previous links feeding into the transit link, one previous link must be specified as the yielding link. Vehicles coming from the yielding link must yield the right-of-way to those coming from the other link.

A transit link may be “closed” when the number of vehicles on it reaches a specified percentage of its capacity. A transit link will also close when the link ahead of it is closed. If there is a branch or scale link feeding into the closed link, the branch or scale link will abandon its switching function and will route vehicles to the non-closed alternative. If both alternatives are closed, the branch or scale link itself will close. When the number of vehicles on a closed link declines to the specified reopening threshold, the link is reopened and the previous branch link resumes its switching function.

1.5.3 Destination

There may be more than one destination link. When a vehicle reaches the end of a destination link, it exits the simulation, its statistics are written to an output file, and on-screen statistics are updated. A destination link is the last link in a vehicle’s journey, unless the vehicle is placed out of service in a parking lot. Each destination link has one or two previous links and no next links. The same merging rules for previous links apply as for transit links. A destination link is never closed.

1.5.4 Branch

A branch link has two next links and one or two previous links. The same merging rules for previous links apply as for transit links. When a vehicle arrives at a branch link, a test is performed, as a Boolean combination of any number of current vehicle characteristics and/or comparisons of current link queue lengths. If the outcome of the specified test is true, the vehicle is routed to the link specified by the test. If the outcome is false, the vehicle is routed to the other link. If a non-zero stop time is specified, each vehicle must come to a stop and must wait for a constant time, or a random amount of time drawn from an Erlang, normal, or uniform distribution with specified parameters. The wait time may be a function of vehicle characteristics. The presence of a transponder, the status of driver credentials, vehicle safety hazmat status, preferred or blacklisted carrier status, and bridge or axle weight violation status are examples of vehicle characteristics that can be defined by the user and checked with a test. The value of one or more vehicle characteristics may be set or reset depending on the result of the test performed at the branch link. Branch links may be closed or open as described in the previous section.

1.5.5 Scale

A scale link is a special case of a branch link. When a vehicle arrives at a scale, a test is performed that compares the measured weight of the vehicle to the defined weight threshold for the scale. An error in the measurement is modeled by choosing the measured weight as a random variable from a normal distribution with the true weight as the average and a specified percentage of the true weight as the standard deviation. Vehicles that are measured above the scale's weight limit are routed to the link specified by the test, and those that are below the weight limit proceed to the other forward link. A static scale is modeled by assigning a non-zero stop time and a small or zero error term, while a WIM scale is modeled by assigning zero stop time and a larger error term. The time taken to perform the weighing is constant or a random number drawn from a normal, uniform, or Erlang distribution.

1.5.6 Parking Lot

A parking lot is a special case of a transit link. The user must specify a third corner point, so that the link is wide enough for diagonal parking. The user also specifies the number of parking spaces. If a vehicle enters an empty parking lot and no service time has been specified, it proceeds directly to the exit. If a waiting vehicle blocks the exit, the entering vehicle proceeds to the empty parking space nearest the exit, pulls into it, and waits. The lot may be treated as a first-in first-out queue, in which case the vehicle cannot pull out of its parking space and proceed to the exit until all vehicles that have entered the lot before the waiting vehicle have exited the lot. Alternatively, no queuing may be specified, in which case the time a vehicle waits does not depend on any other vehicle.

A parking lot is also a special case of a branch link. A test and a wait time may be specified. The wait time begins when the vehicle is first in line to leave the lot if queuing is specified, or as soon as it parks if queuing not specified. If the test results in the vehicle being assigned the characteristic named "OOS", the vehicle is placed out of service. The vehicle remains in the parking lot (occupying a parking space) until the end of the simulation, and its statistics are added into the running totals as if it had finished by leaving a destination link.

1.5.7 Building

A building is not a traveled link at all, but may be specified in the same manner as a link for convenience. It is displayed as a stationary yellow rectangle on the screen with a user-specified label. Examples are an office, an inspection shed, a tollbooth, or a simply a highlighted section of pavement such as a scale. It may overlay other links. It has no active role in the simulation.

1.5.8 Fixed Signal

A fixed signal turns red and green on a fixed cycle. The user specifies the length of the cycle in seconds, the number of seconds the light is green, and whether the simulation begins at the beginning of the red phase or the green phase. A traffic signal serving multiple approaches is modeled as multiple signals, one at the end of each link, with coordinated red and green phases.

1.5.9 Actuated Signal

An actuated signal is defined with pointers to one, two, or three other links. If there are any vehicles on any of the indicated links, the traffic signal is red. Otherwise, the signal is green. In other words, vehicles on the link with the actuated signal must stop until the other link is clear of traffic. An actuated signal may be used to enforce vehicle priority or merging patterns.

1.6 Use of Probability Distributions

Westa uses two independent streams of pseudo-random numbers during the course of the simulation. The first is used for determining vehicle characteristics and arrival times, and the second is used for determining weighing, inspection, toll-payment, and other activities involving delay times. The two streams are independent so that the arrival rate and characteristics of vehicles can be kept identical while station configuration and control strategies are varied.

The following sections describe the probability distributions used in Westa.

1.6.1 Exponential Arrival Rate

The time between the arrival of a vehicle at the origin and the arrival of the next vehicle is drawn from an exponential distribution whose average is the given interarrival rate. Figure 1-4 illustrates the probability of various interarrival times, given an average of 25 seconds. Interarrival times less than the average are most common, but occasional long gaps between arrivals are possible.

The density function for the exponential probability distribution is $f(x) = 1/\alpha \exp(-x/\alpha)$. The parameter α of the exponential distribution is estimated from the empirical interarrival time data as $\alpha = [\sum x]/n$; where x = interarrival time for individual vehicles, and n = number of vehicles observed in the analysis period. The value of the mean and variance for the exponential distribution is α.

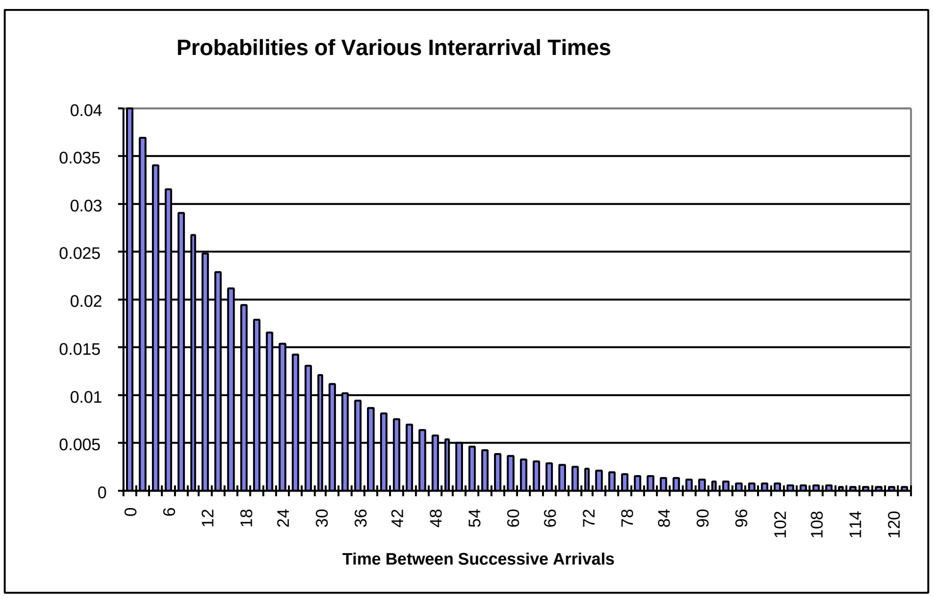

Figure 1-4. Sample Exponential Distribution

The user may specify different average interarrival times for different time periods. The transition between different arrival rates may be gradual or abrupt.

1.6.2 Uniform Distribution for Vehicle Attributes

The user may specify that a certain percentage of vehicles have a certain attribute, or that a certain percentage of vehicles that possess a specified combination of previously defined attributes have the attribute. At the time each vehicle is created, a random number is drawn from a uniform distribution between 0 and 100 percent for each attribute to determine whether the vehicle has the attribute or not. For example, if the user specifies a 20% chance that a vehicle will have a transponder, whenever a vehicle is generated, a random draw of 20 or less means the vehicle has a transponder, and a draw of greater than 20 means the vehicle does not have a transponder.

The density function for the uniform probability distribution is $f(x) = 1/b-a$. The parameters a and b are the lower range value and upper range value, respectively. The mean and variance for the uniform distribution are $(a+b)/2$ and $(b-a)^2/12$, respectively.

1.6.3 Normally Distributed Error for Weight Measurement

The operation of a scale is simulated using a random number from a normal distribution. The density function of the normal distribution is $f(x) = [1/\sqrt{(2\pi\sigma^2)}]\exp(-(x-\mu)^2/2\sigma^2)$. The average value μ for the normal distribution is the true weight of the truck and the variance σ^2 is chosen by the user to reflect the accuracy of the scale. For example, figure 2-5 below illustrates the probability distribution for the measured weight of a truck weighing 85,000 pounds, on a scale with an error of 5 percent.

Because of the error in measurement, a truck that is overweight may be weighed as being underweight or vice versa. For example, a truck with a weight of 75,000 pounds has a 99% chance of being measured over a threshold of 60,000 pounds, a 90% chance of measured over a threshold of 70,000 pounds, and a 10% chance of being measured over a threshold of 80,000 pounds.

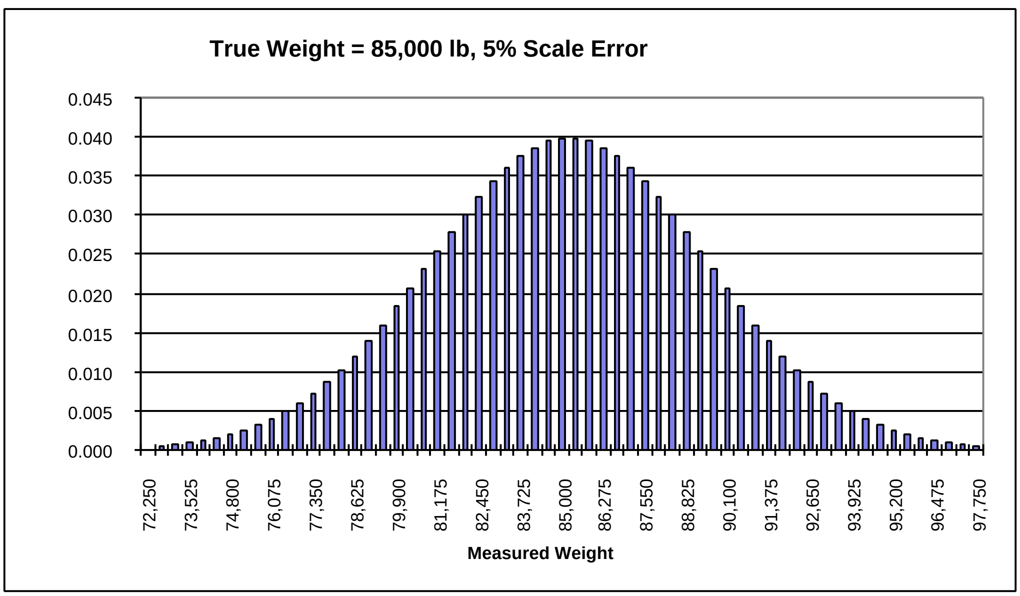

Figure 1-5. Probability of Measured Weight, Using a Normal Distribution

1.6.4 Normal, Uniform, Erlang or Constant Service Times

The time taken to weigh a truck on a scale, perform a safety inspection, write a ticket, or perform any other delay-causing activity is either a specified constant value or a random value drawn from a specified distribution. Random numbers may be drawn from (a) a normal distribution with a specified mean and standard deviation, (b) a uniform distribution between specified minimum and maximum values, or (c) an Erlang distribution with a given average value. Different probability distributions for service times may be specified for different categories of vehicles.

Values drawn from a normal distribution may have a negative value; if a negative value is drawn Westa replaces it with 0.01 times the mean. If the user does not have a large data set on the service times that can be used to select a reasonable probability distribution model, the use of a uniform distribution requiring only the minimum and maximum service-times is recommended.

The probability density function for the Erlang distribution is $f(x) = (\lambda k)^k x^{k-1} \exp(-\lambda k x)/k-1!$; where $\lambda = 1/\mu$, μ = mean value of x, and k = shape parameter and is a positive integer. Westa uses the Erlang distribution with shape parameter k=4, since that value has been found to reflect the observed distribution of service times very well. The figure below illustrates the probability of various truck-inspection times generated from the Erlang distribution for μ = 25 seconds.

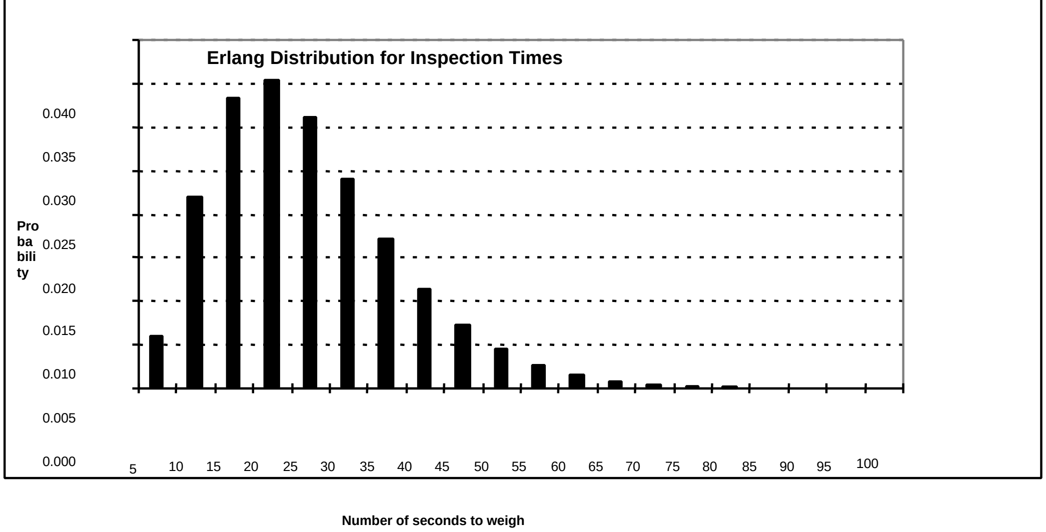

Figure 1-6. Probability of Inspection Times Using an Erlang Distribution

1.6.5 Weibull Distribution of Perception/Reaction Time

The use of the Weibull distribution to represent driver perception-reaction times is presented in section 1.4 and illustrated in figure 1-2. This distribution has been found to be a good match of empirical data on perception-reaction times.

Section 2

Representation of the Ambassador Bridge Scenarios

This section describes and documents the simulation experiments performed for the evaluation of Ambassador Bridge operations. Two components of the Ambassador Bridge border crossing are analyzed. The first component is expected queue development and service rates at primary truck inspection under varying levels of truck participation in the North American Trade Automation Prototype (NATAP) effort. The prospective system impact of improved service times for NATAP participants is examined under three-, four-, and five-lane operations at the peak hourly truck arrival rate. In each configuration, the effectiveness of various combinations of dedicated NATAP, non-NATAP, and mixed-use lanes are evaluated.

The second component of Ambassador Bridge operations considered is the light vehicle (car) primary inspection under varying levels of utilization of Dedicated Commuter Lane (DCL) technologies to reduce service time. The use of one or more dedicated lanes are evaluated at peak car arrival rates under four- and five-lane operations. Combinations of dedicated, non-NATAP, and mixed-use lanes are evaluated.

2.1 Description of Configurations and Scenarios

The base case configuration was constructed using data defining current border crossing operations. Arrival and service rates for both truck and car inspection are discussed in section 2.2. In addition, Section 2.2 documents the input file for the base case configuration. Alternative configurations for each inspection site and the scenarios evaluated are derived by altering various input parameters from their base case settings. In this section, the overall experimental plan is presented, consisting of the configurations considered and the evaluation scenarios are described. Each scenario represents a particular combination of lane use configurations and a prospective level of participation in the NATAP effort described as a percentage of all vehicles.

A shorthand form is used to identify operational configurations throughout the document. A “d” indicates a dedicated NATAP lane (trucks) or DCL (cars). An “m” designates a mixed-use lane where vehicles with or without transponder technologies are served. An “n” indicates a lane where transponder technologies cannot be served. The number of letters strung together designates the total number of lanes operating in the scenario. For example, “dmmn” is the shorthand form for a configuration with four-lanes in operation: one dedicated lane, two mixed-use lanes, and a non-NATAP lane. Similarly, “mmmmm” is shorthand for a five-lane, all mixed-use configuration.

Each configuration is tested under varying levels of utilization of NATAP technologies. For the primary truck inspection evaluation, the following participation rates are considered: 1% (current level), 10%, 25%, 50%, and 75%. For DCL utilization, rates of 5% (current), 25%, 50% and 75% are considered. Not all configurations are tested under every rate of utilization – some combinations are obvious mismatches with respect to the truck arrival stream. For example, a scenario with only one dedicated or mixed-use lane and 75% NATAP participation is clearly an untenable operational policy and is not evaluated. The range of scenarios considered for four-lane configurations at primary truck inspection is presented in Table 2-1 and for five-lane configurations in Table 2-2. A single three-lane configuration is also evaluated (Table 2-3). No additional three-lane configurations were considered when it became clear that no three-lane configuration, regardless of NATAP participation rate, could satisfy peak truck arrival rates.

The range of scenarios considered in the DCL evaluation for cars is presented in Table 2-4. Results in each scenario were generated by averaging the results from four runs obtained using different random number seeds.

		Percent NATAP Participation				
		1	10	25	50	75
Configurations	mnnn	✓	✓	✓	✓	
	dnnn	✓	✓	✓	✓	
	mmnn	✓	✓	✓	✓	✓
	dmnn	✓	✓	✓	✓	✓
	ddnn			✓	✓	✓
	mmmn	✓	✓	✓	✓	✓
	dmmn	✓	✓	✓	✓	✓
	ddmn			✓	✓	✓
	dddn				✓	✓
	mmmm		✓	✓	✓	✓
	dmmm		✓	✓	✓	✓
	ddmm				✓	✓
	dddm					✓

Table 2-1. 4-Lane Primary Truck Inspection Scenarios

		Percent NATAP Participation				
		1	10	25	50	75
Configurations	mnnnn	✓	✓	✓	✓	✓
	mmnnn	✓	✓	✓	✓	✓
	mmmnn	✓	✓	✓	✓	✓
	mmmmn	✓	✓	✓	✓	✓
	mmmmm	✓	✓	✓	✓	✓
	dnnnn	✓	✓	✓	✓	✓
	ddnnn	✓	✓	✓	✓	✓
	dddnn	✓	✓	✓	✓	✓
	ddddn	✓	✓	✓	✓	✓
	dmmnn	✓	✓	✓	✓	✓
	dmmmn	✓	✓	✓	✓	✓
	dmmmm	✓	✓	✓	✓	✓
	ddmnn	✓	✓	✓	✓	✓
	ddmmn	✓	✓	✓	✓	✓
	ddmmm	✓	✓	✓	✓	✓
	dddmn	✓	✓	✓	✓	✓
	dddmm	✓	✓	✓	✓	✓
	ddddm	✓	✓	✓	✓	✓
	dmnnn	✓	✓	✓	✓	✓

Table 2-2. 5-Lane Primary Truck Inspection Scenarios

Configuration	Percent NATAP Participation: 1	10	25	50	75
mmm					✓

Table 2-3. 3-Lane Primary Truck Inspection Scenarios

Configurations	Percent Vehicles DCL Eligible: 5	25	50	75
mmmdd	✓	✓	✓	✓
mmmm	✓	✓	✓	✓
mmmmm	✓	✓	✓	✓
nnnnm	✓	✓	✓	✓
nnnmd	✓	✓	✓	✓
nnnnd	✓	✓	✓	

Table 2-4. DCL Evaluation Scenarios

2.2 Documentation of Input Values for the Truck Scenarios

This section documents the values in the input files for the truck inspection scenarios. The base (current) truck and car inspection scenarios were defined using data collected at the bridge by Booz-Allen & Hamilton (BAH), by bridge operations authorities, and by the firm of Reid, Cool, and Michalsky[2]. For the study of the primary car inspection lanes, a slight change was made to the arrival rate distributions as described in section 2.3.

For each value or set of values, the source of the information is given. The lines of the input file are shown in bold Courier font, and the commentary follows in Times New Roman font. Any characters following the pound sign (#) in the input file are treated as comments.

`Ambassador Bridge Model`

The scenario name is displayed at the top of the screen and included in the output files.

runLength: 120 # run for two hours, 11 a.m. – 1 p.m. (peak period)

The peak period was selected from hourly data from Ambassador Bridge statistics. Figure 2-1 shows the hourly car and truck traffic for the week of June 16, 1998. The peak period for cars is the morning commute, while the peak period for trucks is fairly flat during the midday period. For the base study of truck lanes, since truck congestion was the primary focus, Mitretek modeled a constant arrival rate over a 2-hour midday period.

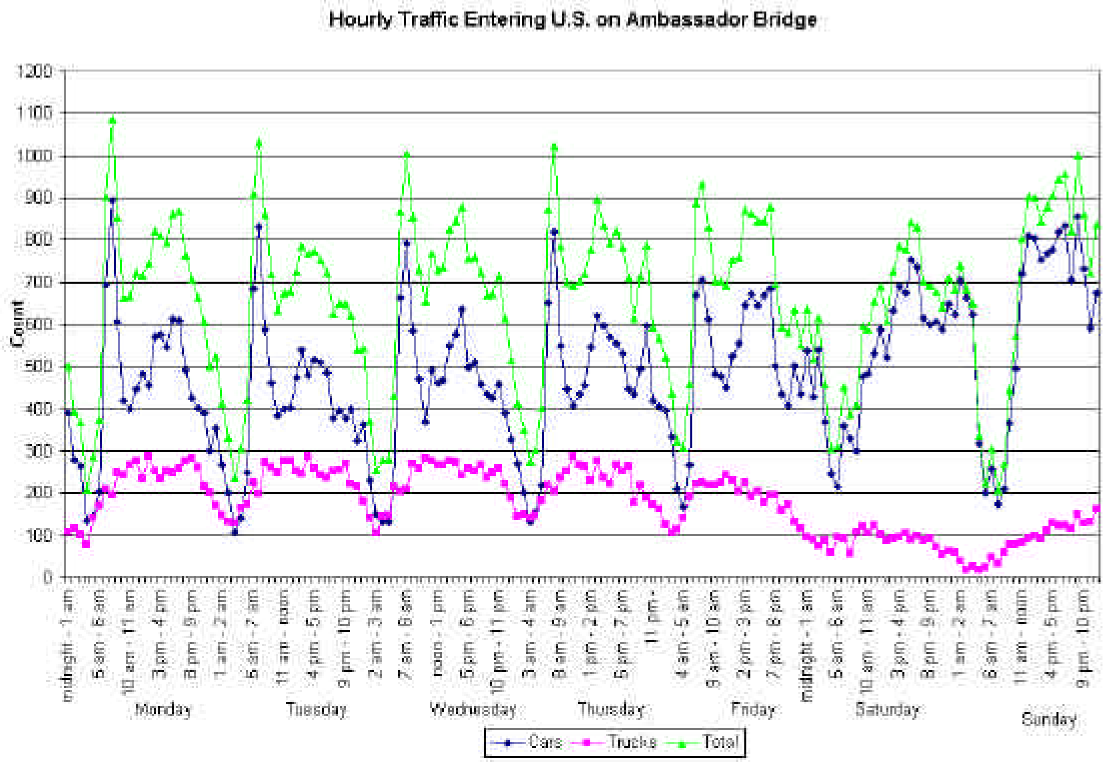

Figure 2-1. Hourly Traffic Entering the U.S on the Ambassador Bridge

```
randomSeed_truck:    241
randomSeed_link:     47
```

These random seeds initialize the random number generators for vehicle generation and weighing/inspection times. The numbers here were used for the first iteration. Mitretek ran each scenario four times with a different set of random seeds for each iteration, and averaged the results together for the final results.

```
avgCreatTime: 3.6
```

A vehicle is generated every 3.6 seconds on the average. The peak arrival rate of 1000 vehicles per hour was taken by Mitretek from the weekly data shown in figure 2-1. The peak arrival rates are consistent with data recorded in May 1998 by the consulting firm of Reid, Cool, and Michalski.

```
maxWt:          80000                # <- maxWt for static scales
```

The maximum legal weight for trucks without a special permit is set at 80,000 pounds. However, since weight is not a concern for this scenario the model does not use this value.

```
TimeStep .2
```

Vehicle motion was re-computed every 0.2 seconds. Time steps this short permitted sensitivity to different vehicle acceleration/deceleration rates and different driver perception/reaction times.

```
OutputFreq 300
```

This line specifies that summary statistics are to be written to the summary file every 300 seconds (five minutes).

`[TruckInfo]`

The following groupings define the distribution of length, weight, and acceleration/ deceleration characteristics for vehicles in each FHWA class. When values for any of these variables are not specified for a class, Westa uses values for the preceding class.

Class 2 Cars

```
maxAccRange:    2.8   6.3     .009        # (mi/hr/sec)
```

The maximum acceleration rate for each car is chosen from a uniform distribution between 2.8 and 6.3 mph per second. These values reflect the range of maximum acceleration capabilities for passenger cars reported in the Road Test Digest of Car and Driver magazine. Those acceleration figures are divided by two since the maximum acceleration used in a congested facility is less than the maximum value on a test track. The value of 0.009 indicates that the maximum acceleration rate declines at .009 times the current speed (the faster a car is going, the smaller is its maximum acceleration).

```
maxDecRange:    17.3   20.7     .30         # (mi/hr/sec)
```

The maximum deceleration rate for each car is chosen from a uniform distribution between 17.3 to 20.7 mph per second. These values are the weighted averages plus and minus two standard deviations for maximum deceleration rates for passenger cars published in Consumer Reports magazine. The value of 0.3 indicates that the normal (comfortable) rate of deceleration is 0.3 times the maximum rate.

```
weightRange:    0      6000                 # (lbs)
weightDistrib:  0.0  0.0  4.1  9.9  31.4  27.3  14.9  6.6  4.1  1.7   # (%)
```

The minimum and maximum weights serve as end points for the weight distribution. The weight range is divided into ten bins of equal size between the minimum and maximum value, and the percentages give the percent of cars in each bin. In this case, the bin size is 600 pounds. The values of weight distribution for cars reflect the weight range of new cars reported in Consumer Reports magazine. The weight of cars is irrelevant to the Ambassador bridge model in any case.

```
lengthRange:   10 20                      # (ft)
lengthDistrib: 0.0  0.0  1.7  7.4  19.0  28.9  27.3  10.7  5.0  0.0  # %
```

The minimum and maximum lengths serve as end points for the weight distribution. The length range is divided into ten bins of equal size between the minimum and maximum value, and the percentages give the percent of cars in each bin. In this case, the bin size is 1 foot. The values of length distribution for cars reflect the length range of new cars reported in the March 1998 Consumer Reports magazine.

```
Class 3   2-axle 4-tire (Pickup trucks)
maxDecRange:    16.8   18.6     .30         # (mi/hr/sec)
```

The maximum deceleration rate for light trucks ranges from 16.8 to 18.6 mph per second. These values are the weighted averages plus and minus two standard deviations for maximum deceleration rates for light trucks published in Consumer Reports magazine. The value of 0.3 indicates that the normal (comfortable) rate of deceleration is 0.3 times the maximum rate.

```
lengthDistrib:  0.0  0.0  96.2  0.0  0.2  1.5  1.9  0.3  0.0
```

The length distribution for this class and for all truck classes was supplied by the South Dakota Department of Transportation (SDDOT). Mitretek assumed that the distribution of truck length for FHWA-defined vehicle classes is the same in Michigan as in South Dakota, so the same values were used. Since the maximum and minimum lengths are not specified, the values for the previous class are used. Similarly, since the acceleration and weight characteristics of class 3 trucks are not specified, the values for cars are used. The weight of pickup trucks is irrelevant to the model in any case since they are not inspected.

```
Class 4   Buses
maxDecRange:  16.8   18.6   .30
lengthRange:    30 40
lengthDistrib:  0.0  0.0 96.2  0.0  0.2  1.5  1.9  0.3  0.0
```

The same deceleration characteristics were used for buses as for small trucks. The distribution of bus lengths came from SDDOT. Bus characteristics are not significant to the Ambassador Bridge model since they are not inspected.

Class 5 2-axle 6-tire single units

The performance characteristics of class 5 trucks were assumed to be the same as for light trucks so they are not specified.

```
weightRange:  0 100000
weightDistrib:  59.6 32.4  7.4  0.5  0.0  0.0  0.0  0.0  0.0  0.0
```

The weight distribution for this and all truck classes was taken from the Class by Gross Vehicle Weight Report produced by the Indiana Department of Transportation (INDOT) from data collected by the Edinburgh Strategic Highways Research Program (SHRP) site. The weight of trucks is not relevant for the Ambassador Bridge model.

```
lengthRange:     0     50                     # (ft)
lengthDistrib:  0.0  2.4  64.1  23.6  9.9  0.0  0.0  0.0  0.0  0.0
```

The length distribution for this class and for all truck classes was supplied by SDDOT.

```
Class 6  3-axle single units
maxAccRange:     1.3    2.6      .009         # (mi/hr/sec)
```

The maximum acceleration rate for each large truck (class 6 and above) is chosen from a uniform distribution between 1.3 and 2.6 mph per second. These values range around the value of .1g (2.2 mph) considered good acceleration for a loaded truck. The value of 0.009 indicates that the maximum acceleration rate declines at .009 times the current speed (the faster a truck is going, the smaller is its maximum acceleration).

```
maxDecRange:      8.2   10.9       .30          # (mi/hr/sec)
```

The maximum deceleration rate for trucks ranges from 8.2 to 10.9 mph per second (.37g to .5g). The upper value was supplied by data in the American Trucking Association library. The lower value was based on the assumption that some trucks will have less than optimal brakes. The value of 0.3 indicates that the normal (comfortable) rate of deceleration is 0.3 times the maximum rate.

```
weightRange:    0      100000                # (lbs)
weightDistrib:  0.3 40.3 32.9 13.6  9.0  2.6  1.1  0.2  0.0  0.0   #(lbs)
```

The weight distribution for this and all truck classes was taken from the Class by Gross Vehicle Weight Report produced by INDOT from data collected by the Edinburgh SHRP site.

```
lengthRange:    0       50
lengthDistrib:  0.0  0.0  0.8 18.7 72.3  8.2  0.0  0.0  0.0  0.0  # %
```

The length distribution for this class and for all truck classes was supplied by SDDOT.

Class 7 4 or more axles, single unit

```
weightRange:   0    100000
weightDistrib:  0.0  0.2  1.6  2.9  7.1  9.1 55.5 22.7  0.7  0.2 #  (%)
lengthRange:   0  50
lengthDistrib:  0.0  0.0  0.0 11.5 50.0 34.6  3.8  0.0  0.0  0.0   # %
```

Class 8 4 or fewer axles, single unit

```
weightRange:    0  100000
weightDistrib:  0.1  5.7 27.3 36.1 22.9  7.5  0.4  0.0  0.0  0.0
lengthRange:    20   70                    # (ft)
lengthDistrib:  0.0  6.8 22.4 35.1 16.4  7.4  6.5  4.2  1.1  0.0    # %
```

Class 9 5-axle, single trailer

```
weightRange:    0  100000
weightDistrib:  0.0  1.5  6.9 16.3 15.2 16.1 16.0 24.2  3.8  0.0
lengthRange:     35  85
lengthDistrib:  0.2  0.6  2.1 10.0 37.1 46.0  3.9  0.2  0.0  0.0   # %
```

```
Class 10  6 or more axles, single trailer
weightRange:    0  100000
weightDistrib:   0.0  0.3  3.1 14.4 14.6 10.3 11.5 18.8 14.6 12.3  #  (%)
lengthRange:     20  90
lengthDistrib:  0.0  0.0  0.9  8.8 31.0 27.9 27.4  3.5  0.4  0.0    # %
```

```
Class 11  1.1 % 5 or fewer axles, multi-trailer
weightRange:    0   100000
weightDistrib:  0.0  0.0  0.4  5.6  9.2 21.5 38.9 22.9  1.5  0.0 # (%)
lengthRange:   20  90#
lengthDistrib:   0.0  0.0  0.9  8.8 31.0 27.9 27.4  3.5  0.4  0.0   # %
```

Class 12 6 axles, multi-trailer

```
weightRange:    0   100000
weightDistrib:  0.0  0.0  0.0  5.8 12.4 18.2 31.4 26.1  5.0  1.1 #  (%)
lengthDistrib:  0.0  0.0  0.0  0.0  0.0  0.0 26.4 36.8 36.8  0.0  # %
```

Class 13 7 or more axles, multi-trailer

```
weightRange:    0  100000
weightDistrib:  0.0  0.0  0.0  2.0  2.0  7.8  3.9  3.9 17.6 62.7 #  (%)
lengthDistrib:  0.0  0.0  0.0  0.0  0.0  0.0 26.4 36.8 36.8  0.0
```

The weight distribution for all truck classes was taken from the Class by Gross Vehicle Weight Report produced by INDOT from data collected by the Edinburgh SHRP site. The length distribution for all truck classes was supplied by SDDOT.

```
ClassDistribution 2 origins
Link   c1   c2   c3   c4   c5   c6   c7   c8   c9  c10  c11  c12  c13
0       0   20    0    0   10    5    0   10   40    5    0   10    0
3       0  100    0    0    0    0    0    0    0    0    0    0    0
```

Link 0 and link 3 are the two origin links, where cars and trucks enter the simulation. Link 3 represents the left lane of the bridge and link 0 is the right lane. These lines in the input file specify the percentage of each vehicle class to enter the simulation on each link. The total distribution between cars (class 2) and trucks (classes 5 through 13) was taken from hourly data collected at the bridge (see figure 2-1). The ratio of cars to trucks is the ratio experienced during the mid-day hours of peak truck traffic. All trucks start the simulation in the right lane, since they are required to exit to the right before the end of the bridge. However, the split of cars between the left and right lanes and the breakdown of trucks by classes are estimates by Mitretek, since the data are not available. The only difference to the Ambassador Bridge simulation made by the FHWA class of a truck is its length distribution.

[Attributes]

Each attribute (also called a characteristic) of a vehicle is determined at the time it enters the simulation. Attributes may be given other values during the simulation as a result of a test. The probability of each characteristic being set to true is specified. The probability may depend on the value of previously set attributes. The cab and/or trailer of a vehicle may be displayed in a certain color to indicate that a certain attribute is true. Attributes need not be defined in numerical order, and there may be gaps in the sequence of attribute numbers.

```
#  name                  cab color  trailer color  %   expr     %   expr
#  ----                  ---------  ------------  --- -------  --- --------
1  "car"                 yellow     yellow         100 { c2 }
```

Cars are displayed in yellow. 100% of the vehicles in class 2 are designated as cars.

```
2  "truck"               default    default      100 { not c2 }
```

Trucks are normally displayed with the default color (blue). If the vehicle is not class 2, there is a 100% chance that the vehicle will be a truck (i.e. all vehicles that are not cars are trucks).

```
3 "DCL"                  lightgreen default     5 { 1 }
```

This line specifies that five percent of the cars (vehicles with attribute 1 true) have transponders, and thus can use the dedicated commuter lane (DCL). These cars are required to stop at primary inspection booths to swipe a participation card, but not for customs inspection. This number was not important for the base case where trucks were being studied. This number was varied for the second set of analyses (see section 2.3).

```
4 "line release"     default    default     57 { 2 }
5 "Monthly"          default    black       14 { 2 and ( not 4 ) }
6 "Brel-BCS-bond"    default    lightred    97 { 2 and ( not 4 ) and ( not 5 ) }
7 "NATAP"            default    lightgreen  100 { 2 and ( not 4 ) and ( not 5 ) and
( not 6 ) }
```

These lines group trucks into four categories: line release, monthly master, Brel/BCS/Bond, and NATAP (also called NCAP). Each category is defined in terms of the percentage of trucks that are not in any of the previous categories, since a truck may not be in more than category. The types or trucks are distinguished in the graphics by the color of their trailers. These percentages are taken from recent trucks counts provided by the Ambassador Bridge Authority. The percentages were varied in subsequent scenarios (see section 2.1).

```
8 "secondary inspec"    default    default     1 { 2 and ( not 7 ) }
```

This line specifies that one percent of trucks that are not NATAP trucks will be sent to secondary inspection. This percentage was supplied by the Ambassador Bridge Authority. Test 13 checks for this attribute.

```
9 "double load LR"      lightred   default     6 { 4 }
10 "double load BCS"    lightred   lightred    40 { 6 }
```

These lines specify that six percent of the line release trucks and forty percent of the BCS trucks are carrying double loads. The double loads take twice as long to inspect, so the specification for service time 1 checks for these attributes. These percentages were estimated by Mitretek, given the total number of loads and the total number of trucks.

```
11 "inspected car"      default    lightred    5 { 1 and not 3 )
```
This line specifies that five percent of the cars that are not enrolled dedicated commuters will be directed to secondary inspection. Mitretek estimated this figure. However, its value is not important to the simulation results since secondary inspection for cars is not implemented in the model.

```
12 "timed truck"      default    default     100 { 2 and ( not 6 ) and ( not 8 ) }
```
The purpose of this attribute is to compute the average transit time for trucks in the simulation. It is set to true for trucks that do not spend time at secondary inspection or waiting in the parking lot while the driver consults a customs broker. In other words, trucks with attributes 6 and 8 are excluded from this type. These trucks spend much longer in the simulation. These longer times should not be counted when determining how much delay is caused to legal trucks by the primary inspection operation.

```
13 "double swipe"      default    lightred    60 { 3 }
```
Booz-Allen reported that 3 out of 5 cars with transponders had to make a second swipe at the card reader. This attribute selects 60% of the cars with transponders to experience the longer stop time.

```
[Tests]
```
Each branch and parking lot link performs a test on each vehicle as it enters the link. The test is a Boolean combination of vehicle attributes. If the value of the test is true, the vehicle leaves the branch link by the alternate link (the second link named in the link file). If the value of the test is false, the vehicle leaves the branch by the main link (the first link named in the link file). More than one branch may perform the same test. If an attribute number is specified in the second part of the test, that attribute is set to true for all vehicles that pass the test. The latter feature is not used in this scenario.

```
1 "Trucks right"      A { 2 }    { }
```
This test requires all trucks to take the alternate branch. This test is applied by link 1, where trucks are required to leave the bridge and enter the inspection compound.

```
2 "Transp & Q check"   A { 7 or ( ( Q 16 < Q 17 ) and ( Q 16 < Q 18 ) and ( Q 16 <
Q 19 ) and ( Q 16 < Q 20 ) ) } { }
```
This test requires all trucks with NATAP transponders (attribute 7) to take the leftmost inspection lane (link 16). Since that link is not dedicated, any other truck will also take this lane if the queue on it is shorter than the queue on any of the other lanes (link 17, link 18, link 19, and link 20). The test is performed on link 11. All trucks failing the test go on to link 12 (some other booth has a shorter queue than link 16). This test is modified for the alternate scenarios (see section 2.1).

```
3 "Q check"          A { ( Q 17 < Q 18 ) and ( Q 17 < Q 19 ) and ( Q 17 < Q 20 ) }
{ }
```
This test requires trucks to take the alternate branch (link 17) if the queue on it is shorter than the queue on any of the other remaining lanes (link 18, link 19, and link 20). The test is performed on link 12. All trucks failing the test go on to link 13 (some other lane has a shorter queue than link 17). This test is modified for the alternate scenarios (see section 2.1).

```
4 "Q check"           A { ( Q 18 < Q 19 ) and ( Q 18 < Q 20 ) } { }
```
This test requires trucks to take the alternate branch (link 18) if the queue on it is shorter than the queue on any of the other remaining lanes (link 19 and link 20). The test is performed on link 13. All trucks failing the test go on to link 14 (some other lane has a shorter queue than link 18). This test is modified for the alternate scenarios (see section 2.1).

```
5 "Q check"           A { Q 19 < Q 20 } { }
```

This test requires trucks to take the alternate branch (link 19) if the queue on it is shorter than the queue on the remaining lane (link 20). The test is performed on link 14. All trucks failing the test go on to link 20. Link 20 is closed in the three-lane and four-lane scenarios. When examined in a queue length comparison, a closed link is considered to have an infinite queue length, so it is never chosen. This test is modified for the alternate scenarios (see section 2.1).

```
6 "to parking lot"     A { 6 or 8 }     {  }
```
This test is performed by every one of the primary inspection links (links 21 through 25). Trucks with attribute 6 (Brel/BCS/Bond) or attribute 8 (tagged for secondary inspection) true must take the alternate branch toward the parking lot. Other trucks may proceed toward the exit.

```
7 "DCL & Q check"      A { 3 or ( Q 71 < Q 82 ) } { }
```
This test requires all cars with DCL transponders (attribute 3) to head toward the rightmost inspection lane (link 87). Any other car will also head right if the queue for the rightmost lanes (link 71) is shorter than the queue for the two leftmost lanes (link 82). The test is performed on link 4, where cars have the choice of changing from the left to right lane after the trucks have left the roadway. All cars failing the test go on to the two left lanes. This test is modified for the alternate lane use scenarios (see section 2.1).

```
8 "Q check"            A { Q 90 < Q 91 } { }
```
This test is performed on link 82 as cars approach the inspection area in the left lane. Cars choose link 90 or 91, whichever has the shorter queue. This test is modified for the alternate lane use scenarios (see section 2.1).

```
9 "Q check"            A { 3 or ( Q 88 < Q 89 ) } { }
```
This test is performed on link 71 as cars approach the inspection area in the right lane. Cars without transponder choose link 87 or 88, whichever has the shorter queue. Cars with transponders also stay to the right so they can reach the rightmost (DCL) lane. This test is modified for the alternate lane use scenarios (see section 2.1).

```
10 "Q check"           A { 3 } { }
```
This test is performed on link 74 as cars approach the inspection area in the right lane. Cars with transponders stay to the right so they can reach the rightmost (DCL) lane. Other cars take the left branch to link 88. This test is modified for the alternate lane use scenarios (see section 2.1).

```
11 "Auto customs"      A { 11 }  { }
```
This test is performed by every one of the primary inspection links for cars (links 93 through 97). Cars with attribute 9 true (tagged for secondary inspection) must take the alternate branch. However, the model does not yet include a secondary inspection area of cars, so both branches are the same.

```
13 "Secondary inspec"  A { 8 } { }
```
This test sends all trucks that have been tagged for secondary inspection (attribute 8) to the parking lot.

[ServiceTimes]

Service times are specified for scales and branches as probability distributions. Different distributions may be specified for different Boolean combinations of vehicle classes. The types of possible distributions are Normal, Uniform, Erlang, or Constant.

```
# name          expression  random type parms
# ----          ----------  ----------- -----
```

1 "primary truck inspection" { 9 } Erlang 72 { 10 } Erlang 72 { 4 } Erlang 36 { 5 } Erlang 24 { 6 } Erlang 36 { 7 } Uniform 15 35 { } Erlang 85

The recorded service for NATAP trucks was not usable since it exceeded the service time for other types of trucks (the NATAP trucks were required to undergo both electronic and paper screening). Because of the dual processing and the fact that the communications line shut down whenever a long period passed between NATAP trucks, no data were collected for the average service time for pure electronic processing. Therefore Mitretek used as the service time for NATAP trucks the distribution derived by a team of researchers from Cornell University and Rensselaer Polytechnic Institute for trucks crossing the Peace Bridge between Buffalo, New York and Port Huron, Ontario[3]. This distribution is a uniform distribution between 15 and 35 seconds.

The average primary inspection times for each other type of truck were estimated by Mitretek given a set of arrival rate and queue length data collected at the bridge by the consulting firm of Reid, Cool, and Michalsky[2]. Mitretek derived the service times such that the weighted average service time across all trucks (32.4 seconds) yielded moderate length queues when the truck arrival rate and number of lanes in service were as recorded every fifteen minutes in the Reid, Cool & Michalsky study. The weighted average service time is on the same order as the time recorded by the Cornell/Rensselaer team for trucks crossing the Peace Bridge. This average time (when added to the average time between trucks of 15 seconds), yields a total average service time of 57.4, for an average throughput of 62.7 trucks per hour per lane. This number falls within the range of 60-65 trucks per hour per lane reported by Booz-Allen.

These inspection times do not include the time required for a truck to pull away from the booth at the end of inspection and for the next truck to pull into place. This time is not input to the model, but is a realized outcome of reaction time and vehicle dynamics. The average value between trucks realized in the model is 15 seconds, which is close to the value of 17 seconds recorded by the Cornell/ Rensselaer study.

The average service times provided by the Ambassador Bridge Authority were not consistent with observed arrival rates and queue formation, so they were not used. However, Mitretek used these service times as a pattern for differentiating the service times for the various types of trucks. The inspection times for double loads are double the times for corresponding single load trucks.

2 "primary car inspection" { 11 } Constant 6.0 { 3 } Constant 3.0 { 1 } Erlang 17.3

The average primary inspection time for cars was measured by the Cornell/Rensselaer team for cars at the Peace Bridge. Subtracting the average time required in the model for one car to pull away from the booth and the next car to pull up leaves the average time of 17.3 seconds. Cars with transponders are required to stop and swipe a participation card through a card reader at the inspection booth. Booz-Allen estimated this time as three seconds. 3 out of 5 times, however, a second swipe was needed because of a bad read or because a person with short arms or a small car wasn't able to reach the reader adequately. The stopped time for this set of cars was doubled to six seconds.

3 "consult brokers" { 6 } Erlang 1520 { } Constant 10

The average time for a truck to remain parked while the driver consulted a customs broker was recorded by the Cornell/Rensselaer team. The second half of the specification allows trucks that are merely passing through the parking lot after going through secondary inspection not to be delayed in the parking lot.

4 "secondary truck inspection" { } Erlang 2220

The average time spent by trucks at secondary inspection was recorded the Cornell/Rensselaer team.

`[LinkInfo]`
This section specifies information for each link in the simulation. The first column is the link number. The second column gives the type of link. The third and fourth columns specify the first and second links following the given link. Two exit links are specified only if the link is a branch or scale; otherwise there is a dash (-). The fifth column specifies the free speed limit in miles per hour. The sixth and seventh columns specify the x and y coordinates (in feet) of the start of the link and the eighth and ninth columns specify the x and y coordinates of the end of link.

The remaining fields are optional, depend on the type of link, and may be specified in any order. A "T" precedes the test number for a branch link. An "ST" precedes the service time number for a branch or scale link. A "Y" indicates that traffic on that link must yield when merging with traffic from another link. A "CC" precedes the coordinates of the center of curvature for a curved link. A "PS" precedes the number of parking spaces for a parking lot, and an "OC" precedes the x and y coordinates of the opposite corner of a parking lot. An "A" indicates the proportion of arrivals to appear on each origin link. An "LL" indicates the link number of the left-hand lane for lane-changing purposes, while an "RL" indicates the link number of the right-hand lane.

Notes on individual links follow the listing. Figure 2-2 provides an overview of the customs facility as modeled in Westa. Figures 2-3 through 2-6 show close-ups of the four corners, showing link numbers.

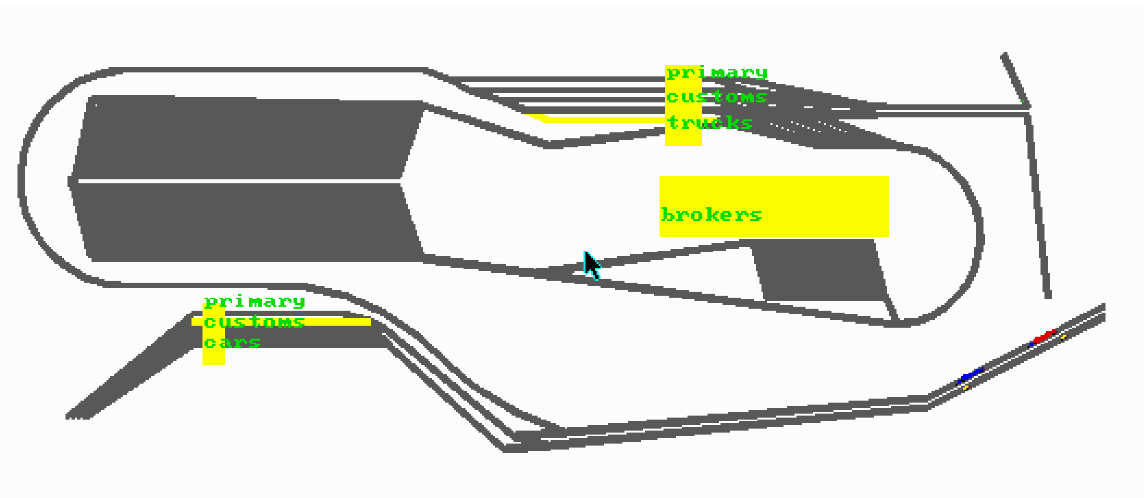

Figure 2-2. Overview of Ambassador Bridge Customs Inspection Area

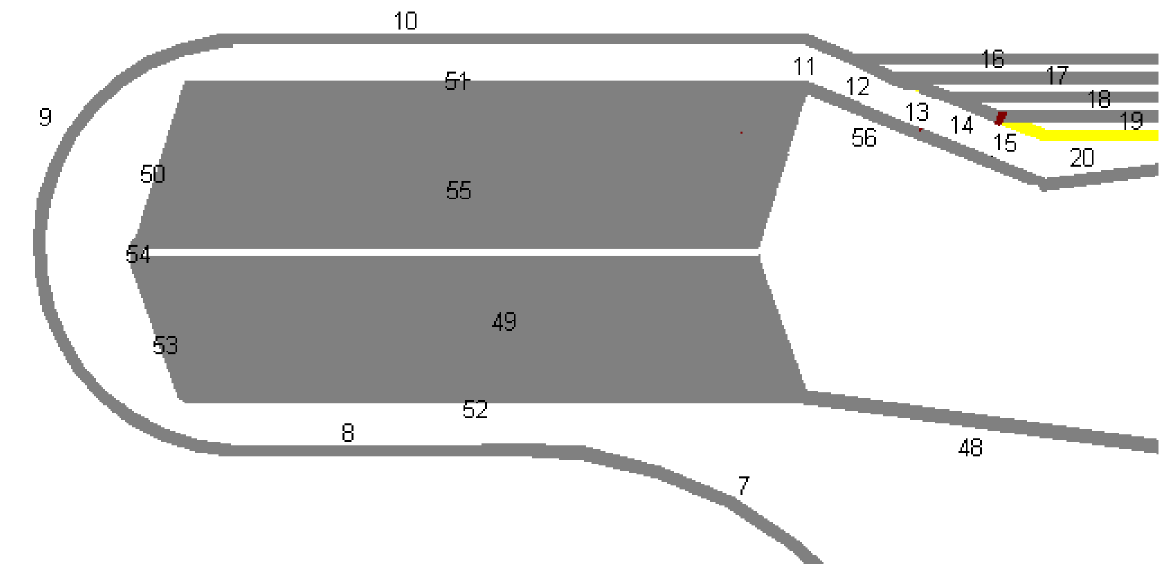

Figure 2-3. Northwest Corner of Ambassador Bridge
Customs Inspection Area

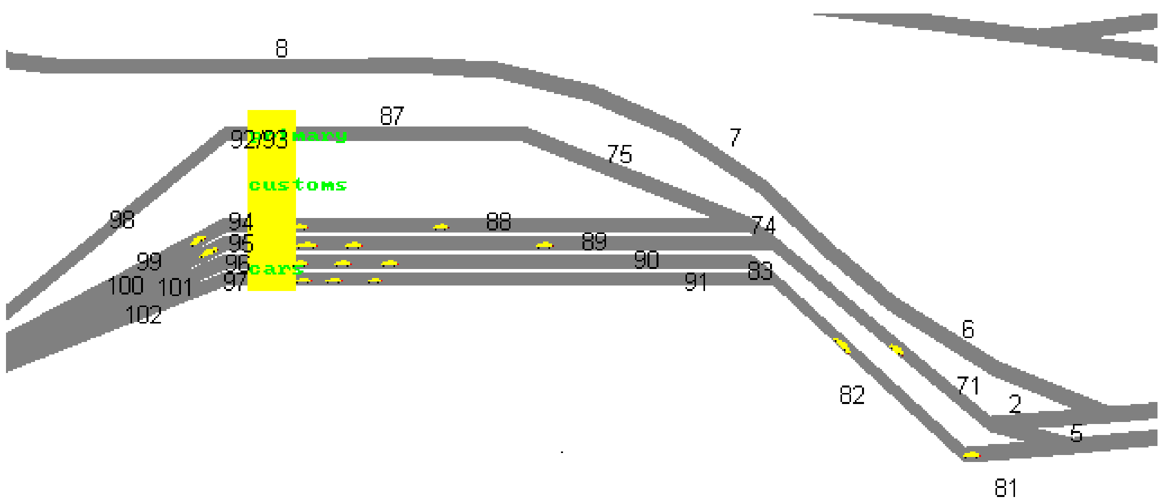

Figure 2-4. Southwest Corner of Ambassador Bridge
Customs Inspection Area

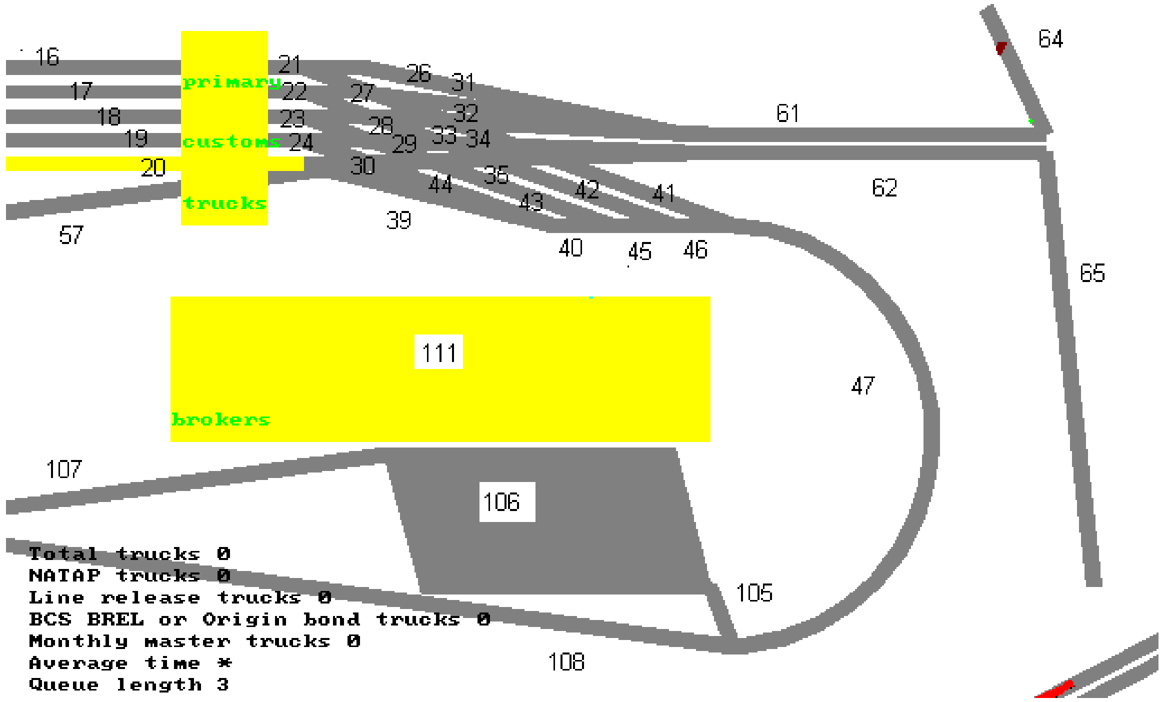

Figure 2-5. Northeast Corner of Ambassador Bridge
Customs Inspection Area

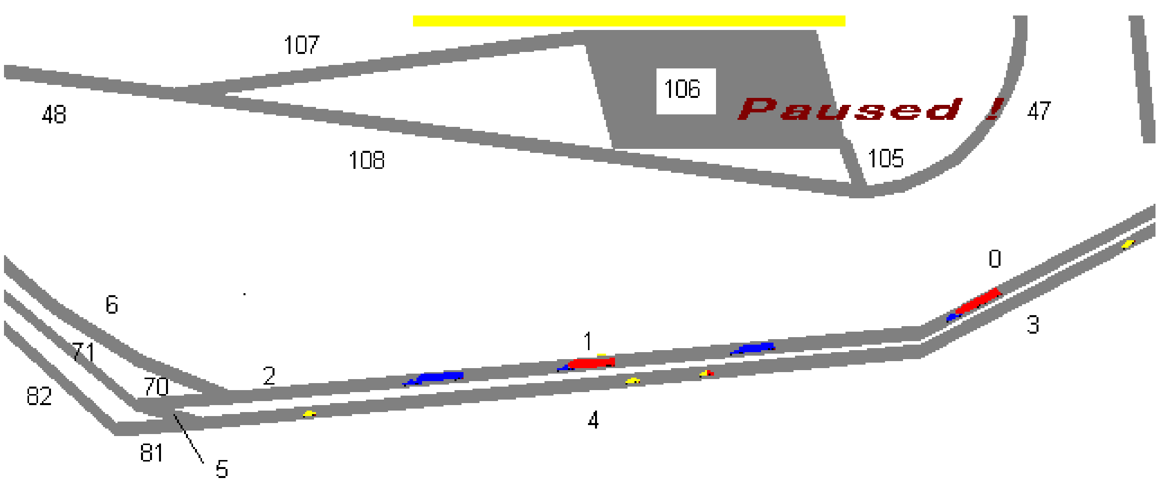

Figure 2-6. Southeast Corner of Ambassador Bridge
Customs Inspection Area

```
#  type        ahead    spd     dimensions          typespecific
#  ----        -- --    ---     ----------          ------------
0  Orig        1   -     30    2150  385 1800  205    A .4 "Right_lane"
1  Branch      2   6     30    1800  205 1080  138    Q LL 4 T 1 C 0.5 O 0.1 SC
2  Trans       71  -     20    1080  138  980  130    T 1
3  Orig        4   -     30    2150  366 1800  186    A .6
4  Branch      81  5     30    1800  186 1050  112    T 7
5  Trans       71  -     30    1050  112  980  130    Y
6  Trans       7   -     20    1080  138  850  270    Q CC 1250 700
7  Trans       8   -     20     850  270  460  425    Q CC  501 -40
8  Trans       9   -     20     460  425  200  425    Q
9  Trans       10  -     15     200  425  200  850    Q CC 210 637
10 Trans       11  -     15     200  850  800  850    Q
11 Branch      12 16     10     800  850  850  830    Q T 2
12 Branch      13 17     10     850  830  890  810    Q T 3
13 Branch      14 18     10     890  810  950  790    Q T 4
14 Branch      15 19     10     950  790 1000  770    Q T 5
15 Trans       20  -     10    1000  770 1050  750    Q CL 7 O 1.0 C .1
16 Trans       21  -     10     850  830 1330  830    Q"To_Bay_1"
17 Trans       22  -     10     890  810 1330  810    Q "To_Bay_2"
18 Trans       23  -     10     950  790 1330  790    Q "To_Bay_3"
19 Trans       24  -     10    1000  770 1330  770    Q
20 Trans       25  -     10    1050  750 1330  750    Q CL 7 O 1.0 C .1
21 Branch      26 41     10    1330  830 1380  830  ST 1  T 6
22 Branch      27 42     10    1330  810 1380  810  ST 1  T 6
23 Branch      28 43     10    1330  790 1380  790  ST 1  T 6
24 Branch      29 44     10    1330  770 1380  770  ST 1  T 6
25 Branch      30 39     10    1330  750 1380  750  ST 1  T 6 CL 7 O 1.0 C .1
26 Trans       31  -     15    1380  830 1430  830  "Pass_Booth_1"
27 Trans       32  -     15    1380  810 1430  810  "Pass_Booth_2"
28 Trans       33  -     15    1380  790 1430  790  "Pass_Booth_3"
29 Trans       34  -     15    1380  770 1430  770  "Pass_Booth_4"
30 Trans       35  -     15    1380  750 1430  750  "Pass_Booth_5"
31 Trans       60  -     30    1430  830 1700  775
32 Trans       60  -     30    1430  810 1700  775  Y
33 Trans       61  -     30    1430  790 1720  775
34 Trans       62  -     20    1430  770 1700  760
35 Trans       62  -     15    1430  750 1700  760  Y
39 Trans       40  -     20    1380  750 1590  700 "Fail_Booth_5"
40 Trans       45  -     20    1590  700 1640  700  Y
41 Trans       47  -     20    1380  830 1740  700 "Fail_Booth_1" Y
42 Trans       46  -     20    1380  810 1690  700 "Fail_Booth_2" Y
43 Trans       45  -     20    1380  790 1640  700 "Fail_Booth_3"
44 Trans       40  -     20    1380  770 1590  700 "Fail_Booth_4" Y
45 Trans       46  -     30    1640  700 1690  700
46 Trans       47  -     30    1690  700 1740  700
47 Branch     108  105   20    1740  700 1740  350  CC 1730 525  T 13
48 Branch      52  49    20    1020  450  800  480  T 1
49 Park        50  50    15     800  480  100  620  T 1 ST 3 OC 750 620  PS 30 NQ
50 Trans       51  -     15     100  620  140  795
51 Trans       56  -     20     140  795  800  780  Y
52 Trans       53  -     15     800  480  140  480
53 Trans       54  -     15     140  480  100  620
54 Trans       55  -     15     100  620  100  640
55 Park        56  56    15     100  640  800  780  ST 3 T 5 OC 150 780  PS 30 NQ
56 Trans       57  -     20     800  780 1050  700
57 Trans       35  -     20    1050  700 1430  750
60 Trans       61  -     20    1700  775 1720  775
61 Trans       64  -     40    1720  775 2000  775 FS 80 40 1
62 Trans       65  -     40    1700  760 2000  760 FS 80 40 1
64 Dest        -   -     10    2000  775 1950  880
```

```
65 Dest         -   -    10    2000  760 2040  400
71 Branch      89  74    25     980  130  800  280 Q T 9
74 Branch      88  75    20     800  280  780  295 Q T 10
75 Trans       87  -     20     780  295  590  370 Q
81 Trans       82  -     25    1050  112  960  105 Q
82 Branch      91  83    20     960  105  800  250 Q T 8
83 Trans       90   -    20     800  250  780  265 Q
87 Trans       93   -    15     590  370  400  370 Q
88 Trans       94   -    15     780  295  400  295 Q
89 Trans       95   -    15     800  280  400  280 Q
90 Trans       96   -    15     780  265  400  265 Q
91 Trans       97   -    15     800  250  400  250 Q
93 Branch      98  98    20     400  370  340  370   T 11 ST 2
94 Branch      99  99    20     400  295  340  295   T 11 ST 2
95 Branch     100 100    20     400  280  340  280   T 11 ST 2
96 Branch     101 101    20     400  265  340  265   T 11 ST 2
97 Branch     102 102    20     400  250  340  250   T 11 ST 2
98 Dest         -   -    20     340  370   90  170
99 Dest         -   -    20     340  295  100  170
100 Dest         -   -   20     340  280  110  170
101 Dest         -   -   20     340  265  120  170
102 Dest         -   -   20     340  250  130  170
105 Trans      106  -    15     1740 350  1720 400
106 Park       107 107   15     1720 400  1450 510  T 1 ST 4 OC 1690 510 PS 8
107 Trans       48  -    20     1450 510  1020 450  Y
108 Trans       48  -    20     1740 350  1020 450
111 Bldg        -   -      0    1270  520 1720  640  "brokers"
112 Bldg        -   -      0    1280  700 1350  750  "trucks"
113 Bldg        -   -      0    1280  750 1350  800  "customs"
114 Bldg        -   -      0    1280  800 1350  860  "primary"
115 Bldg        -   -      0     360  270  400  390  "cars"
116 Bldg        -   -      0     360  310  400  350  "customs"
117 Bldg        -   -      0     360  350  400  390  "primary"
 [End]
```

Links 3, 4, and 81 are the left lane of the bridge. Link 3 is an origin link, delivering 60 percent of the vehicles. Only cars may originate on this link. Link 4 is a long transit link. Cars in the left lane may not switch lanes until beyond the point where the trucks turn off. At that point cars may take link 5 to the right lane if the rightmost inspection lanes have shorter queues than the leftmost lanes, or if they have transponders.

Links 0, 1, and 2 are the right lane of the bridge. Link 0 is an origin link, delivering 40 percent of the vehicles. All the trucks originate on this link, and some of the cars. Link 1 is a long transit link. Cars on link 1 may switch lanes to link 4 if there is a sufficient gap in the left lane. All trucks on link 1 must exit to link 6, while cars go on to link 2. Cars shifting to the right lane on link 5 yield to cars on link 2.

Trucks approaching primary inspection follow links 6, 7, 8, 9, and 10 around the parking lot. Although these links are wide enough for two trucks side-by-side, trucks seldom double up, and the links are modeled as one lane only.

Section 2.1 describes how the rules for how trucks may select primary inspection lanes were modified to create different scenarios. The number of lanes was varied between three and five, and the service policy for each lane was varied among three options. A lane could operate as dedicated to NATAP trucks only, as dedicated to non-NATAP trucks only, or as being available to either type (mixed use).

When trucks approach the primary inspection area, they have the choice of three or four or five inspection lanes, depending on the scenario. For the four-lane scenarios, the rightmost lane (link 20) is closed, so it is not an option. For the three-lane scenarios, the rightmost two lanes (links 20 and 19) are closed so they are not options. Trucks with NATAP transponders take the lane dedicated to NATAP trucks (usually the leftmost lane(s)) or open to any trucks that has the shortest queue. All other trucks look for the available lane (not dedicated to NATAP) with the shortest queue. At each branch (links 11, 12, 13, and 14), a truck will take the left branch leading to a booth if the queue for that booth is shorter than the queue for any of the remaining booths. Otherwise the trucks branches to the right looking for a shorter queue. Links 16 through 20 hold the queues for the customs booths, and links 21 through 25 represent the booths themselves.

Customs booths 21 through 25 apply test 6, checking whether the truck is a BCS/Brel/Bond truck requiring a stop at the customs brokers, and whether the truck should be sent to secondary inspection. The average service time required for each type of truck is specified in service time 1. Double loads require twice the inspection time. The primary inspection times are not constant; they are drawn from probability distributions with the specified averages.

Links 26 through 30 are the left branches leading from the customs booths. They lead toward the exit, continuing on links 31 through 35 to links 60, 61, and 62. There is a fixed signal at the end of links 61 and 62 representing the actual traffic signal on Fort Street. Trucks on link 62 turn right and trucks on link 61 turn left; the model ignores lane maneuvering at this stage. Because of the stop lights, it is possible for traffic to back up to the inspection booths so that trucks cannot proceed. Links 64 and 65 are destination links; when a truck goes one block on Fort Street it leaves the simulation.

Links 39 and 41 through 44 are the right branches leading from the customs booths toward the parking and secondary inspection areas. Although these links cross links 26 through 35, explicit intersections are not modeled, since trucks are moving at slow speeds and low volume. Apparent collisions in the model are not actual collisions.

Links 40 and 45 through 47 lead toward the parking lot. Link 47 is a branch link, using test 13 to direct trucks with attribute 8 to the secondary inspection area. The secondary inspection is parking lot link 106. The average inspection time for trucks is defined by service time 4. The inspection time does not begin for a truck until all trucks that arrived previously have completed inspection. The test performed by the parking lot is irrelevant because all trucks leave the same way and none are placed out of service. Trucks completing inspection leave the parking lot on link 107.

Links 49 and 55 are both parking lots with 30 parking spaces. Link 48 approaching the lots is a branch link. If lot 49 is full, trucks will take the other link exiting link 48, namely link 52. Links 52, 53, and 54 lead around the edge of lot 49 to enter lot 55. Trucks entering either lot will park in the empty space closest to the far end of the lot, and will begin waiting the appropriate time independent of other trucks in the lot. Trucks leaving lot 49 takes links 50 and 51 around the edge of lot 55. All trucks leaving the parking lot take links 56 and 57 to join the other trucks passing primary inspection.

Cars may enter the simulation on origin link 0 (the right lane) or origin link 3 (the left lane). Most cars are in the left lane because of the volume of trucks in the right lane. Cars on link 1 (the right lane) may shift to link 4 (the parallel left lane) if there is an adequate gap, or may proceed to link 2 and link 71. Cars with transponders must take the rightmost inspection lane (link 87) while other cars on link 71 choose between link 88 and 89, whichever has the shorter queue.

Cars in the left lane (link 4) may switch to the right lane via link 5 if the queue for the rightmost lanes (link 71) is shorter than the queue for the leftmost lanes (link 82). Cars with transponder must also shift to the right at this time. Cars on link 82 choose between link 90 and 91, whichever has the shorter queue.

Scenarios with different numbers of car inspection lanes and different lane policies are described in section 2.1. The number of lanes was varied between four and five, and the service policy for each lane was varied among three options. A lane could operate as dedicated to cars with transponders only, as dedicated to cars without transponders only, or as being available to either type (mixed use).

Primary customs booths 93 through 97 apply test 11, checking whether the car should be stopped for secondary inspection. At the primary inspection booths cars without transponders were required to wait an average of 17.3 seconds for primary inspection. Two-fifths of the cars with transponders had to stop for three seconds, and the other three-fifths had to stop for six seconds. These average service times are explained in the discussion of service time 2.

Secondary inspection is currently not modeled for cars, since cars in secondary inspection do not affect the queues of cars for primary inspection. Therefore both exit links for the primary customs booths are the same, namely destination links 98 through 102.

Links 112 through 117 are not links at all, but represent the customs booths. Link 111 represents the customs brokers building. These rectangles are displayed in yellow with a label.

[GraphInfo]

The following lines define the statistics boxes in the lower left corner of the screen. The first five statistics display the current cumulative count of vehicles with certain attributes. A vehicle does not get counted in these statistics until it leaves the simulation by exiting a destination link. The sixth statistic displays the cumulative average transit time for all trucks that did not spend time in the parking lot or secondary inspection. The last statistic gives the total number of trucks in links defined with a “Q” (i.e. links 6 through 20).

```
[GraphInfo]
Stat "Total trucks" Count 2
Stat "NATAP trucks" Count 7
Stat "Line release trucks" Count 4
Stat "BCS BREL or Origin bond trucks" Count 6
Stat "Monthly master trucks" Count 5
Stat "Average time" Time 12
Stat "Queue length" QueueLen
```

The following lines define four “views”. These are preset coordinates that can be invoked by pressing a single number key during the simulation.

```
View 1  909  2108 -173  726
View 2   94  1053  -83  636
View 3  -26  1173   83  983
View 4  765  1964  256 1155

[End]
```

2.3 Alternate Arrival Rate for Car Scenarios

The base case scenarios described in the previous section were designed to study queues of trucks during the peak arrival times for trucks. Therefore the vehicle arrival rate and the ratio of cars to trucks were selected to represent the mid-day peak for truck traffic. When studying the backups for cars, Mitretek used the arrival rate and ratio of cars to trucks appropriate for the morning rush hour, the peak period for car traffic.

The total vehicle arrival rate turned out to be the same for both sets of scenarios (1000 vehicles per hour). However, during the morning rush hour the proportion of cars was 80%. That is, the peak arrival rate for cars during the peak period was 800 cars per hour. This figure is consistent with hourly traffic counts provided by the Ambassador Bridge Authority and the study performed by Reid, Cool, and Michalsky. Since these studies focussed on cars, the breakdown of trucks into FHWA classes or among the NATAP/Brel/line release/monthly master categories was not important. The proportion of vehicle types on each origin link was modeled by the following lines in the input file:

```
ClassDistribution 2 origins
Link   c1   c2   c3   c4   c5   c6   c7   c8   c9  c10  c11  c12  c13
0       0   50    0    0    5    0    0    5   30    5    0    5    0
3       0  100    0    0    0    0    0    0    0    0    0    0    0
```

Section 3
Results: Primary Truck Inspection Operations

Mitretek ran four iterations for each scenario considered using a different random seed for each iteration. Section 2.1 presents the notation used to indicate the number of lanes and lane usage policy for each configuration. After a 30-minute run-in period from an empty facility condition, statistics were collected for a one-hour period on the following performance measures:

1. Percent of Peak Hour With Trucks Blocking Gore

   Westa is configured to track the amount of time that the queue of trucks waiting for primary inspection stretches back onto the bridge span just beyond the gore. The gore is the point where truck and car traffic are directed to their respective primary inspection sites. When the density of trucks reaches a level high enough to impede traffic flow beyond the gore, Westa internally tracks the duration of this condition. The condition is lifted if the density of trucks drops sufficiently to allow unimpeded movement of vehicles across the right lane of the bridge span. This statistic is only collected over the one-hour period following the 30-minute run-in period.

2. Number of Queued Trucks Waiting for Primary Inspection

   At the conclusion of the one-hour data collection period, the total number of trucks waiting for primary inspection is tallied. WESTA does not track vehicles which cannot enter the first link of the bridge span, and so queues which extend significantly beyond the gore and across the bridge span are not included in this statistic. Up to a maximum queue length of roughly 40 trucks can be reliably measured by WESTA. When discriminating between two highly congested scenarios, the percent of peak hour with trucks blocking gore is a more revealing performance measure.

3. Minutes of Time Savings, NATAP Participants vs. Line Release Trucks

   The performance of NATAP and Line Release trucks are monitored throughout the one-hour data collection period. The total time in the simulation is recorded for each truck. This includes time to reach the end of the queue, time waiting in queue, time undergoing primary inspection, time in secondary inspection or the broker parking lot (if any) and time to exit the facility. The computed measure compares the average time for NATAP trucks to the average time for Line Release trucks. Trucks that waited in the broker parking lot or for secondary inspection were excluded from the calculation since these longer times are not solely associated with primary inspection operations. Providing NATAP participants with time savings over non-participants is an incentive to continued growth in NATAP participation. Note that the comparison is made here relative to the two types of trucks under the same conditions – time savings is not expressed as a change from current conditions.

4. Average Time Savings as a Function of NATAP Percentage

   The average times in the simulation for NATAP trucks and for line release trucks were plotted as a function of the percentage of NATAP trucks. This analysis estimated the potential benefit to all trucks resulting from increased levels of NATAP participation. Trucks that waited in the broker parking lot or for secondary inspection were excluded from the calculation since these longer times are not solely associated with primary inspection operations.

3.1 Four-Lane Configurations

<u>Summary</u>: Under the current configuration (mnnn) and level of NATAP participation (1%), the simulation indicates that the gore is blocked 80% of the peak hour with 39 trucks waiting for primary inspection. Overall, the impact of increasing NATAP participation is the reduction of both gore blocking time and queue length. For example, under the current configuration, the percent of time the gore is blocked is cut to 58% with a 50% NATAP participation rate. Gore blocking is essentially eliminated when high levels of participation (75%) are combined a configuration of four mixed-use lanes. Queue lengths of 18 vehicles are expected in this case.

<u>Gore Blocking</u>: Table 3-1 presents the results for gore blocking under 4-lane configuration scenarios. At the 1% NATAP participation rate, combinations of mixed-use and non-NATAP have the best performance. The addition of a dedicated lane results in gore blocking of nearly 100% in all cases with only 1% NATAP participation. Dedicated lanes have a negative impact on gore blocking time with respect to mixed-use lanes until a 50% participation rate is reached. At high participation rates, the gore blocking issue is largely resolved. At these levels, however, care must be taken to reserve more than one lane for non-NATAP trucks. For example, at the 75% participation level, both the "dddn" and "dddm" configurations have high gore blocking percentages. This is because one conventional lane cannot serve 25% of the arrival stream even though three NATAP-capable lanes can serve 75% of the arrival stream.

	Percent NATAP Participation				
Configurations	1	10	25	50	75
mnnn	81%	68%	58%	100%	
dnnn	99%	91%	78%	100%	
mmnn	79%	69%	61%	40%	94%
dmnn	99%	93%	85%	41%	94%
ddnn			100%	71%	94%
mmmn	80%	78%	52%	47%	27%
dmmn	99%	92%	78%	28%	5%
ddmn			100%	75%	15%
dddn				100%	91%
mmmm		70%	54%	34%	1%
dmmm		92%	87%	45%	1%
ddmm				75%	1%
dddm					74%

Table 3-1. Percent Time Gore Blocked By Queued Trucks, 4-Lane Configurations

Figure 3-1 illustrates the impact of increasing NATAP participation on gore blocking time for 4-lane configurations. Configurations with combinations of mixed-use lanes and non-NATAP lanes are color-coded using blue lines and symbols. Configurations with combinations of dedicated NATAP lanes and non-NATAP lanes are color-coded using red lines and symbols. Configurations with both dedicated and mixed-use lanes are color-coded using green lines and symbols. The first observation is that configurations with no dedicated lanes (blue) are the most effective configurations at low participation rates and are competitive at higher participation rates. At the higher participation rates, configurations with dedicated lanes and mixed lanes can be competitive with all-mixed configurations.

A second observation is that if configurations minimizing gore blocking are selected at each participation level, the percentage of time the gore is blocked drops by 10% for each 10% increase in participation. Note that configurations comprised solely of dedicated lanes and non-NATAP lanes are never minimizing configurations at any participation rate.

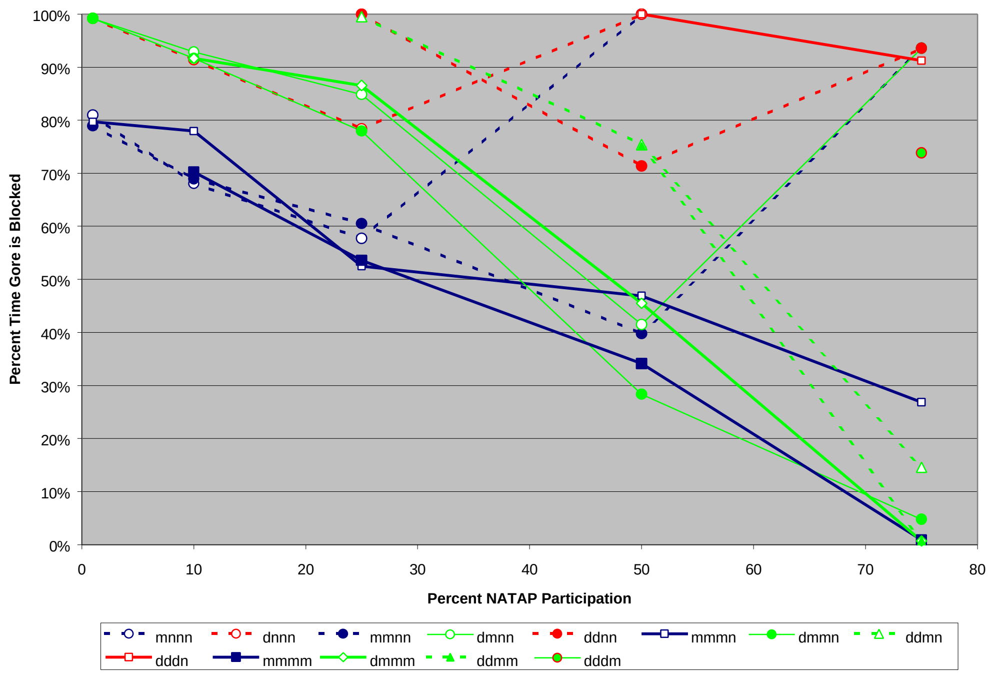

Figure 3-1. Impact of NATAP Participation on Gore Blocking, 4-Lane Configurations

Queue Length: Table 3-2 presents the results for truck queue length under 4-lane configuration scenarios. Note that queue length counts trucks in all lanes waiting for inspection, but not those currently being served (undergoing primary inspection). The results have similar implications to those found with respect to the gore blocking performance measure. At the 1% NATAP participation rate, combinations of mixed-use and non-NATAP have the best performance. At higher rates of participation, three or more mixed-use lane configurations have the best performance. Given the difficulty in measuring queue lengths greater than 40 vehicles, comparing performance of this measure beyond 35 trucks is less meaningful than comparisons made between scenarios where queue length is 30 trucks or fewer. If configurations minimizing queue length are selected at each participation level, the expected queue length drops 2.8 trucks for each 10% increase in participation.

Configurations	Percent NATAP Participation: 1	10	25	50	75
mnnn	38.6	36.3	33.2	36.8	
dnnn	47.0	44.4	38.5	36.8	
mmnn	38.0	37.3	34.5	30.0	37.2
dmnn	47.0	44.8	39.3	29.0	37.2
ddnn			44.2	35.3	37.2
mmmn	38.6	38.7	33.9	30.1	27.3
dmmn	47.0	44.8	38.9	30.0	26.5
ddmn			44.7	35.6	26.6
dddn				43.3	39.4
mmmm		37.5	35.2	28.2	17.7
dmmm		44.8	40.1	31.2	17.7
ddmm				35.3	18.9
dddm					35.6

Table 3-2. Queued Trucks at End of Data Collection Period, 4-Lane Configurations

Time Savings, NATAP Participants vs. Line Release Trucks: In general, the mixed use lanes are minimizing configurations for the two system performance measures (gore blocking and queue length). However, configurations without dedicated lanes are likely to provide only small time savings for NATAP participants relative to Line Release trucks. Only the use of configurations with dedicated lanes result in substantial differentials in processing time. Travel time savings for NATAP participants in each scenario are presented in Table 3-3. Although large travel time savings for NATAP participants are indicated at low participation rates, these results are unreliable because so few NATAP trucks are available to track. At higher participation rates, where dedicated lanes can be introduced without major disruption to overall system performance, travel time savings relative to Line Release trucks are roughly 2 minutes at 50% participation (e.g., “dmmn”) and less than a minute at 75% participation (e.g., “ddmm”). The maximum travel time savings for NATAP participants (10% or greater participation rate) is between 4 and 5 minutes if configurations are chosen without regard to impact on system performance (e.g., “ddnn”).

NATAP trucks may perform worse than non-NATAP trucks at higher participation rates if too few lanes are provided for their use. For example, at 50% market penetration, NATAP trucks must wait 2.7-2.8 minutes longer than non-NATAP trucks when only one mixed use or dedicated lane is available (“mnnn” and “dnnn”).

Time in System: Overall, the impact of increased NATAP participation is the reduction of time-in-system for both line release and NATAP trucks. For an all-mixed lane configuration, the average time-in-system for NATAP trucks dropped from 12.6 minutes at the 10% participation level to 6.0 minutes at the 75% participation level. The impact on average line release truck time-in-system is similar; 12.8 minutes at the 10% participation level drops to 6.8 minutes at the 75% participation level. The average time in system for the base case (1% participation, “mnnn” configuration) is 13.6 minutes for line release trucks. The impact of increasing NATAP participation on time-in-system for both line release and NATAP trucks is summarized in Figure 3-2. The time-in-system is reduced by roughly 1 minute for each additional 10% growth in NATAP participation.

Configurations	Percent NATAP Participation				
	1	10	25	50	75
mnnn	3.1	0.2	0.4	-2.8	
dnnn	8.4	3.6	2.8	-2.7	
mmnn	3.1	0.1	0.8	0.7	-1.7
dmnn	8.4	3.9	2.9	1.3	-1.7
ddnn			3.9	3.0	-1.7
mmmn	4.0	-0.2	0.7	1.0	-0.7
dmmn	8.4	3.6	2.9	1.9	-1.1
ddmn			4.2	3.7	-1.4
dddn				4.9	2.9
mmmm		-0.3	0.5	0.7	0.8
dmmm		3.6	3.0	1.7	0.3
ddmm				3.5	0.6
dddm					3.3

Table 3-3. Time Savings (minutes) for NATAP Participants vs. Line Release, 4-Lane Configurations

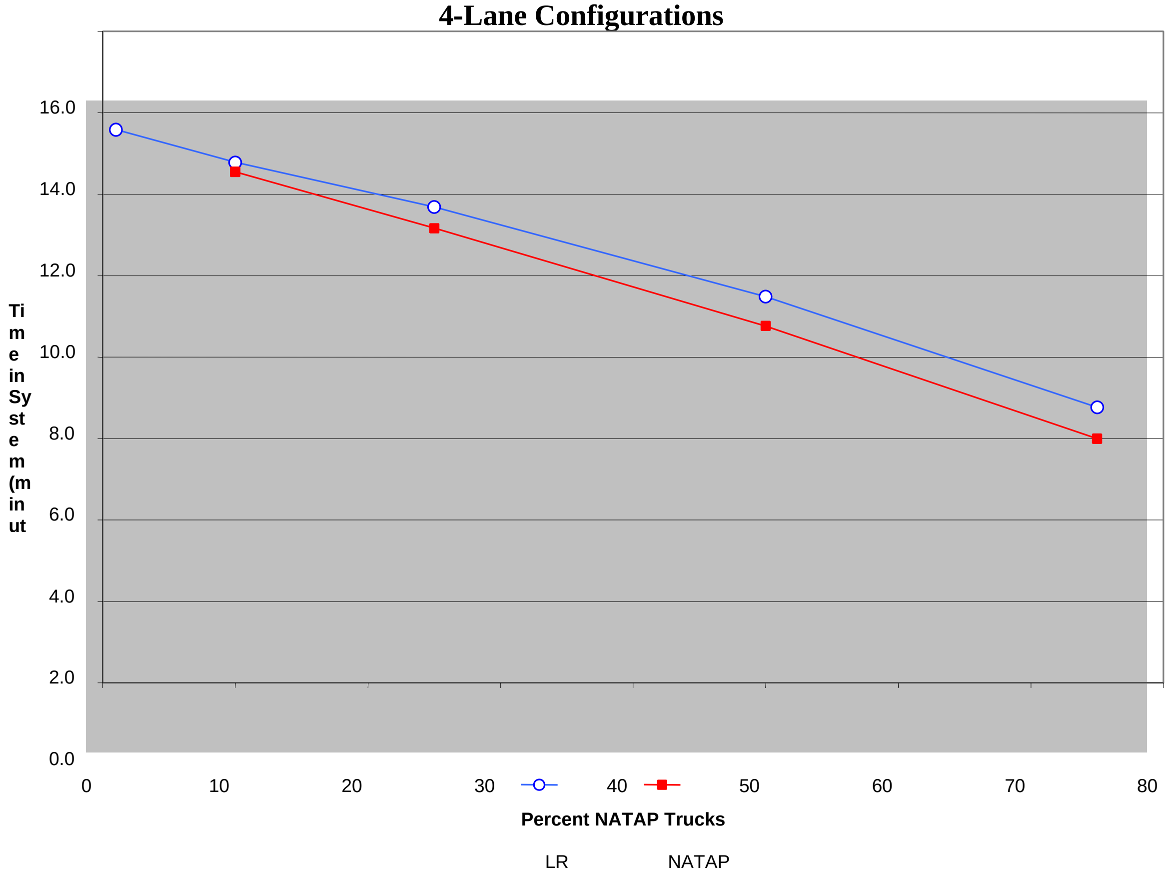

Figure 3-2. Average Time in System by Level of NATAP Participation, 4-Lane "mnnn" or "mmmm" Configurations

3.2 Five-Lane Configurations

Summary: The impact of NATAP technologies under five-lane configurations are less dramatic than under four-lane configurations. With five lanes operating, the issues of gore blocking and the potential for uncontrolled queue growth are less significant. In the current condition case (mnnnn configuration and 1% participation), the gore is blocked only 4% of the peak period and the number of trucks waiting is 24. Increasing NATAP participation eliminates the small chance of gore blocking and reduces the number of trucks queued for primary inspection. At the highest levels of NATAP participation tested (75%) and a configuration of five mixed-use lanes, the number of trucks waiting at the end of the hour is reduced to 14.

<u>Gore Blocking</u>: Table 3-4 presents the results for gore blocking under 5-lane configuration scenarios. At the 1% NATAP participation rate, combinations of mixed-use and non-NATAP have the best performance. The addition of a dedicated lane results in increased gore blocking in all configurations with only 1% NATAP participation. Dedicated lanes have a negative impact on gore blocking time when compared to mixed-use lanes until a 25% participation rate is reached.

		Percent NATAP Participation				
		1	10	25	50	75
Configurations	mnnnn	4%	3%	20%	100%	100%
	mmnnn	39%	5%	18%	1%	95%
	mmmnn	21%	18%	1%	2%	1%
	mmmmn	3%	6%	2%	1%	0%
	mmmmm	13%	3%	2%	0%	0%
	dnnnn	76%	56%	3%	100%	100%
	ddnnn	99%	92%	80%	0%	95%
	dddnn	100%	100%	100%	74%	0%
	ddddn	100%	100%	100%	100%	75%
	dmmnn	76%	62%	2%	0%	8%
	dmmmn	76%	63%	5%	1%	0%
	dmmmm	76%	63%	2%	5%	0%
	ddmnn	99%	92%	79%	3%	1%
	ddmmn	99%	92%	79%	1%	1%
	ddmmm	99%	92%	80%	1%	1%
	dddmn	100%	100%	100%	72%	0%
	dddmm	100%	100%	100%	79%	0%
	ddddm	100%	100%	100%	100%	66%
	dmnnn	76%	59%	3%	0%	95%

Table 3-4. Percent Time Gore is Blocked By Queued Trucks, 5-Lane Configurations

		Percent NATAP Participation				
		1	10	25	50	75
Configurations	mnnnn	23.2	21.6	23.4	36.5	37.6
	mmnnn	28.6	22.4	22.8	16.5	37.3
	mmmnn	27.0	22.9	17.0	14.8	18.1
	mmmmn	25.5	22.5	19.6	15.2	13.9
	mmmmm	26.3	22.7	17.7	14.2	13.9
	dnnnn	40.4	35.1	22.0	36.6	37.6
	ddnnn	45.7	43.0	37.5	17.4	37.3
	dddnn	46.7	45.2	44.6	35.1	17.5
	ddddn	46.6	45.9	45.5	43.4	33.9
	dmmnn	40.4	36.3	21.5	15.1	20.9
	dmmmn	40.4	36.3	21.7	14.8	13.6
	dmmmm	40.4	36.3	23.8	17.5	14.2
	ddmnn	45.7	43.0	38.1	16.8	16.3
	ddmmn	45.7	43.0	38.3	16.9	14.1
	ddmmm	45.7	43.0	37.8	17.9	13.6
	dddmn	46.7	45.5	44.1	33.9	14.8
	dddmm	46.7	45.5	44.1	35.6	14.4
	ddddm	46.6	45.9	45.5	43.9	32.2
	dmnnn	40.4	36.7	24.7	16.6	37.3

Table 3-5. Queued Trucks at End of Data Collection Period, 5-Lane Configurations

Queue Length: Table 3-5 presents the results for truck queue length under 5-lane configuration scenarios. Queue length is a better discriminator between configurations in the five-lane case than gore blocking because of the limited amount of queue growth beyond the scope of the constructed WESTA network. Figure 3-2 illustrates the impact of increasing NATAP participation on queue formation for 5-lane configurations. Configurations with combinations of mixed-use lanes and non-NATAP lanes are color-coded using blue lines and symbols. Configurations with combinations of dedicated NATAP lanes and non-NATAP lanes are color-coded using red lines and symbols. Configurations with both dedicated and mixed-use lanes are color-coded using green lines and symbols.

Here, as in the 4-lane experiments, configurations with no dedicated lanes (blue) are the most effective configurations at low participation rates and are competitive at higher participation rates. At the higher participation rates, configurations with dedicated lanes and mixed lanes can be competitive with all-mixed configurations. The balance point for the inclusion of dedicated lanes appears to be somewhere between 25% and 50% NATAP participation. At 25% participation, the addition of one dedicated lane still has some impact on system queue formation (e.g., 21.7 trucks for a dmmmn configuration versus 17.0 for mmmnn) but by 50% participation, dedicated lanes can be included without impact on system performance.

Examining the configurations that minimize queue length at each participation level, it appears that a second mixed lane should be added between 10-25% participation and a third lane by 25% participation.

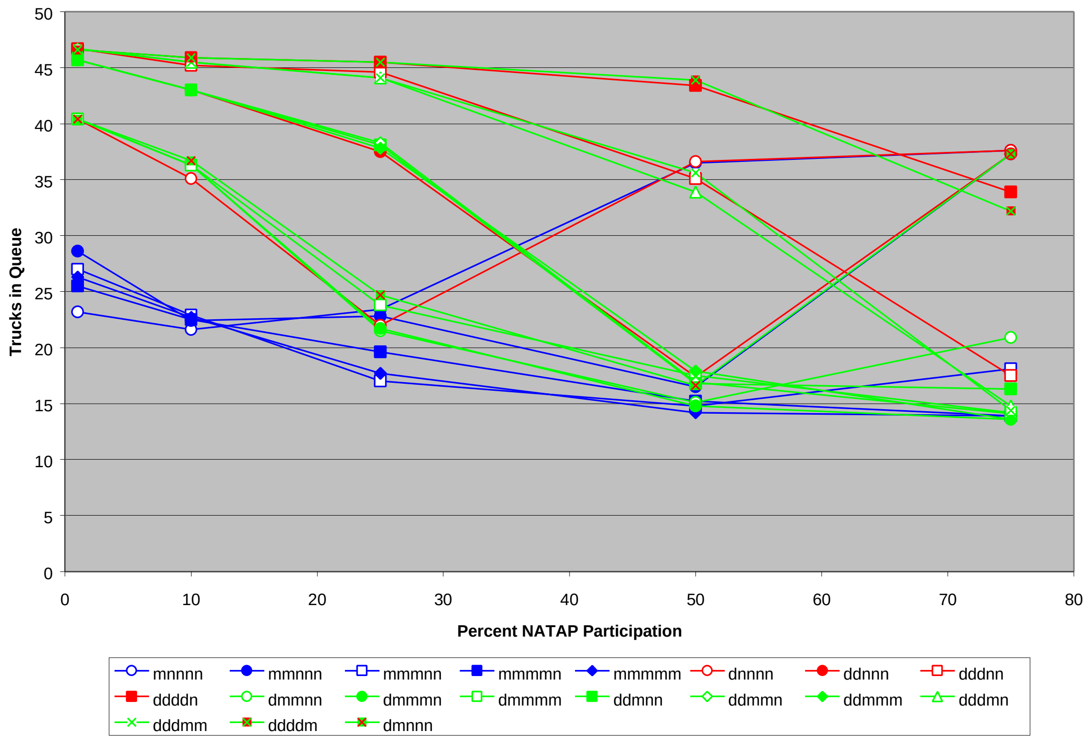

Figure 3-3. Impact of NATAP Participation on Queue Formation, 5-Lane Configurations

Time Savings, NATAP Participants vs. Line Release Trucks: Travel time savings for NATAP participants in each scenario are presented in Table 3-6. Although large travel time savings for NATAP participants are indicated at low participation rates, these results are unreliable because so few NATAP trucks are available to track. At higher participation rates, where dedicated lanes can be introduced without major disruption to overall system performance, travel time savings relative to Line Release trucks are roughly 2 minutes at 50% participation (e.g., "ddmmm") and roughly a minute at 75% participation (e.g., "dddmm"). The maximum travel time savings for NATAP participants (10% or greater participation rate) is just over 4 minutes if configurations are chosen without regard to impact on system performance (e.g., "dddnn" at 10-50% participation).

Time in System: Overall, the impact of increased NATAP participation is the reduction of time-in-system for both line release and NATAP trucks. For an all-mixed lane configuration, the average time-in-system for NATAP trucks dropped from 7.2 minutes at the 10% participation level to 4.6 minutes at the 75% participation level. The impact on average line release truck time-in-system is similar; 7.5 minutes at the 10% participation level drops to 5.3 minutes at the 75% participation level. The impact of increasing NATAP participation on time-in-system for both line release and NATAP trucks is summarized in Figure 3-4. The time-in-system is reduced by roughly 1 minute for each additional 25% growth in NATAP participation.

Configurations	Percent NATAP Participation: 1	10	25	50	75
mnnnn	0.6	0.5	-0.7	-2.7	-2.8
mmnnn	0.6	0.9	0.8	0.1	-2.2
mmmnn	0.9	0.7	0.7	0.6	-1.8
mmmmn	0.2	0.6	0.6	0.5	0.4
mmmmm	0.2	0.3	0.5	0.5	0.8
dnnnn	3.0	2.7	0.5	-2.8	-2.8
ddnnn	6.9	2.9	3.5	0.5	-2.2
dddnn	9.3	4.1	3.3	3.7	-1.9
ddddn	22.1	2.5	4.2	3.8	3.7
dmmnn	3.0	2.9	1.9	0.9	-2.5
dmmmn	3.0	2.9	1.8	0.7	0.9
dmmmm	3.0	2.9	2.3	0.9	0.6
ddmnn	6.9	2.9	3.2	1.5	-1.8
ddmmn	6.9	2.9	3.4	1.7	0.7
ddmmm	6.9	2.9	3.3	1.7	0.6
dddmn	9.3	4.3	3.9	3.4	0.7
dddmm	9.3	4.3	3.9	3.9	1.3
ddddm	22.1	2.5	4.2	4.2	3.2
dmnnn	3.0	2.9	2.4	-0.1	-2.2

Table 3-6. Time Savings (minutes) for NATAP Participants vs. Line Release, 5-Lane Configurations

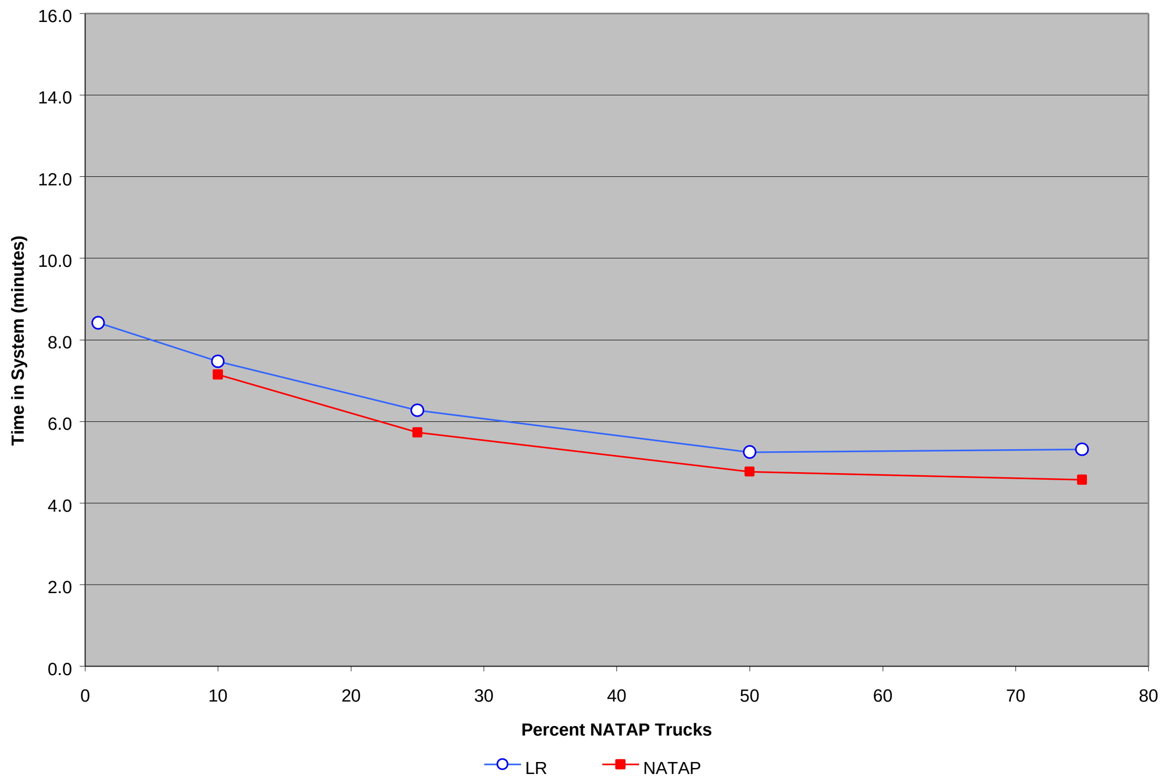

Figure 3-4. Average Time in System by Level of NATAP Participation, 5-Lane "mmmm" Configuration

3.3 Three-Lane Configurations

Summary: Even at the highest levels of NATAP participation, the arrival rate of trucks exceeds the ability of the primary inspection facility to process vehicles. Uncontrolled queue growth and 99% or higher gore blockage were found in a series of tests using 75% NATAP participation and three mixed-use lanes. These results indicate that the NATAP technologies cannot increase efficiency enough at primary truck inspection to allow 3-lane operations during peak truck arrival periods.

Section 4

Results: Primary Car Inspection Operations

Mitretek ran four iterations for each scenario considered using a different random seed for each iteration. Section 2.1 presents the notation used to indicate the number of lanes and lane usage policy for each configuration. Of note here is that dedicated lanes for cars are configured at the drivers' right in the inspection plaza, rather than at the drivers' left as in the truck inspection plaza. Our notation reflects this reversal, so that dedicated and mixed lanes are listed last in the configuration (e.g., "nnnnd" rather than "dnnnn"). Truck arrivals were set to an off-peak rate, while cars arrived at their peak arrival rate (800 cars per hour). After a 60-minute run-in period from an empty facility condition, statistics were collected for a one-hour period on the following performance measures:

1. Percent of Peak Hour With Cars Backed Up Past Gore

   Westa is configured to track the amount of time that queue of cars waiting for primary inspection stretches back onto the bridge span just beyond the gore. The gore is the point where truck and car traffic are directed to their respective primary inspection sites. When the density of cars reaches a level high enough to impede traffic flow beyond the gore, WESTA internally tracks the duration of this condition. The condition is lifted if the density of cars drops sufficiently to allow unimpeded movement of vehicles across the left lane of the bridge span. This statistic is only collected over the one-hour period following the 60-minute run-in period.

2. Number of Queued Cars Waiting for Primary Inspection

   At the conclusion of the one-hour data collection period, the total number of cars waiting for primary inspection is tallied. Westa does not track vehicles which cannot enter the first link of the bridge span, and so queues which extend significantly beyond the gore and across the bridge span are not included in this statistic. Up to a maximum queue size of roughly 50 cars can be reliably measured in the simulation. Note that this counts cars in all lanes, not just in one lane. It does not count cars currently being served (undergoing primary inspection).

3. Minutes of Time Savings, DCL-eligible vs. Non-DCL Vehicles

   The performance of DCL-eligible and non-DCL vehicles are monitored throughout the one-hour data collection period. The total time the car is in the simulation network is recorded for each car. This includes traversing the last leg of the bridge span, waiting time in queue at primary inspection, processing time at primary inspection, and time to exit the network. Providing DCL users with time savings over non-participants is an incentive to continued growth in DCL participation. Note that the comparison is made here relative to the two types of cars under the same conditions – time savings is not expressed as a change from base case conditions.

Summary: Increasing participation in the DCL program results in reduced queue growth and gore blocking from cars backing up at primary inspection. In the base case condition scenario (nnnnd and 5% DCL participation) the simulation indicates that queues of vehicles will backup and block the gore 94% of the time with an expected queue length of 51 vehicles. Raising participation to 25% or higher and switching to mixed lane operations eliminates the gore blocking problem. At the highest levels of participation tested (75%), the average number of cars in queue is reduced to roughly 7 vehicles (fewer than 2 cars waiting per lane). At this level of participation, a four-lane configuration of all mixed-use lanes performs nearly as well as the best-performing 5-lane configuration. The use of dedicated lanes after 50% participation saves DCL users between one and two minutes over non-DCL participants.

<u>Gore Blocking</u>: Table 3-7 presents the results in each scenario with respect to cars backing up past the gore and onto the bridge span. One or more mixed-use lanes and at least 25% DCL participation virtually eliminates the chance of gore blocking.

		Percent Vehicles DCL Eligible			
		5	25	50	75
Configurations	mmmdd	98%	98%	91%	0%
	mmmm	73%	71%	21%	0%
	mmmmm	31%	1%	0%	0%
	nnnnm	29%	1%	66%	81%
	nnnmd	92%	45%	0%	29%
	nnnnd	94%	7%	66%	

Table 4.1 Percent of Time Gore is Blocked With Queued Cars

<u>Queue Length</u>: Table 3.8 presents the results for each scenario with respect to queue length. Queue length is cut by more than half from the base case 51.5 level (nnnnd at 5%) when participation reaches the 25% level. Additional gains in queue length reduction are achieved as participation rates rise to 75% and other configurations are considered. Queues are reduced to fewer than seven vehicles at 75% participation under a "mmmmm" configuration.

Figure 3-3 illustrates the impact of increasing DCL utilization on queue formation. Configurations with combinations of mixed-use lanes and conventional lanes are color-coded using blue lines and symbols. Configurations with combinations of dedicated lanes and conventional lanes are color-coded using red lines and symbols. Configurations with both dedicated and mixed-use lanes are color-coded using green lines and symbols.

		Percent Vehicles DCL Eligible			
		5	25	50	75
Configurations	mmmdd	45.0	44.0	40.3	7.6
	mmmm	36.1	32.9	21.5	8.9
	mmmmm	39.0	14.3	8.5	6.9
	nnnnm	38.5	14.7	33.3	108.5
	nnnmd	44.2	36.9	8.6	15.6
	nnnnd	51.5	24.1	33.3	

Table 4.2 Number of Cars in Queue at Primary Inspection

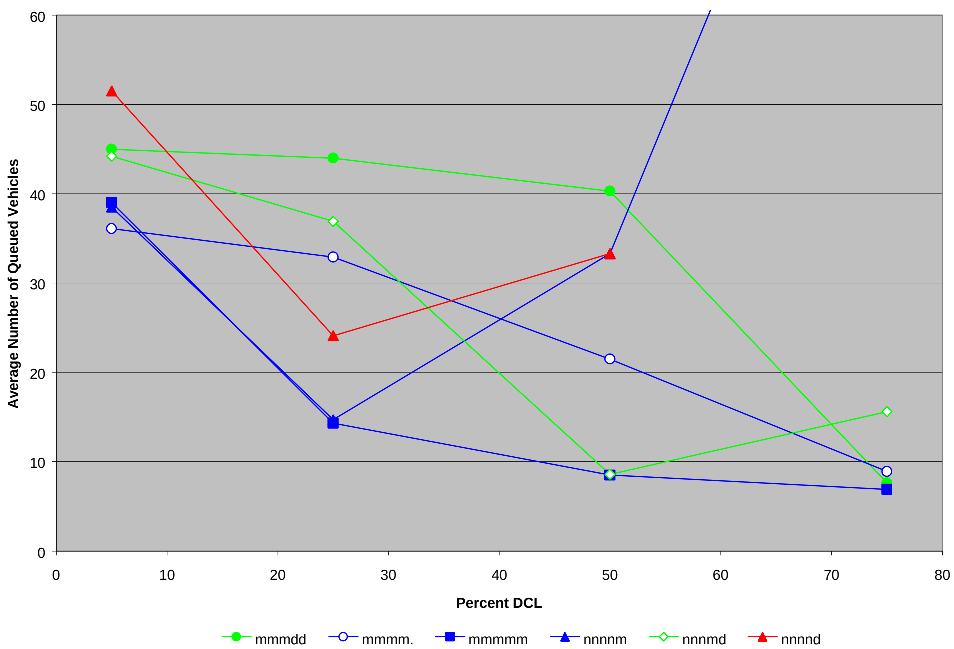

Figure 4-1. Impact of Increasing DCL Utilization on Average Number of Cars in Queue at Primary Inspection

Time Savings, DCL vs. Non-DCL cars: Table 3.9 presents the travel time savings for DCL-eligible vehicles over non-DCL cars in each scenario. As in the NATAP truck experiments, mixed-use lanes are superior from the system impact perspective (queue length) but provide only limited incentive to DCL participation. Dedicated lanes, although they provide greater relative time savings over non-DCL cars, tend to degrade system performance, particularly at lower participation rates. At 25% participation rates or higher, DCL users save a maximum of 1-2 minutes over non-DCL users depending on the configuration.

		Percent Vehicles DCL Eligible			
		5	25	50	75
Configurations	mmmdd	1.5	1.5	1.0	0.1
	mmmm	-0.9	0.1	0.0	0.1
	mmmmm	-0.1	0.1	0.1	0.0
	nnnnm	-3.8	0.1	-2.3	-4.8
	nnnmd	2.6	1.9	0.1	-0.3
	nnnnd	3.6	1.8	-2.3	

Table 4.3 Time Savings, DCL vs. Non-DCL Cars

Section 5
Conclusions

5.1 Key Findings: Primary Truck Inspection Operations

As expected, increasing NATAP participation results in shorter queues and reduced risk of gore blocking with judicious alteration in primary inspection lane configurations. Outside of all-mixed-use combinations, no single configuration is optimal across all participation rates studied. At participation rates above 75% with four-lane configurations and at participation rates above 25% with five-lane configurations, the risk of truck queue growth beyond the gore is virtually eliminated even under peak truck arrival rates.

Impacts of NATAP participation is more dramatic under 4-lane configurations than 5-lane configurations because the system is inherently more congested. The improvements in primary inspection efficiency from increased NATAP participation are enough to transition the operation from a saturated to an unsaturated condition. Hence, larger marginal impacts are associated with the 4-lane case than in the less congested 5-lane case. This is contrasted with the 3-lane configuration testing where the system is so overwhelmed that the improvement from NATAP cannot be discerned using the performance measures defined in the other cases.

Dedicated lanes are generally inimical to overall system performance, but are the only option under current station design to provide a travel time saving relative to non-NATAP participants. Only under high market penetrations (generally 50% or more) can dedicated lanes be included without increasing the number of trucks in queue. In these cases, time savings for NATAP participants is expected to be between 1-2 minutes.

5.2 Key Findings: Primary Car Inspection Operations

Findings for the car inspection operations are quite similar to those for truck inspection. Increasing participation in the DCL program reduces overall queue size and risk of queues stretching back onto the bridge span past the gore diverge point. An increase to 25% participation from the current 5% level eliminates the risk of queue growth past the gore even at peak car arrival rates. Dedicated lanes have negative impacts on system performance until higher market penetrations can be reached. Travel time savings for DCL users is expected to be 1-2 minutes in these cases.

5.3 Observations

- <u>Effect of operations geometry on travel time savings for NATAP participants</u>. In the case of primary truck inspection, a shared long queue of trucks leads up to small plaza of inspection lanes. Consequently, the operational capability to prioritize waiting queue in favor of NATAP participants is nil. The small advantages experienced by NATAP trucks is directly related to the fact that they must wait with everyone else until reaching the inspection plaza, where they are processed more efficiently. The bulk of the time the truck spends at the crossing is in the queue, this more efficient processing results in modest time advantage over non-NATAP participants. One alternative geometry suggested would be to have separate long queues around the bend for NATAP and non-NATAP participants and then all-mixed use lanes at primary inspection. Although such a geometry was not evaluated as a part of this study, such an approach might improve system efficiency as well as differential time savings benefit to NATAP participants.

- Increasing NATAP participation results in a reduced number of trucks parking in the broker lot for paperwork. Since NATAP trucks do not undergo secondary inspection, the large parking lot reserved for this activity is nearly empty at 50% or higher NATAP participation. Utilization of this space for other purposes may be possible. For example, the lot could be converted for use as additional buffer space for waiting trucks or as a staging ground to perform preferential sorting of waiting trucks for NATAP participants .

TABLE OF ACRONYMS

BAH	Booz·Allen & Hamilton
CVO	Commercial Vehicle Operations
DCL	Dedicated Commuter Lane
FHWA	Federal Highway Administration
FOT	Field Operational Test
ITS	Intelligent Transportation Systems
JPO	Joint Program Office
NATAP	North American Trade Automation Prototype
OMC	Office of Motor Carriers
PRT	Perception-reaction time
PT	Perception time
RT	Reaction time
SDDOT	South Dakota Department of Transportation

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