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16. Abstract

Project 0-1800 pioneered the use of modern micro-simulation models to analyze the complex procedures involved in international border crossings in Texas. Animated models simulate the entire southbound commercial traffic flow in two important international bridges, Ysleta-Zaragoza in El Paso and World Trade in Laredo. The simulations addressed all the crossing procedures, starting with U.S. Customs export inspections on the U.S. side, all the way to the Mexican exit gates. The results were impressive, including identification of bottlenecks, test of possible solutions, and estimate of future impacts of traffic on crossing times and on adjacent roadways, for both bridges: Zaragoza and World Trade. This report presents an executive summary of the project findings, focusing on the usefulness of simulation models as a tool to analyze international crossings. The animated models helped visualize the problems, as well as the effectiveness of the proposed strategies, and are an excellent way to improve and promote exchange of ideas among the different agencies concerned with international commerce.

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ABSTRACT

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IMPLEMENTATION RECOMMENDATIONS

Project 0-1800 was the first to develop a practical tool for integrated analysis of the complex traffic flows on Texas international bridges together with their impact on adjacent infrastructure. The project developed animated models of two bridges in Texas and used the

models to analyze traffic impacts and propose traffic operations strategies, some of them already implemented. The overall conclusion of the project is that animated models are very powerful tools to accurately analyze existing and proposed crossings, allowing visualization of the traffic operations inside the facility, as well as impacts of international traffic on adjacent roadways. Animated models are ideal tools with which to analyze and visualize the impacts of infrastructure investments, traffic demand management strategies, and implementation of ITS and other automated procedures to expedite commercial traffic. The approach developed by this project is recommended for future studies of existing and proposed border crossings in Texas.

In order to ensure validity of the models as an analysis tool, it is necessary to implement a plan to collect and update the data used in these models, check all model assumptions, recalibrate models, and if necessary rerun model scenarios. Ideally, this data collection and recalibration should be done periodically for all developed models, since operations may change, invalidating model assumptions and results. This implementation plan is strongly recommended for the World Trade Bridge, whose model was developed while it was under construction, and for this reason relied on data collected at other facilities. It is also recommended that models for the other Texas-Mexico border crossings be developed and that the modeling encompass both the southbound and northbound operations.

Prepared in cooperation with the Texas Department of Transportation and the U.S. Department of Transportation, Federal Highway Administration.

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EXECUTIVE SUMMARY

INTRODUCTION AND OBJECTIVE

International traffic across the Texas-Mexico border has been increasing at staggering rates since NAFTA was approved. In Laredo alone, truck traffic grew by a total of more than 72 percent in the past five years. In 1999, 2,754,000 trucks crossed Laredo's international bridges, moving a total of 194 billion dollars in international commerce.[1]

This thriving international trade has beneficial consequences, shown by impressive numbers such as Laredo's 6.7 percent growth in employment, and 12.2 percent growth in building permits.[1] But it also brings difficulties, such as truck lines several miles long, air pollution, pavement wear and tear, and safety problems. More infrastructure is needed, of course, but will not solve problems by itself. As the results discussed later in this report will demonstrate, equally needed are ways to streamline the traffic flow through the numerous inspection points, and optimize the merchandise flows to minimize empty trucks.

Project 0-1800 pioneered the use of modern micro-simulations as a tool to analyze international traffic flows in Texas. The project team selected two busy border crossings to analyze as case studies, using general-purpose industrial engineering simulation software. This report presents a summary of the results of these simulations and recommendations for improving transborder traffic operations, as well as for more efficient future studies.

PROJECT REPORTS

Project 0-1800 generated three reports. The first two document the development of animated traffic simulation models respectively for the Zaragoza Bridge in El Paso and the World Trade Bridge in Laredo (1, 2). Those reports document the models' development and subsequent use to analyze traffic circulation and recommend strategies for traffic operations, future improvements, and interagency communication.

The present report consists of an executive summary of the main findings of the study, focusing on its general application to future border transportation planning. The contribution of Project 0-1800 can be seen as twofold: first, to analyze international traffic impacts in two areas historically subjected to traffic congestion; and second, to demonstrate that animated simulations are the ideal way to analyze the complexities of international traffic operations, as well as their impacts on adjacent infrastructure.

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1 Source: Laredo Development Foundation.

A MICRO-SIMULATION APPROACH TO NAFTA TRAFFIC OPERATIONS

Simulation and modeling refer to a broad range of methods to replicate the behavior of a system, under existing and proposed conditions. They are used to design a new system, measure the performance of an existing system, or study the impacts of changes in the system. Simulation results provide up-to-date assessment of the capacity utilization of all ports of entry, and identify which system components are causing congestion. Animated models are the ideal media to convey information about traffic flows under existing and proposed conditions, helping optimize the time and expenditures necessary to develop an information exchange system among border agencies. Alternatives can be tested earlier in the design phase, providing some time for adjustments. These benefits can be accrued during the project development.

Graphical animated simulation programs are powerful tools to visualize what is happening with a particular system. This is a very useful element in situations where effective interagency communication is essential.

Project 0-1800 developed two animated simulations of the southbound traffic flows, in two busy border crossing facilities, using them to develop recommendations for traffic operations. The objectives of the simulation were:

- To estimate queue lengths at the facility southbound entrance, if any,
- To estimate crossing times,
- To analyze the efficiency of the bridge operations,
- To identify bottlenecks in the bridge layout and/or operations,
- To quantify the traffic impacts on the adjacent infrastructure, and
- To develop recommendations for efficient traffic operations.

The scope of Project 0-1800 included:

- A survey of Commercial Vehicle Operation (CVO)/Intelligent Transportation Systems (ITS) technologies applicable to international border crossings. This survey identified NATAP (North American Trade Alliance Prototype) as the only traffic-expediting effort. Its utilization was (and still is) extremely low. Traditional dispatch trade still dominates transborder commerce in Texas.
- Development of a simulation methodology to analyze international border crossings, as well as the traffic impacts of the facilities on the adjacent infrastructure. This was done through two case studies: Ysleta-Zaragoza Bridge in El Paso and World Trade Bridge in Laredo.
- Data collection and analysis for the models. The simulation required three types of input data: traffic volumes, inspection times, and operational details. These data were all collected in situ for the Ysleta-Zaragoza Bridge in El Paso. The World Trade Bridge in Laredo was under construction when this research was under way, and for this reason the model inputs consist of estimates based on data from existing bridges. Data and information sources

included, but were not restricted to, U.S. Customs, General Services Administration (GSA), the Laredo Development Foundation, Mexican Customs, Mexican Federal Police, and other Mexican federal agencies.

- Development of two southbound simulation models: World Trade Bridge in Laredo and Ysleta-Zaragoza Bridge in El Paso.
- Model runs and analyses of results for both case studies, for present and future traffic, and for different scenarios that included modifications in traffic operations, traffic demand patterns, and facility layout.
- Development of recommendations for traffic operations, to minimize traffic impacts of the facilities on the adjacent infrastructure.
- Development of recommendations for future studies, based on the methodology developed in Project 0-1800.

MODEL DEVELOPMENT AND ASSUMPTIONS

The development of a simulation model is a complex process. Successful simulation requires thorough and critical knowledge of the system itself, as well as of the statistical and mathematical models and logical methods that underlie the simulation, ensuring a realistic, accurate representation. The model development requires several steps, which are depicted in Figure 1.

The steps depicted in Figure 1 are thoroughly documented in the previous reports of the 0-1800 series (1, 2). In order to understand the research results, however, it is important to mention a few of the model assumptions (see "model formulation" box if Figure 1). The capacity of adjacent roadway network was presumed to always be enough to output the peak hours assumed for simulated future scenarios. For the year 2010, international traffic was still considerably less than the theoretical capacity of the adjacent freeways, but their capacity to carry the international commercial traffic may be limited by local traffic. Analysis of the border cities' network was beyond the scope of this study. The simulations determine the ability of the international bridges to carry traffic and the international traffic impacts on the adjacent infrastructure.

The study scope was limited to traffic impacts on the U.S. side. Accordingly, the analyses were done only for the southbound direction. The input data and assumptions used in both models are thoroughly documented in the previous reports of the 0-1800 series. They included, but were not restricted to:

- Hours of operations,
- Traffic volumes and distributions (daily, weekly, and monthly),
- Staffing schedules and shifts,
- Probability distributions of times spent at each component, and

- Probability distributions for selection to different inspections.

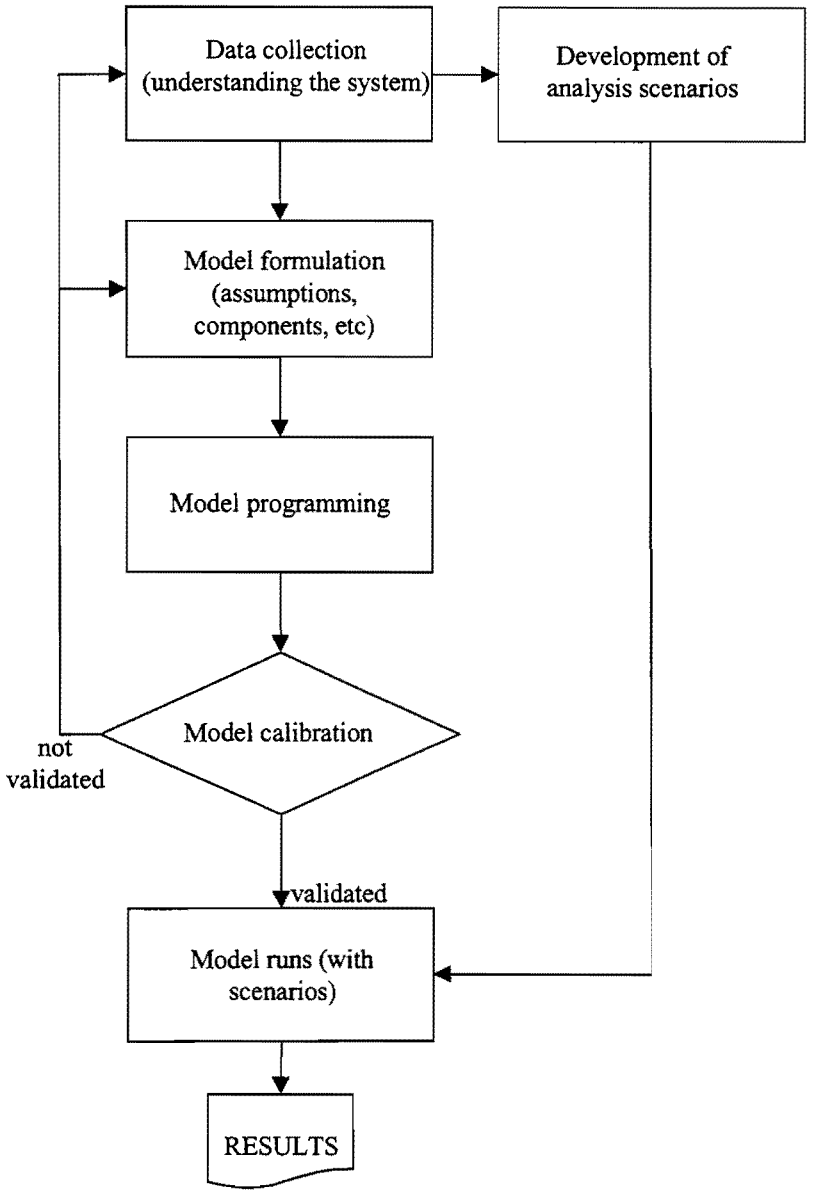


Figure 1. Simulation Model Development Framework

The World Trade Bridge was under construction when its model was developed and used in the analysis. Consequently, the model includes considerably more assumptions and estimated data than the Ysleta-Zaragoza model, which was developed for an existing facility.

SIMULATION RESULTS

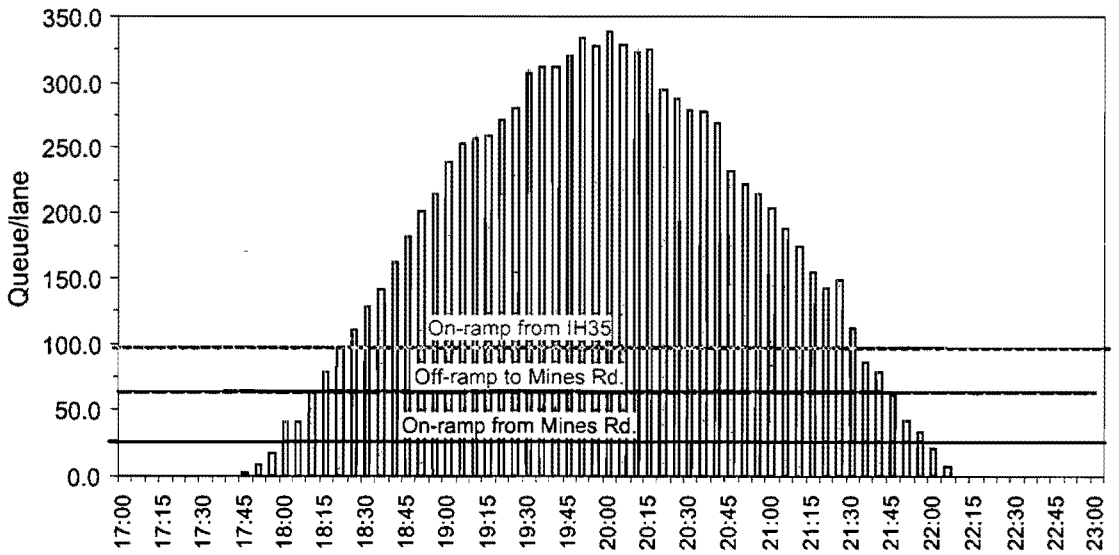
For each of the two simulation models, several scenarios were developed that reflected different traffic volumes and patterns, changes in traffic operations within the facility, and changes in the facility layout. The scenarios were used to determine how the system would respond to changes in its structure and/or demand—the "what-if" questions likely to assist in the development of traffic circulation plans for the bridge under investigation, and its adjacent infrastructure.

For each scenario, the model provided:

- Quantification of traffic impacts on adjacent infrastructure;
- Identification of bottlenecks within the system;
- Quantification of transborder operations efficiency, in terms of crossing times, times spent at each component, queues, and several other measures of efficiency; and
- More importantly, a powerful visual tool that clearly shows all results in a manner that facilitates interagency communication.

World Trade Bridge in Laredo

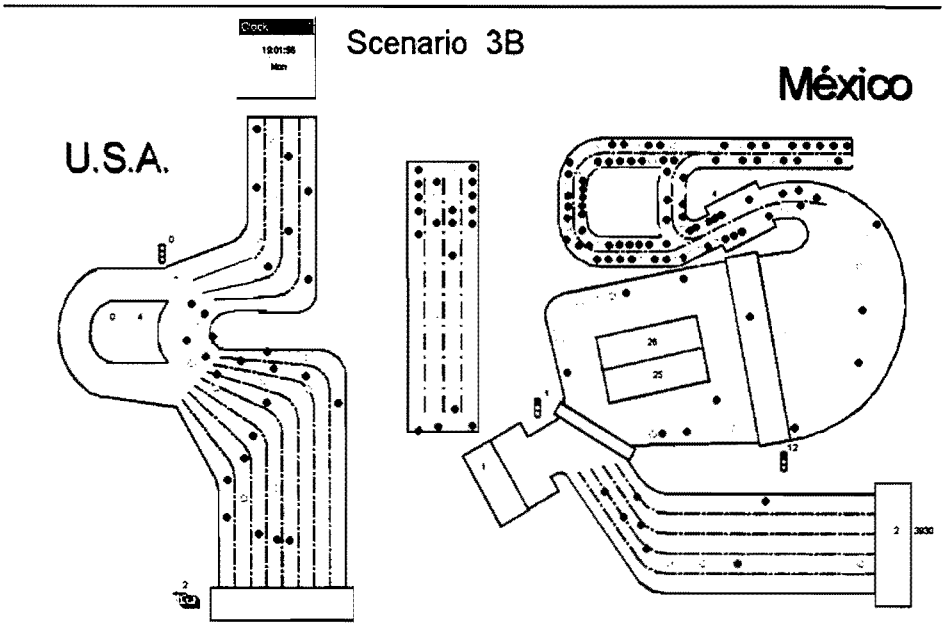
During the diagnostic phase of the project, the World Trade Bridge was analyzed for 20 scenarios, which included several combinations of facility operations, layout expansion, and traffic volumes. The scenarios included the years 2000, 2005, and 2010, with some intermediate years when necessary. Model results include average, minimum and maximum crossing times with and without inspections, graphs of queue development at the facility entrance (as illustrated in Figure 2), identification of bottlenecks, and animated simulation of the traffic flows (as



Scenario for operations: Mexican Police randomly stopping 20 percent of the trucks throughout the day, and U.S. Customs activating the flashing beacon during the two afternoon peak hours.

Figure 2. Queue Development on Loop 20, Year 2005

illustrated on the screen capture depicted in Figure 3). This study phase measured queue lengths in terms of number of average trucks, considering an average truck length of 22m (73ft) and an average gap of 3.5m (11ft), as observed on slow truck lanes in Laredo.



Note: this simulation screen is not to scale. On the U.S. side, traffic flows from the top of the screen to the bottom. On the bridge (represented by the rectangle in the middle of the screen), traffic flows from bottom to top. On the Mexican side, traffic starts at the uppermost right part if the two lane Mexican bridge egress, and flows along the layout, exiting at the rectangle on the bottom right.

Figure 3. World Trade Screen Capture Illustrating Bottleneck at the Mexican Federal Police

The diagnostic study phase indicated that, for the year 2010, the World Trade Bridge will no longer support the current combination of peak hour distribution, percent of empties, diversion from Colombia, and inspection activities that require stoppages in the traffic stream. If the assumptions made for traffic demand, inspection times, percent inspected, and operation of the flashing beacon remain true, it will be more important to expand queuing area than to expand the inspection docks on either side or the tollbooths on the U.S. side. However, the analysis clearly indicates that infrastructure expansion alone is not the answer for the increasing truck traffic demand in Laredo. Maintaining the current types of inspections without causing serious congestion in Laredo will require modifying the current hourly distribution, percent of empties, and/or diversion from Colombia.

There are two ways to manage the demand patterns observed in Laredo today: reducing or rerouting the empty trucks, and reducing peak hour factors. The results of a thorough analysis

of an additional 12 scenarios of different demand management strategies indicated that the solution for the growing commercial traffic demand in Laredo will require a combination of strategies to modify traffic demand patterns, decrease or reroute empty trucks, and expand some of the infrastructure. The project did not analyze strategies requiring changes either in federal legislation or in international commerce practices, such as eliminating equipment swap, and automating inspections. These strategies should be pursued, of course, but they are not pertinent to the scope of this research, which focuses on cost-effective measures for immediate implementation at state and local levels.

The following strategies can control southbound congestion in Laredo in the next 10 years, provided that the assumptions used in this research are valid throughout 2010:

- Work with trucking companies and Customs brokers to distribute traffic more evenly throughout the day.
- Install a variable message sign (VMS) to re-route empties to Colombia, especially when U.S. Customs and the Mexican Police are inspecting either full-time or during the peak. One possible way to enforce this strategy is using city ordinance to fine empties trying to cross the World Trade Bridge when the VMS indicates the alternate route. The scales on the tollbooths would flag the empty trucks.
- Use the VMS to warn drivers of congestion on the U.S. side of the bridge, and encourage voluntary re-routing to other facilities, especially if the World Trade Bridge is open to private vehicles.
- Double the Mexican loop by the end of 2006.
- Double the area upstream of the tollbooths on the U.S. side, and change the location of the beacon to provide additional queuing inside the facility.
- Fully staff all components on both sides of the border.
- Ensure that the U.S. Customs inspectors stationed at the beacon take less than 8 to 10 seconds to select trucks for export inspections, and are able to handle three trucks at the same time.
- If it is difficult for inspectors to direct traffic efficiently, install a VMS near the flashing beacon to direct trucks on the U.S. side.
- Locate one shippers export declaration drop-off box at each of the tollbooths, using the same stop for the two actions. Make sure that no driver needs to get off the truck to deliver the documents or pay toll.
- Weight trucks for toll payment without stopping them, using weigh-in-motion devices.
- Mexican Federal Police inspections should take an average time of 20 seconds or less, and avoid pulling trucks over for detailed inspection when the parking area provided for complete inspections is full.

- Make sure that all trucks take an average of one minute at the Mexican primary inspection signals. Any activity other than passing by the signal should be located outside the traffic flow.
- If the signals for inspections are manually activated by the driver, make sure no driver has to get off the truck to do so.
- Make sure that all trucks not selected for Mexican primary inspection are able to drive by the signals for secondary inspection without any additional delays.
- Final document check at the Mexican exit gate should take an average time of 16 seconds.

Zaragoza Bridge in El Paso

The Ysleta-Zaragoza Bridge in El Paso was renovated in 1992 and was fully operational for commercial and non-commercial traffic when this research was being conducted. Accordingly, traffic conditions were still quite good. Currently, the only observed congestion was observed at the nearest signalized intersection when the east tollbooth closes for personnel shift. Figure 4 shows a screen capture of the simulation window highlighting the signalized intersection outside the toll booths.

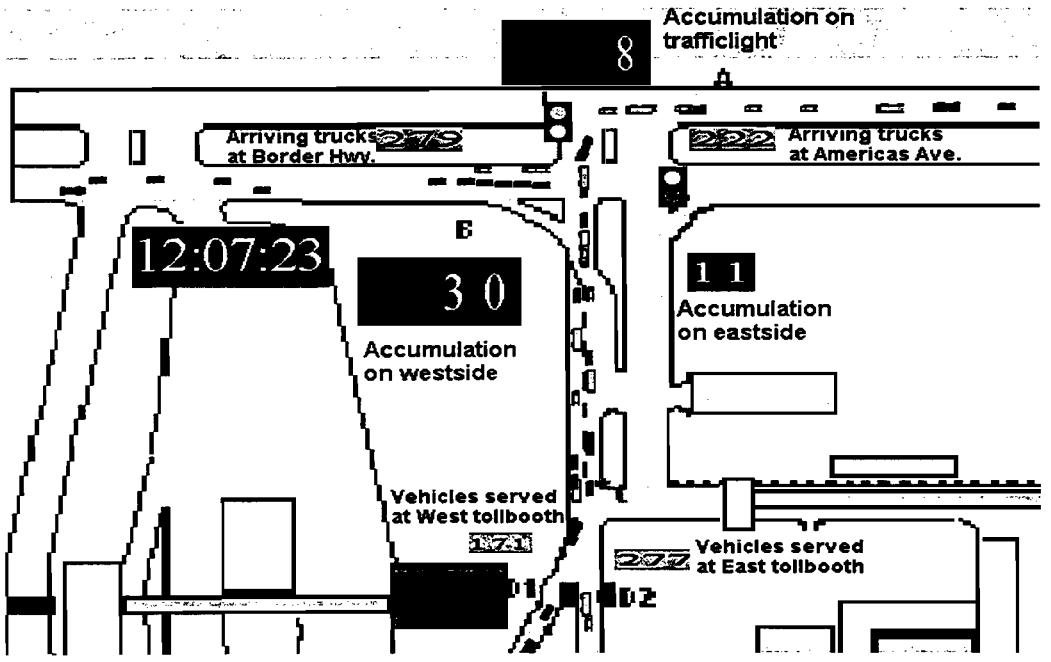


Figure 4. Signalized Intersection Adjacent to the Ysleta-Zaragoza Bridge

All data used in this model was obtained in situ, and the model inputs are based on a thorough statistical analysis of times spent at each component, as well as on interarrival times at the bridge entrance. The model was analyzed for eight different scenarios, which covered current and future traffic, existing and expedited toll collection operations, and existing and expanded tollbooths.

The model outputs are analogous to those described in Figures 2 and 3 for the World Trade Bridge. They include queues on the adjacent infrastructure, crossing times, and visually animated bottleneck identification.

The analysis indicated that the Zaragoza Bridge is, for the most part, efficient and can handle the current traffic. Two sources of congestion were identified: closing the tollbooth, and the procedure followed by the exported cars drop box on the U.S. export lot. If these two conditions are corrected, the bridge can handle a 50 percent increase in traffic demand before international traffic significantly affects the adjacent infrastructure.

CONCLUSIONS AND RECOMMENDATIONS FOR RESEARCH IMPLEMENTATION

The World Trade Bridge in Laredo opened to traffic in April 2000. It is very important to emphasize that the model discussed in this report was developed while the World Trade Bridge was under construction. Therefore, it used ad-hoc information in conjunction with data from the existing bridges. We strongly recommend a thorough implementation phase to collect data, verify these assumptions, and recalibrate the model, after the traffic stabilizes on the new bridge. Several of the assumptions used in the model need to be verified. An important example: the model assumed that eight U.S. Customs document drop boxes would be located at each of the tollbooths, eliminating one stop and streamlining the traffic on the U.S. side. During a visit to Laredo right after the bridge opened to traffic (which coincided with the end of the project), the project staff was pleased to notice that this assumption was implemented. However, a few months after project 0-1800 ended, the authors visited Laredo again, and noticed that U.S. Customs had placed only one drop box at the bridge entrance, creating a one-lane bottleneck at the facility entrance. These decisions can significantly affect the research results, and should be modeled due to their extremely high potential to cause congestion on Loop 20. For this reason, we strongly recommend the following research implementation plan for Laredo:

- Collect traffic data at the new bridge, especially demand and diversion from Colombia, after the traffic demand stabilizes.
- Collect data on the inspection and toll collection areas: service times, staffing scheduling (if not fully staffed), and details of traffic operations.
- Count traffic at the facility entrance and estimate the actual interarrival times.
- Obtain daily traffic counts and use those to obtain weekly traffic patterns.
- Compare the new data with the model assumptions.
- Run a sensitivity analysis on all the differences.

- Depending on the results of the sensitivity analysis, recalibrate the model, and run all scenarios again.
- Redo the entire model logic if auto traffic becomes significant in this bridge.

The Zaragoza model was developed for a fully operational facility, and as such required less follow-up work than the World Trade. A research implementation plan for El Paso should include modeling the other bridges in the El Paso area, and using the existing model to test additional scenarios that may become relevant in the near future.

As mentioned before, the scope of these case studies is limited to traffic management alternatives that are implementable through local and state initiatives. Accordingly, the recommendations above do not include measures that depend either on federal laws, or on changing long-established international commerce practices.

This is not to be understood as meaning that such strategies are either not valid, should not be pursued, or will be needed only in a remote future. Quite the opposite: the research results clearly indicate that the only way to prevent congestion in the near future is by rather aggressive traffic management strategies. Measures to streamline inspections, such as NATAP (North America Trade Alliance Prototype), an automated system of expediting commercial traffic, will be instrumental in preventing future congestion. Taking full advantage of NAFTA provisions to eliminate equipment swap has a potential to drastically decrease the number of empties. Reducing empties is another measure that can help prevent congestion. Many other options concerning inspections have been suggested in other border transportation studies. These options should also be actively pursued by the appropriate agencies.

CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE RESEARCH

Project 0-1800 pioneered the use of modern micro-simulation software to analyze the complex procedures involved in international bridges in Texas. The animated models simulated the entire southbound commercial traffic flow, starting at the bridge access upstream of the U.S. Customs export inspections on the U.S. side, and ending at the Mexican exit gates. The results were impressive, including identification of bottlenecks, test of possible solutions, estimates of future impacts of traffic on crossing times and on adjacent roadways, and a powerful visual tool to disseminate the study results.

The animated models help visualize the problems, as well as the effectiveness of the proposed corrective strategies, and are an excellent way to improve and promote exchange of ideas among the different agencies concerned with international commerce. We recommend that future studies of international border traffic include simulation models such as those used in this study. These models can be used to investigate and predict important issues such as:

- Traffic impacts on adjacent infrastructure.
- Impacts of changes in traffic operations.
- Impacts of demand management strategies.

- Traffic circulation under future (increased) traffic.
- Impacts of infrastructure improvements.
- Impacts of staffing schedules and number of available personnel.
- Impacts of changes in inspection times, and many other issues.

The animated simulation provides an effective media to convey findings, recommendations of traffic studies. Visual simulation of what-if scenarios has proved much more effective than numbers and graphs, to communicate impacts of suggested traffic operations strategies. Moreover, animated scenarios can be embedded in a computerized slide presentation and shown by a speaker without any training on simulation programming. It is believed that the most important contribution of Project 0-1800 was to demonstrate the effectiveness of the micro-simulation methodology in analyzing transborder traffic and disseminating the results.

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