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16. Abstract

Project 0-1800 pioneered the use of modern micro-simulation software to analyze the complex procedures involved at international border crossings. The animated models simulate the entire southbound commercial traffic flow, 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. This report presents the analysis of the World Trade Bridge in Laredo, TX, which was under construction while the model was being developed. The model indicates that the World Trade Bridge will work under capacity and with few or no queues for the first five years. After that, congestion builds up, and in 2010 the facility will no longer support its average daily traffic. The model indicates that, in addition to expanding infrastructure, the solution for future congestion in Laredo will require demand management strategies to modify the hourly distribution, decrease the number of empty trucks, and increase the attractiveness of Laredo's Colombia Bridge. The animated model helps the user visualize the problems, as well as the effectiveness of the proposed strategies, and is an excellent way to improve and promote an exchange of ideas among the different agencies concerned with international commerce.

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ANALYSIS OF CAPACITY AND TRAFFIC OPERATIONS IMPACTS OF THE WORLD TRADE BRIDGE IN LAREDO

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Research Report 1800-2

Research Project 0-1800
"NAFTA Impacts on Operations"

Conducted for the

TEXAS DEPARTMENT OF TRANSPORTATION

in cooperation with the

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by the

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and the

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ABSTRACT

Project 0-1800 pioneered the use of modern micro-simulation software to analyze the complex procedures involved in international border crossings. The animated models simulate the entire southbound commercial traffic flow, 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. This report presents the analysis of the World Trade Bridge in Laredo, TX, which was under construction while the model was being developed. The model indicates that the World Trade Bridge will work under capacity and with few or no queues for the first five years. After that, congestion builds up, and in 2010 the facility will no longer support its average daily traffic. The model indicates that, in addition to expanding infrastructure, the solution for future congestion in Laredo will require demand management strategies to modify the hourly distribution, decrease the number of empty trucks, and increase the attractiveness of Laredo's Colombia Bridge. The animated model helps the user visualize the problems, as well as the effectiveness of the proposed strategies, and is an excellent way to improve and promote an exchange of ideas among the different agencies concerned with international commerce.

DISCLAIMERS

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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 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.

The World Trade Bridge was under construction during the development of the model discussed in this report. Therefore, its analysis is based on ad-hoc information in conjunction with data from other Texas bridges existing up to 1999. In order to ensure validity of the model as an analysis tool, it is necessary to implement a plan to collect data at the new bridge, check all model assumptions, recalibrate the model, and if necessary rerun model scenarios. Ideally, this data collection and recalibration should be done periodically for all models, since operations may change, invalidating model assumptions and results.

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

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INTRODUCTION

BACKGROUND

International traffic across the Texas-Mexico border has been increasing at staggering rates after NAFTA was approved. In Laredo alone, truck traffic grew a total of over 72 percent in the past five years (1994-1998). 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 6.7 percent growth in employment and 12.2 percent growth in building permits.[1] But it also brings problems, 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.

OBJECTIVES

This situation requires a case-study approach, which is conducive to efficient problem-solving in complex situations. Project 0-1800 selected three busy border crossings to analyze as case studies. This report describes the traffic impact analysis of the World Trade Bridge, in Laredo, Texas.

Given the complexity of international traffic management and operation, and the need to quickly steer this sense of urgency in solving the border transportation problem into interagency collaboration, it is essential that a practical, implementation-oriented approach be used. The study of the World Trade Bridge includes:

(1) Development of a basic model simulating the traffic flows of the World Trade Bridge.

(2) Development of scenarios to be analyzed. These scenarios include future traffic, opening year traffic, different levels of diversion from Colombia, different percentages of empty trucks, different hourly distributions, and different schedules of export inspections and Mexican Federal Police.

(3) Development of recommendations to expedite commercial traffic, based on technologies and procedures that are viable and cost-effective to all relevant parties (already implemented at the Zaragoza Bridge in El Paso, the first case study analyzed in this project).

(4) Recommendations to facilitate interagency cooperation and provide real-time information about traffic conditions to trucking companies, travelers, and border

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1 Source: Laredo Development Foundation.

agencies, using technologies and procedures that are viable and cost-effective to trucking companies, border agencies, TxDOT and the general public.

RESEARCH APPROACH

The study approach was developed to address basic issues affecting transborder traffic. These are primarily: effective interagency communication, future expansion and modernization, need to investigate traffic impacts of possible actions by other agencies, and viable as well as cost-effective recommendations to reduce congestion.

These issues are intertwined. Realistic border transportation plans must consider a binational, multi-agency perspective at three levels: data collection, systems conceptualization, and input from decision-makers and agencies involved on both sides of the border. All this decision-making must rely on results of highly technical studies. However, results of traffic circulation studies are traditionally reported in terms of statistical analyses, plots, charts, and capacity analyses. This traditional approach has not been conducive to easily visualizing the mechanisms by which border crossing agencies and procedures intertwine and affect traffic flow. These difficulties are one important factor hindering interagency communication and cooperation as well as the dissemination of technical findings.

After investigation of several possible approaches, it was decided to develop and implement animated simulations of traffic circulation on the facilities, using software that provides both technical results and model animation. The benefits of animated models are many. Results of such simulation provide up-to-date assessment of the capacity utilization of all ports of entry and identify which system components are causing congestion, thus needing expeditious procedures for efficient traffic management. The simulation results can also be used to determine how a system will respond to changes in its structure. 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 project development.

With the project objectives in mind, the case study started out by surveying the processing of international traffic flows: where are the stopping points, how long it takes at each of them, what are the criteria for delaying a vehicle, and other pertinent information. Once this process is well understood—and always having in mind the project objectives—one can select an appropriate simulation method, which in turn requires some basic data. All these factors lead to a plan for the data collection, which was developed and then carried out in the field. While the data are being collected, one can already start developing the model, which is then loaded with the data, checked for accuracy and adjusted until it represents the observed traffic flows with a desired level of accuracy. Based on the project objectives as well as on information obtained during the data collection, one can develop study scenarios—the "what-if" questions more likely to assist in the development of traffic circulation plans for the bridge under investigation. By use of the simulation model, the scenarios are analyzed to obtain information such as queue lengths, bottleneck identification, delays at each point, waiting times, and effects of infrastructure improvements and traffic operation changes. This information can be used to prepare recommendations for future improvements in the bridge under study. Moreover, the animated model can be used in interagency meetings to facilitate communication.

REPORT OBJECTIVE AND ORGANIZATION

This report documents the development of an animated traffic simulation model for the World Trade Bridge, as well as its use to analyze the traffic circulation and recommend strategies for traffic operations, future improvements, and interagency communication. The report is divided into five chapters.

Chapter 1, "Introduction," is this introductory chapter. It documents project objectives as well as report objectives and organization.

Chapter 2 contains a "Case Study Description." It starts with a description of the general characteristics of southbound commercial traffic. Then it describes the World Trade Bridge layout and the traffic operations proposed for it. It is important to keep in mind that the facility was under construction when this research project was developed, and the information presented here may change after the facility is open to traffic.

Chapter 3 documents the "Model Development." It begins with a discussion on the concept of simulation. Then it discusses the model inputs: traffic volumes, traffic operations, and inspection activities. The animation of the model is explained next, followed by a brief discussion of the practical model use for case study analysis. This discussion serves as an introduction for Chapter 4.

Chapter 4 documents the "Case Study Results." It first explains the basic scenarios and hourly distributions used in the analysis. It then presents the results and discusses options to manage international traffic demand in Laredo. The scenarios span the next 10 years, and the chapter examines different combinations of empty trucks, daily peaks within the week, hourly distributions, diversion from the Colombia Bridge, Mexican Police activity, U.S. export inspection activities. It includes realistic scenarios as well as purely hypothetical ones developed to identify bottlenecks.

Chapter 5 is a "Summary of Conclusions and Recommendations." It was developed as a "stand-alone" text that can be used as an executive summary for discussing infrastructure improvements and changes in traffic operations.

CHAPTER 2

CASE STUDY DESCRIPTION AND MODEL ELEMENTS

INTERNATIONAL TRAFFIC CHARACTERISTICS

International traffic flow follows general rules that include inspections and, in the case of most Texas international bridges, toll collection.

This case study concerns itself with southbound traffic, which is the direction more prone to hinder traffic circulation in Laredo. This section presents a brief description of the general procedures involved with southbound international traffic, based on information collected from the following sources: Customs officials, and Customs brokers, in Laredo, Nuevo Laredo, El Paso, and Ciudad Juarez; and a report prepared by the Binational study. [1]

Figure 2.1 shows the main types of southbound commercial traffic. In order of complexity (from the U.S. Customs point of view), they are:

(1) NATAP (North American Trade Alliance Prototype),

(2) Maquiladora,

(3) Dispatch, and

(4) Agricultural and hazardous materials.

For the World Trade Bridge, the most important types of traffic are dispatch and Maquiladora trade. Hazardous materials go through Colombia Bridge only. NATAP, an automated system of expediting commercial traffic, was still being tested. Very few companies were participating in NATAP when this research project was finalized. The most active NATAP site, Otay Mesa in California, had fewer than 500 NATAP crossings a year. In Laredo, 500 crossings represent about 10 percent of the daily southbound traffic, and NATAP in Laredo is used considerably less frequently than in it is Otay Mesa. If fully implemented, NATAP will substantially decrease traffic delays. It is an option that should be actively pursued.

Figure 2.2 shows the traditional dispatch trade. This form of international commerce still depends on equipment swap and broker activities in warehouses. These activities are considerably more time-consuming than the U.S. Customs export inspection, but they are all performed before the trucks are sent to cross the border, and these activities do not affect international traffic circulation.

Figure 2.3 shows the Maquiladora trade. This form of international commerce does not depend on equipment swap and broker activities in warehouses. The trucks go directly to the maquiladoras, but they may be selected for U.S. export inspections.

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[1] Binational Study: Website.

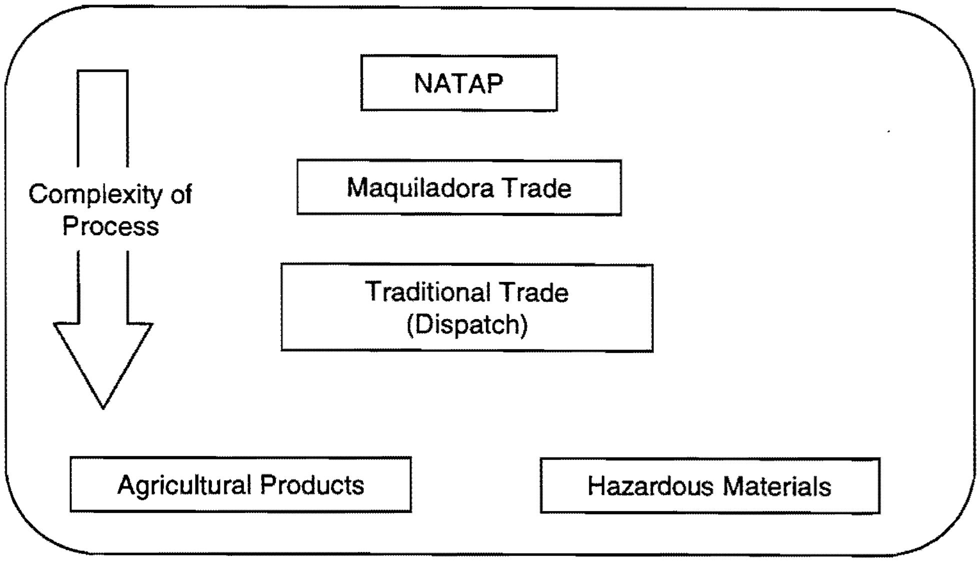

Figure 2.1 General Types of Southbound Commercial Trade

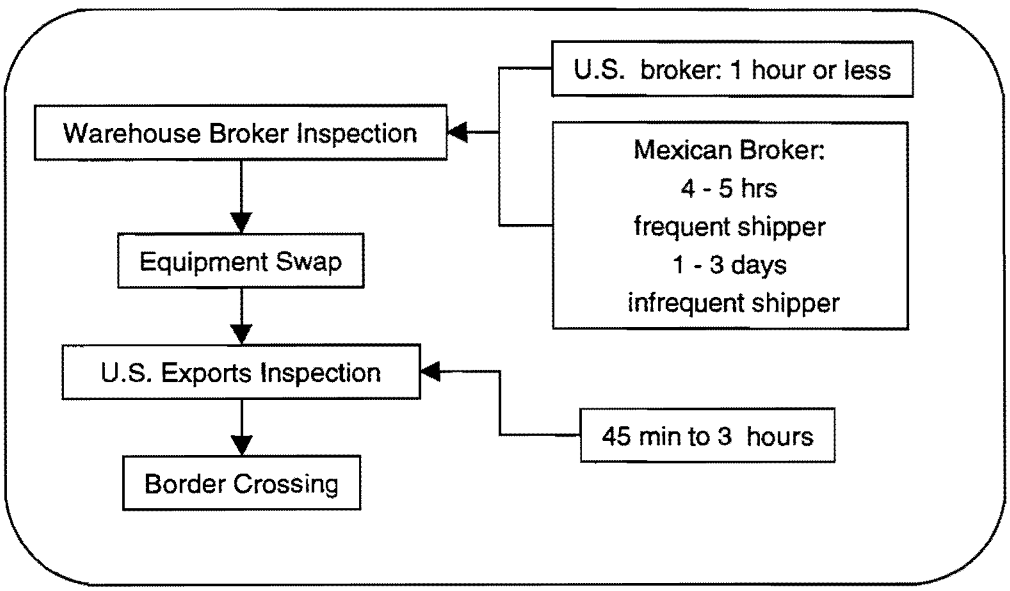

Figure 2.2 Southbound Dispatch Trade

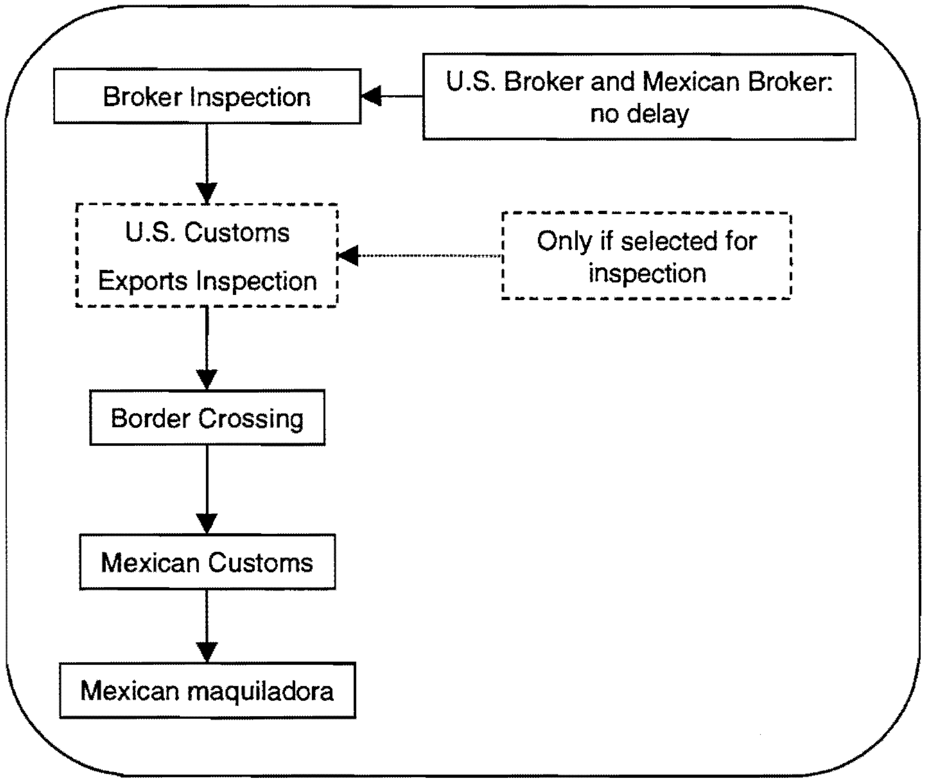

Figure 2.3 Southbound Maquiladora Trade

WORLD TRADE INTERNATIONAL BRIDGE LAYOUT

The general characteristics of international commerce described above are common to all border crossings, but each facility has its own layout. Moreover, the site-specific management and operations are typical of each bridge, and they affect the international traffic circulation. The modeling process described in the next chapter requires thorough understanding of the future traffic operations in the World Trade International Bridge.

This rest of this chapter explains the planned bridge operation, as well as the necessary assumptions and concepts needed for model development. It is important to note that many details of traffic and inspection operations, scheduling and layout were still undecided on both sides of the border when the model was developed.

Figure 2.4 shows a layout of the southbound U.S. side of the World Trade Bridge, while Figure 2.5 shows the southbound Mexican facilities. Figures 2.4 and 2.5 complement each other in depicting the southbound traffic flow and process.

Figures 2.4 and 2.5 together, and to scale, do not fit an average computer screen, and for this reason could not be used for the model animation (to be discussed in chapters 3 and 4). Figure 2.6 depicts the schematic figure actually used for the model animation. In this figure, the relative sizes of the different areas were distorted to ensure visibility of the entire facility on the animated model. The animation was made on a distorted scale figure only for aesthetic purposes. The model underlying logic reproduces the actual lane lengths, facility sizes, and all other parameters in the appropriate way.

Figures 2.4 through 2.6 show numbers for the facility components. On the US side, they are numbered from US1 through US6. Likewise, on the Mexican side the components are numbered M1 through M9.

The rest of the chapter describes each of these components, referring to them by their function and number in figures 2.4 to 2.6. The descriptions include traffic operations and inspection details. Since the model was developed while the bridge was under construction, the information presented here comes from architectural plans and from interviews with the city officials responsible for toll collection and inspection officials on both sides of the border.

U.S. SIDE

Nearest Intersections (US1)

The World Trade Bridge access is Bob Bullock Loop, or Loop 20. Figure 2.7 shows a schematic layout of Loop 20 and its intersections closest to the facility. The closest intersection to the World Trade Bridge entrance is the grade-separated intersection of Loop 20 and FM1472 (Mines Road), located 990m from the facility entrance. Loop 20 has three lanes each way near in this segment. Mines Road's on-ramps are located about 470m (1,570ft) east of the facility entrance. It was assumed that this segment of Loop 20 has queuing area for 20 large trucks per lane (60 trucks in all) before the on-ramps are blocked by southbound queues spilling back into Laredo.

The next critical area to be affected by queue spill-back are Mines Road's off-ramps, located 1,260m (4,200ft) east of the on-ramp. There are two lanes on the segment between Mines Road's on- and off-ramps. It was assumed that this segment can accommodate 50 trucks per lane (100 trucks in all) before blocking the Mines Road off-ramps.

The last intersection considered in the model was the IH35 on-ramps, located 570m (1,900ft) east of the Mines Road off-ramps. This segment has two lanes for eastbound traffic and one lane for right turns onto Mines to Road. It was assumed that all bridge-bound traffic would queue on the two leftmost lanes. This segment, therefore, has space for 23 additional trucks per lane, or 46 trucks in all, before blocking the IH35 on-ramp.

Facility Entrance (US2)

The simulated traffic circulation starts at this point. On Loop 20, upstream, only the potential queues were simulated (see figure 2.6).

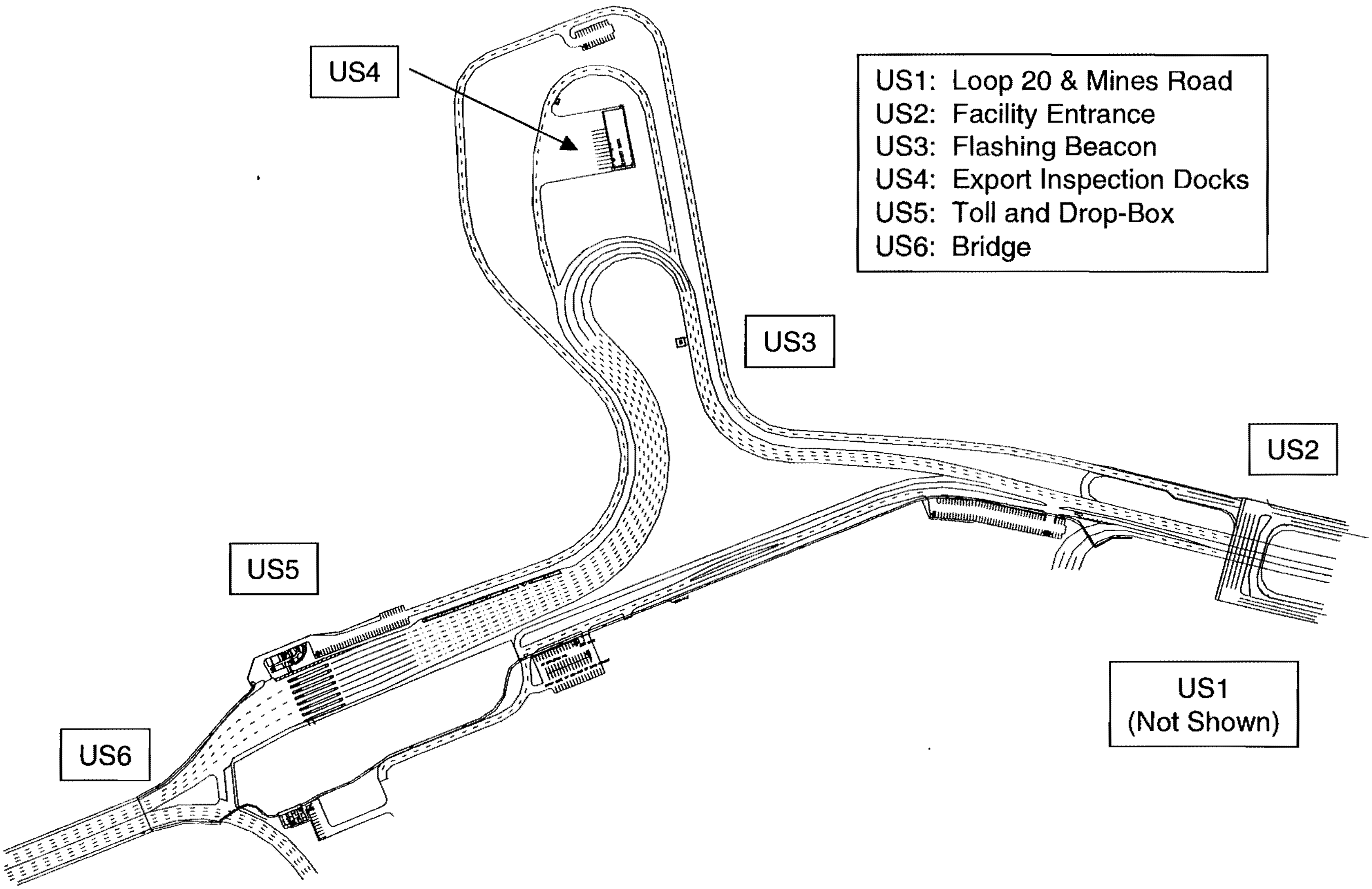

Figure 2.4 Southbound Facilities on the U.S. Side

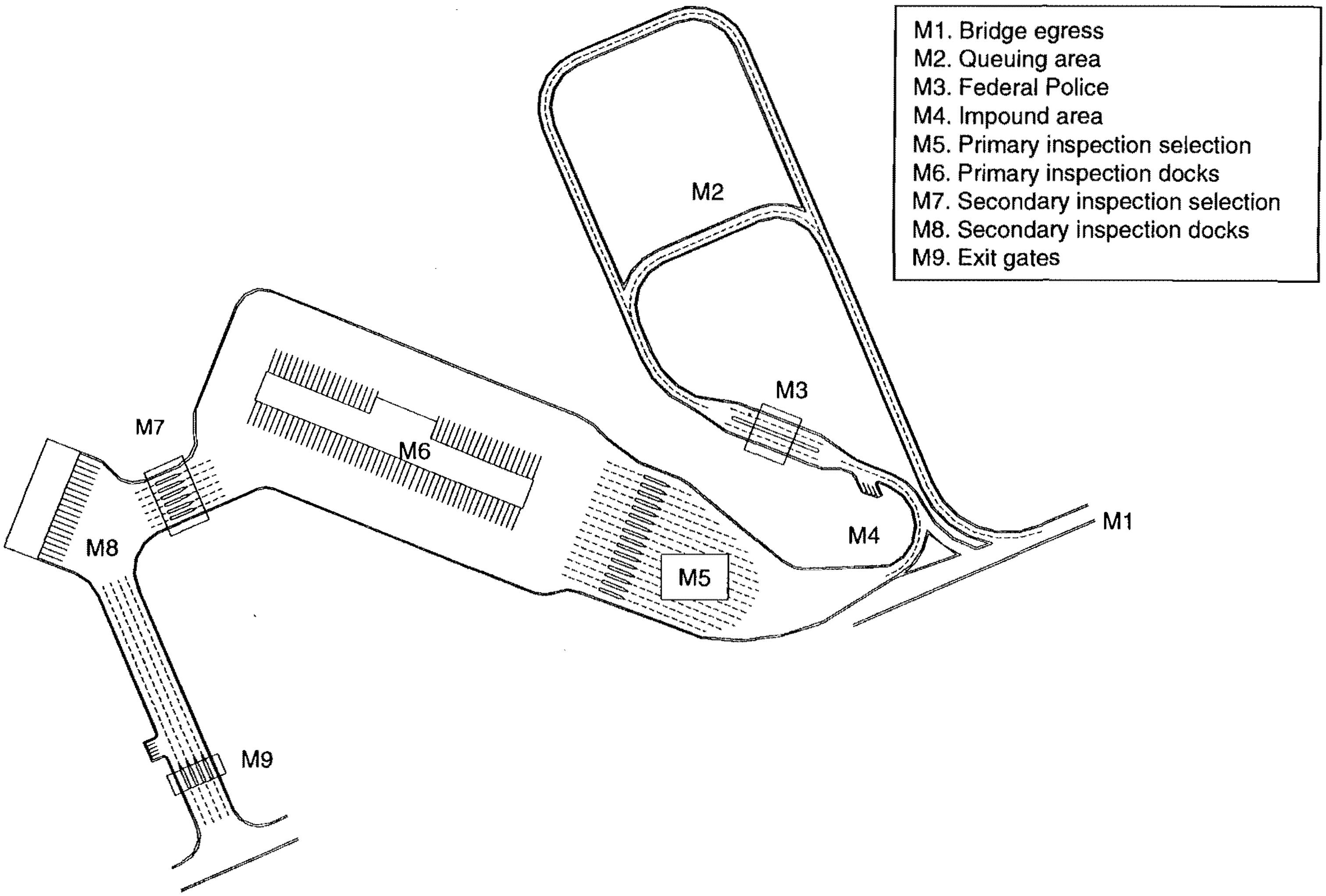

Figure 2.5 Southbound Facilities on the Mexican Side

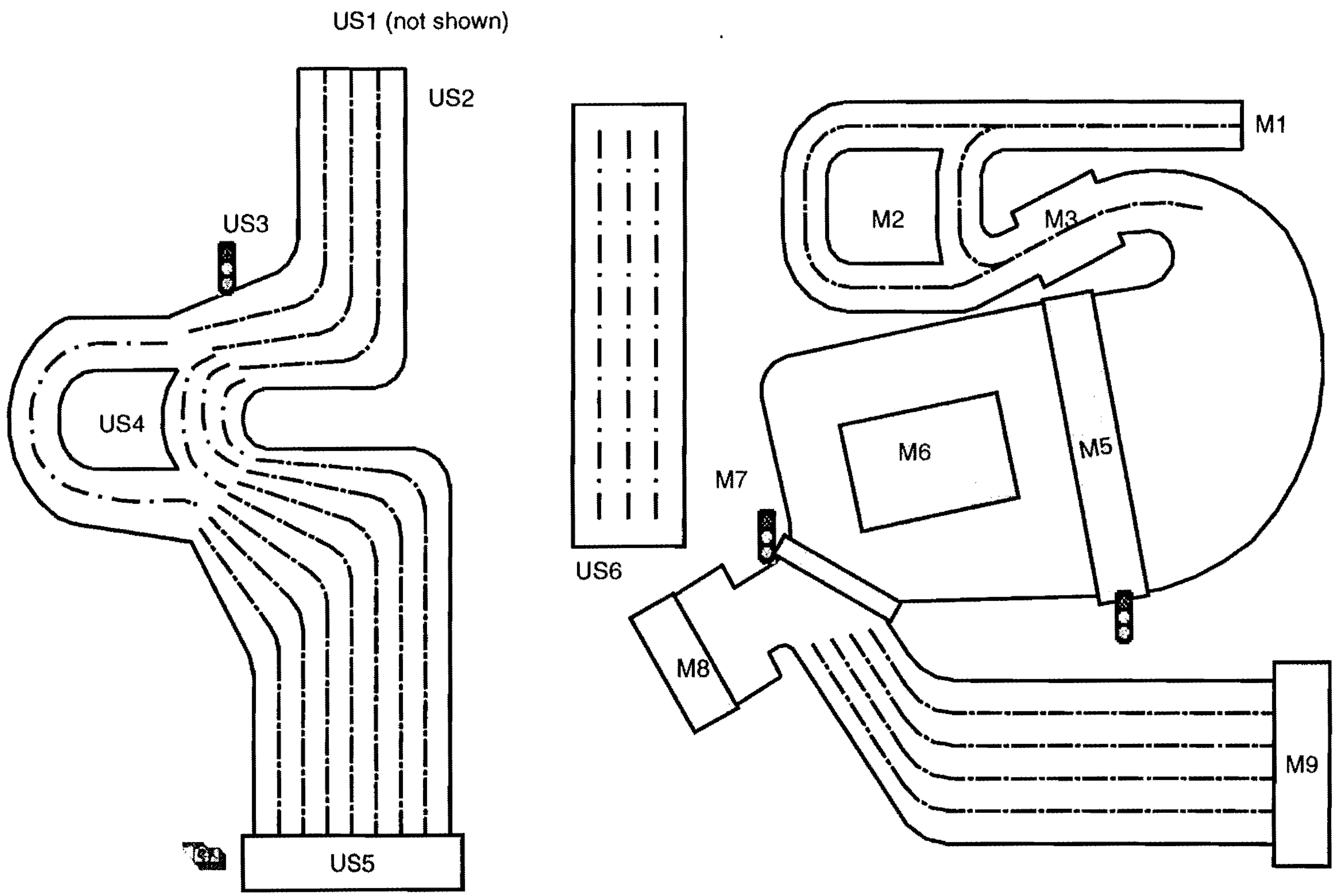

Figure 2.6 Schematic Layout Used for Model Animation

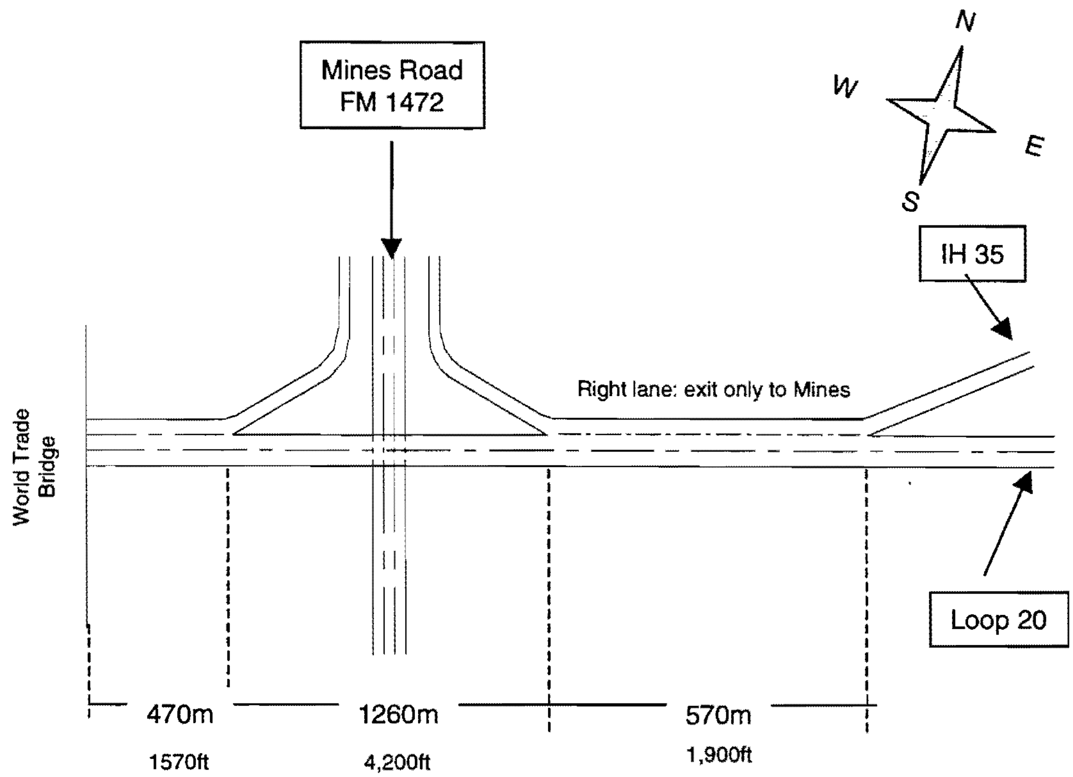

Figure 2.7 Loop 20 Segment Accessing World Trade Bridge

Flashing Beacon (US3)

U.S. Customs will install a flashing beacon at the position indicated by "US3" in figure 2.4. According to U.S. Customs officials, the beacon will not always be operational. When it is, all trucks must stop and Customs inspectors will direct some of them to the next component, the export docks.

Export Inspection Docks (US4)

The export inspection docks will operate as needed. There was no set plan for these operations when the project 0-1800 research team completed the model development. According to Mr. J. L. Gonzalez, Chief Inspector of U.S. Customs in Laredo, there will be U.S. Customs inspectors placed at key points in the export loop. The first one is the flashing beacon upstream of the export docks (US3) and the second one is located at the entrance of the export docks (US4). Still according to Mr. Gonzalez, one out of 100,000 shipments will be inspected on average. However, these inspections are sometimes concentrated on specific days, and thus they have a potential to cause congestion.

The number of lanes of the loop leading to the inspection docks was undecided when the model was developed. Researchers used the worst-case scenario, which consists of two lanes.

Toll Booths (US5)

There are eight tollbooths managed by the city of Laredo. The leftmost will also serve pedestrians. Researchers assumed that it will serve trucks as well. Service times at the tollbooths observed at Laredo 2 were expedited by a system of pre-payment and were on the average from 5 to 11 seconds in length. The same service times were used in the World Trade Bridge model.

Drop-Off Box for Shippers Export Declaration (Form SED-701) (US5)

Drop-off boxes for the Export Declaration are located right before the scale to determine the toll at Bridge II in Laredo. Observations by UTSA staff estimate the average time to drop off the forms as 6 seconds. At Laredo II, the project staff observed that the drop box is designed for the height of the tractor-trailer combinations and that, when a smaller truck needs to use it, there are delays associated with the driver having to get out of the vehicle to drop the export papers.

The actual location of the drop boxes for the World Trade Bridge had not been decided when this model was developed. The research team is assuming and recommending that U.S. Customs will arrange for the drop boxes to be located right at the toll collection (US5). This would eliminate one stop, greatly improving efficiency at a point with significant potential to cause congestion on Loop 20.

Bridge Structure (US6)

The bridge structure has four lanes southbound.

MEXICAN SIDE

Bridge Egress (M1) and Queuing Loops (M2)

The preliminary layout includes two loops. Following an interview with a representative from CABIN ("Comisión de Avaluos de Bienes Nacionales") in Nuevo Laredo on January 27, 2000 it was still unclear whether the two loops were going to be constructed during phase I. Since then, apparently the Mexican authorities decided to build the additional loop. Both loops were included on the model, as shown in figure 2.5. The next chapters will demonstrate the importance of this additional queuing area on the Mexican side.

Mexican Federal Police and SAGAR (Department of Agriculture) (M3)

At this inspection point, the Police check for safety of the driver and the vehicle, as well as for the necessary papers. Empty trucks also go through this booth. If the load is agricultural then SAGAR will be involved and the load may have to undergo fumigation. A fumigation facility is planned to be located inside the small loop so that the procedure will not hinder traffic. The rest of the trucks go to the parking area (M4) only if selected for further inspection, if selected for a drug test, or if they are impounded. The area has four parking spaces, but there are plans to use the space inside the loop as additional parking if needed. Therefore, it was assumed that lack of parking space at this component will not constrain the traffic circulation. There are no specific data on the percent of impounded trucks or on drivers subjected to drug testing, but Mexican officials referred to it as "very small." The drug test lasts between 15 and 20 minutes.

At Zaragoza Bridge in El Paso, Project 0-1800 researchers measured service times at the Mexican Police lanes and fitted an Erlang distribution with a mean of 14.7 seconds and a shape factor of 2. It is not yet known what will happen in the World Trade Bridge, so researchers used the same service time distribution observed at Zaragoza, another facility at which preoccupation with efficient traffic operations is a factor.

Mexican Primary Inspection Signals (M5)

After passing through the Federal Police, all trucks proceed to an area where there are 17 signals for random selection for primary inspection. Loaded trucks wa it for the signal to turn red or green, while empty trucks may drive by. Details of the operation were still undecided when the model was being developed. Researchers assumed that loaded trucks have a 10 percent chance of being selected to go to the next component, the primary inspection docks. Average times observed at the Zaragoza Bridge and at Laredo II for truck selection fluctuated between 15 seconds and 1 minute.

Mexican Primary Inspection Docks (M6)

The primary inspection area has a capacity of 110 trucks. It is wide enough to allow for the movement of the trucks to and from the platform without conflicting with those not requiring inspection.

Mexican Secondary Inspection Signals (M7)

The Secondary Inspection module has 12 signals. The procedure is the same followed by the primary inspection signals. According to the platform supervisor of the primary inspection in Nuevo Laredo, about 10 percent of the trucks undergoing primary inspection are randomly selected at this module for a secondary inspection.

Mexican Secondary Inspection Docks (M8)

The platform has a capacity for processing 12 trucks, and the yard is wide enough to cause no hindrance to traffic flow.

Exit Gate (M9)

At the five-lane exit, Mexican Customs officials will look at the shipment invoice and will stamp the papers to certify that the truck has been checked. It was observed at other bridges that Mexican Customs officials rarely perform extra inspections; they only stamp the papers. At the Zaragoza bridge, this procedure was observed to follow an Erlang distribution bound at 6 seconds, with mean of 6.2 seconds. However, Mexican officials interviewed in Nuevo Laredo indicated that the process may take rather longer. The model uses a normal distribution with a mean of 16 seconds and a standard deviation of 4 seconds.

BASIC CONCEPTS AND ASSUMPTIONS USED IN THE MODEL

In order to develop the model and later analyze and report its results, some basic definitions and concepts are necessary. The first concept is that of capacity of a model component. There are two types of components: service points, at which the trucks must stop and do something, and roadway links. The capacity of service points is determined by the following parameters:

(1) Layout. Capacity is constrained by factors such as number of tollbooths, number of lanes with traffic lights in Mexican Customs, number of docks in primary and secondary inspection, availability of maneuvering space, etc.

(2) Service time. The longer the service time, the less capacity the element has. This parameter is always automatically considered in the model.

(3) Staffing. A large facility with few staff members may have less capacity than a smaller, fully staffed one. When the model was being developed, there was no information as to staffing schedules. It was assumed that all model components would be staffed to utilize their full physical capacity at all times.

The traditional definition of lane capacity refers to the maximum traffic flow rate (vehicles per unit time) that can pass through a roadway section. For the purposes of developing a border crossing model and analyzing the resulting data, this traditional definition of roadway capacity is not relevant. International traffic travels very slowly and stops often. The facility capacity is actually constrained by the maximum concentration, not the flow rate. In this project researchers use the term lane "capacity" to indicate maximum concentration for an average truck length of 22m (73ft) and an average gap of 3.5m (11ft), as observed on slow truck lanes in Laredo.

This capacity definition has a limitation. Actually, speed, density, volume and headway are interdependent, and, in any system, the trucks will decrease speed and increase density in areas near booths and other stoppages and will decrease density while increasing speeds in areas such as the bridge deck. However, modeling dynamic speed/density/volume relationships is beyond the capabilities of the software. The model represents two different combinations of speeds only, for all concentrations. The speeds and their variation are discussed further in chapter 3, model development.

SUMMARY AND CONCLUSIONS

This chapter provides a description of the World Trade bridge as available from architectural plans, as well as its future traffic and inspections operations. Plans for traffic operations and inspections were provided by officials on both sides of the border. Many details were undecided; they had to be assumed for modeling purposes. All service times are ad-hoc values obtained from other bridges and/or estimates made by inspections officials on both sides.

After the actual facility is fully operational, it is strongly recommended that the layout and procedures described here be checked. The project implementation phase should also include recalibrating the model with observed values and updating the results using the newly calibrated model.

CHAPTER 3
MODEL DEVELOPMENT

INTRODUCTION

Realistic border transportation plans must consider a binational, multi-agency perspective at three levels: data collection, systems conceptualization, and input from decision-makers and agencies involved on both sides of the border. A better understanding of these mechanisms may help foster interagency cooperation and further dissemination of research results.

The ideal way to achieve a better understanding of these mechanisms is by simulating the traffic flows on the vehicular binational bridges. Results of these simulations provide assessments of the capacity utilization of each system component and identify which of them are causing congestion and thus are in of need of expeditious procedures for efficient traffic management.

This chapter discusses the conceptual approach of modeling and simulating the southbound border crossing procedure at the World Trade International Bridge in Laredo, Texas.

SIMULATION AND MODELING: CONCEPT

Simulation and modeling refer to a broad range of methods to replicate the behavior of a system under both 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. Graphical animated simulation programs are powerful tools enabling a user to visualize what is happening at a particular system, a very useful feature in a situation where effective interagency communication is essential.

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.

Step 1: Understanding the system. This step begins with a thorough analysis of the existing system, including a first rough basic logic for the future model. In the case of a planned facility, this step must include visits to similar existing sites and conversations with all agencies involved in the facility's operations.

Step 2: Formulating the model. Once there exists a basic understanding of the system, one needs to critically analyze it and formulate the model representation of the system. Practical judgment and a deep understanding of both the modeling software capabilities and the mathematical methods embedded in it are the basis of an efficient model formulation. Specificity about what can be learned from the simulation, which system components need to be modeled, which ones can be represented in a simplified manner, and what are the basic model assumptions is paramount for accuracy and efficiency.

Step 3: Programming the model. Once the model is formulated, i.e., all the components are in place, the relevance of each has been determined, and the statistical functions that best represent their behavior have been fitted, one can program, i.e., translate the model concept into the simulation software.

Step 4: Calibrating the model. Also called model validation in the literature, this step consists of loading actual data in the model, running it, and verifying that the results match the observed numbers (from existing facilities) or make sense in terms of previous experience (planned facilities). If not, one must go back to step 2 and reformulate the model. Failing that, one must go back to step 1 and make sure that the system was really well understood and is accurately represented. Calibration is usually the most time-consuming step in simulation studies. Rarely, if ever, can a modeling analyst develop the perfect formulation in the first attempt. This step is also the most critical, because an improperly designed model cannot provide useful results.

Step 5. Designing the scenarios. In concert with the relevant agencies, the modeling analyst must decide what changes in the system to simulate and what impacts to measure. In a border crossing facility, possible scenarios include changes in inspection procedures, changes in traffic demand, and infrastructure improvements. Some scenarios can be modeled with a change in model parameters or input data, while more complex scenarios may require modifications in the model structure and logic.

Step 6. Running the scenarios. Here the calibrated model is actually put to use to achieve scenario results. Depending on the complexity of the desired scenario, changes in the model system components may be required.

Step 7. Analyzing the results. This is the final step in which the actual results are critically examined and a determination is made regarding what the implications are and what types of traffic operations are suggested by the results. The model can estimate impacts of different scenarios on queue lengths, time in queue, capacity of the facility (number of trucks serviced per unit time), and identification of bottlenecks.

MODEL INPUTS

The inputs consist of the following elements: traffic demand, service times at each inspection and toll facility, percent of trucks undergoing inspections, and average traffic speeds and concentration between system components. As in any other transportation study, the traffic is by far the most relevant input, and it will be discussed in more detail.

Since this bridge was under construction while this Project 0-1800 was being developed, there are no actual traffic or service times data to accurately represent it. The researchers had to use traffic data collected at the other Laredo bridges and service times collected not only in Laredo but also at newer facilities in El Paso, which represent the case study more accurately than a congested border crossing such as Laredo II.

Traffic Volumes

Truck traffic in Laredo has been growing at rather staggering rates, especially in the past five years. In addition, the percentage of empty trucks is rather high. Figure 3.1 shown the southbound traffic growth in Laredo for the past ten years, while figure 3.2 shows the observed yearly growth rates for the same period.

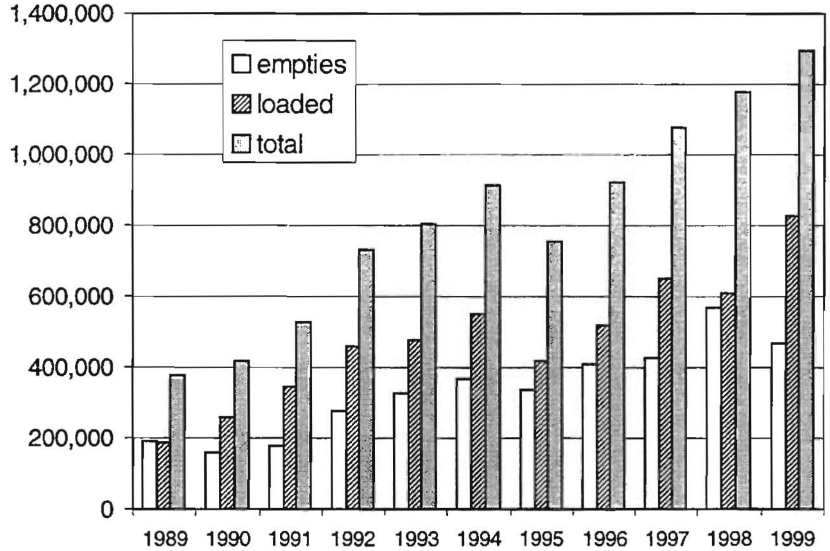

Figure 3.1 History of Southbound Truck Traffic in Laredo

Source: Laredo Bridge System and MPO

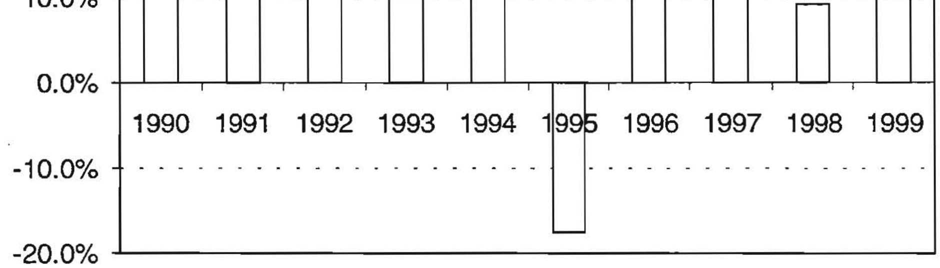

Figure 3.2 Southbound Truck Traffic Growth in Laredo

Source: Laredo Bridge System and MPO

Southbound truck traffic has grown at an average rate of 14 percent a year in the past ten years, factoring in the year 1995, which reflects a traffic decrease observed during the peso devaluation. If this trend continues, there will be more than 2.8 million southbound trucks in Laredo in 2005 and 5.5 million in 2010. At a more modest growth rate of 10 percent, numbers would still be quite high: 2.3 million trucks in 2005 and 3.7 million in 2010.

Traffic Distribution

Truck traffic demand in Laredo varies hourly within a day, by day within a week, and by month within a year. The percent of empty trucks also shows weekly, daily, monthly and hourly variations. Since empty trucks rarely undergo inspections, it is important to distinguish between empty and laden trucks in the simulation. In order to obtain an hourly distribution that represents a typical busy week day at the World Trade Bridge, researchers analyzed the hourly, weekly and monthly traffic distributions at Laredo II and Colombia, using data provided by the bridge manager and U.S. Customs.

Figure 3.3 shows the monthly distribution of Laredo's empty and loaded truck traffic. October is the busiest month, carrying 10 percent of the loaded trucks observed in the same year, as well as 9 percent of the empties.

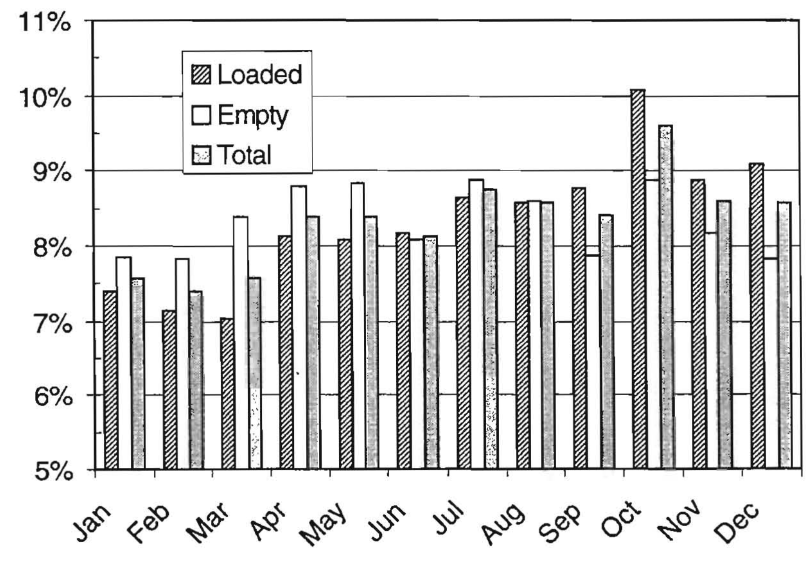

Figure 3.3 Monthly Traffic Distribution

Source: Laredo Bridge System, 1998 and 1999

Figures 3.4 and 3.5 respectively show the average 1998 and 1999 weekly distribution of Laredo's empty and loaded truck traffic at Laredo II and Colombia Bridges. For both bridges, the busiest day carries 19 percent of the empties, as well as (respectively) 21 and 20 percent of the weekly loaded trucks. Laredo I is carrying only a small number of small trucks, so it was not considered in the analysis.

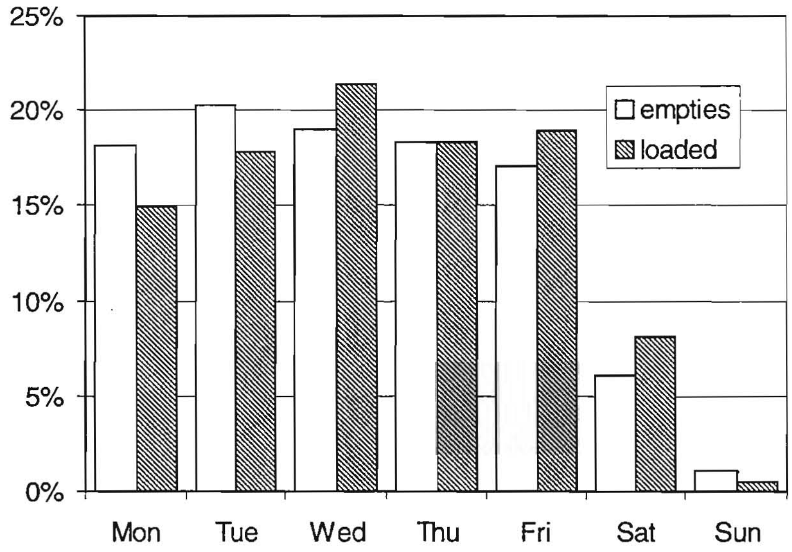

Figure 3.4 Weekly Traffic Distribution at Laredo II Bridge

Source: Laredo Bridge System, 1998 and 1999

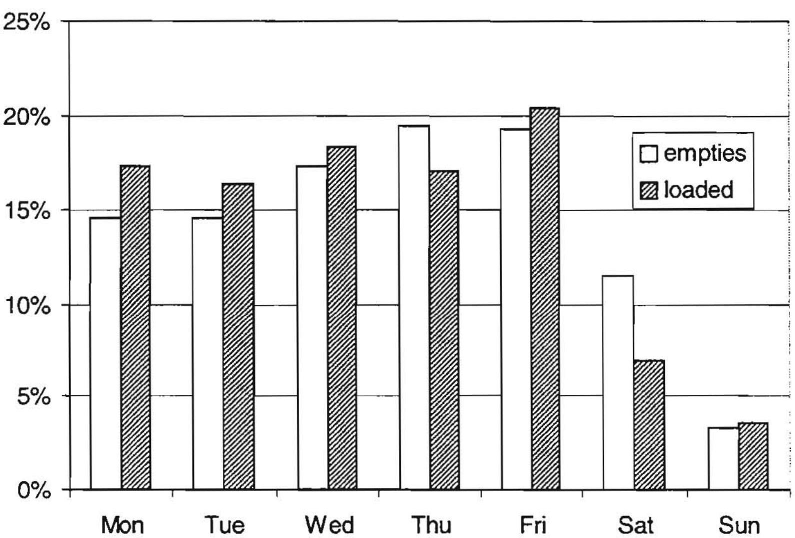

Figure 3.5 Weekly Traffic Distribution at Colombia Bridge

Source: Laredo Bridge System, 1998 and 1999

Figure 3.6 shows the hourly distribution of empty and loaded truck traffic at Laredo II, while figure 3.7 shows the same for Colombia. The percentages were totaled over Monday through Friday on an average workweek. Laredo II is currently congested, and for this reason its hourly distribution probably reflects its hourly capacity, rather than the actual hourly demand, especially in the afternoon and early evening.

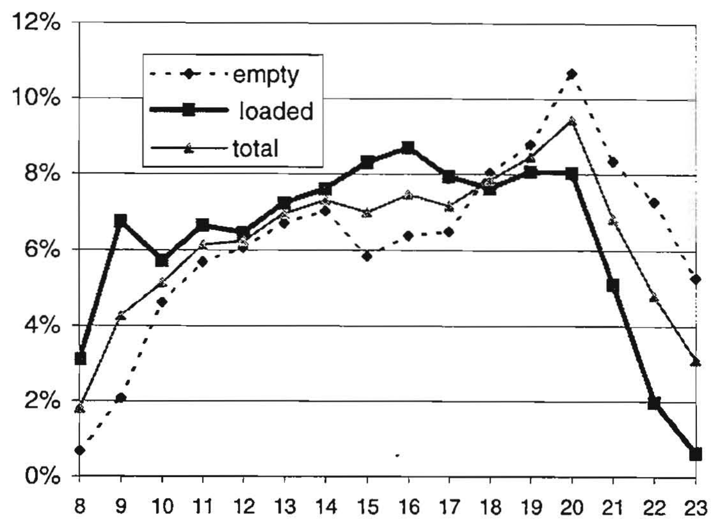

Figure 3.6 Hourly Traffic Distribution at Laredo II

Source: Laredo Bridge System, 1998 and 1999

Colombia is working under capacity, and its hourly distribution is more likely to represent the actual demand pattern of the Laredo area. Figure 3.7 clearly shows the demand gradually picking up throughout the day, increasing sharply at 5:00PM and peaking at 7:00PM, without the rather flat pattern seen for Laredo II, which is typical at facilities working near, at and over capacity. Assuming that the hourly pattern seen at Colombia is typical of Laredo truck traffic, it should be shifted by about an hour to account for the additional travel time to Colombia. This can be seen on the chart comparing total trucks, depicted in figure 3.8.

The data also indicates that empty trucks prefer to use Laredo II rather than Colombia. During the available raw data period, 9 percent of the empty trucks and 34 percent of the loaded trucks used Colombia, on the average. Figures 3.9 and 3.10 show this distribution by weekday. Traffic on Sundays is negligible and, although considered in the calculations, is not shown on illustrative graphs.

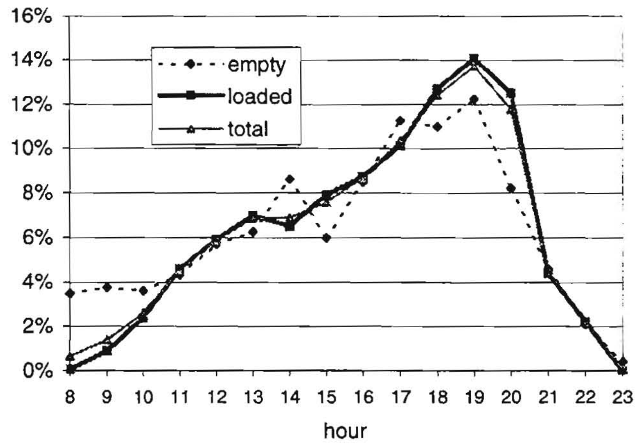

Figure 3.7 Hourly Traffic Distribution at Colombia

Source: Laredo Bridge System, 1998 and 1999

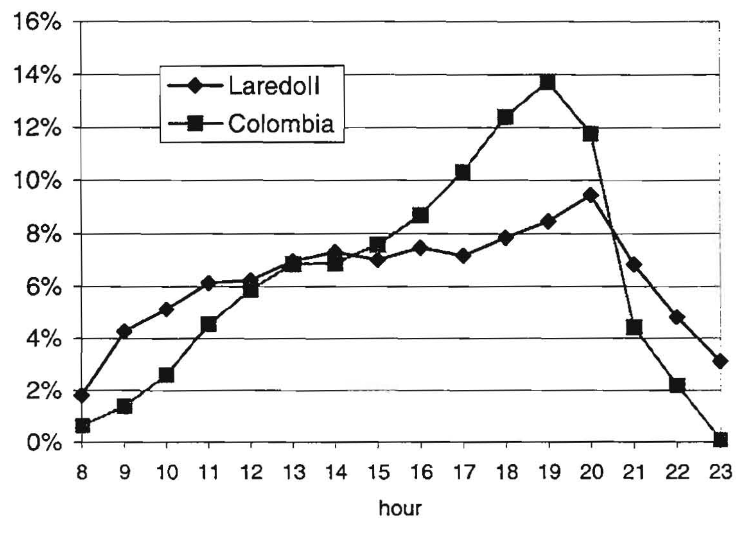

Figure 3.8 Hourly Traffic Distributions at Colombia and Laredo II

Source: Laredo Bridge System, 1998 and 1999

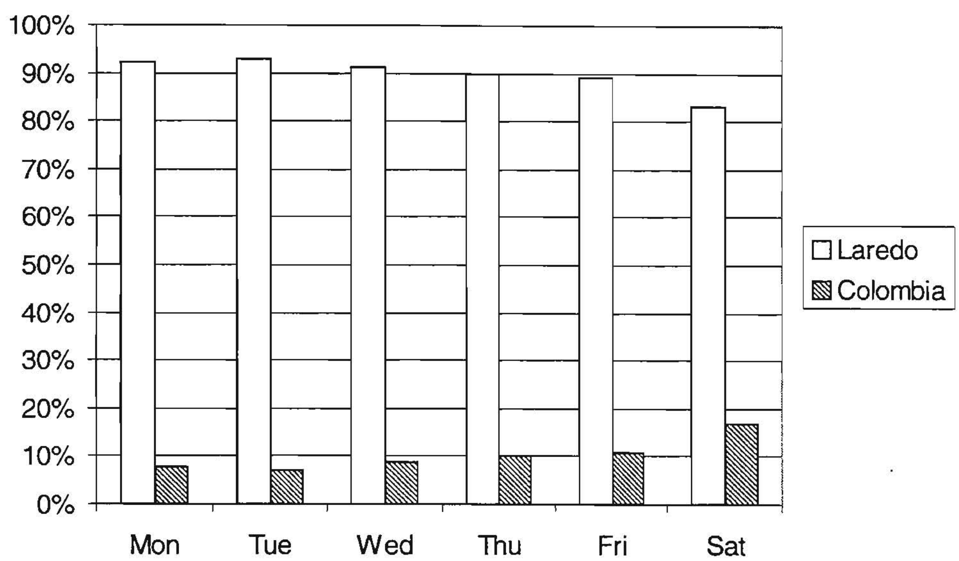

Figure 3.9 Distribution of Empty Trucks between Colombia and Laredo

Source: Laredo Bridge System, 1998 and 1999

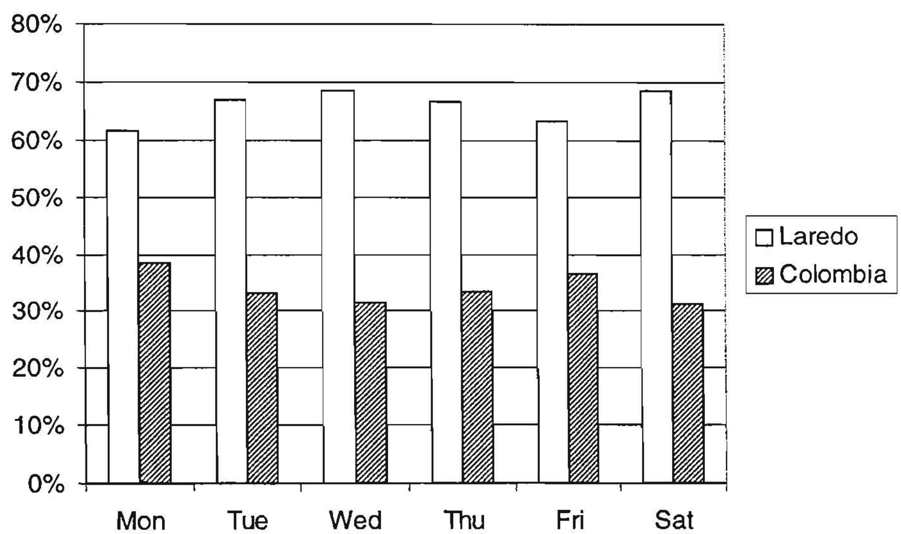

Figure 3.10 Distribution of Loaded Trucks Between Colombia and Laredo

Source: Laredo Bridge System, 1998 and 1999

Data Reduction for Use in Model

The simulation was designed to require two hourly distributions: one for loaded trucks and another for empties. Moreover, the preceding analysis indicates the existence of monthly, weekly and hourly fluctuations. In order to verify the differences between the "normal" day and the "busy" day, two types of hourly distributions were developed.

The monthly demand was obtained by multiplying the projected annual demand by monthly factors derived from data depicted in figure 3.3. For the "average day," researchers used the average monthly traffic (annual demand divided by 12). For the "busy" day, we used the percent of traffic observed in the busiest month. Then the weekly traffic was estimated by dividing the monthly demand by the number of weeks. To this was applied the highest weekday factor (shown in figure 3.4) to obtain the "busiest day," and the average working day factor to obtain the "average day." There was no need to consider weekends because the demand is considerably lower. Researchers used the hourly distributions observed in Colombia to derive an hourly distribution for the average and busiest days. Laredo II data was not considered a proper representation of the actual hourly demand because the bridge access is very congested. The hourly distributions used in the model are shown in chapter 4 (tables 4.2 through 4.5). They assume that all commercial traffic is distributed between the World Trade and Colombia Bridges.

Inspections Operational Details

This section consists of a summary of the inputs related to traffic operations for the World Trade Bridge. The case study layout and details were thoroughly described in Chapter 2. Figures 2.4 through 2.6 in chapter 2 also present details of the border crossing components. The reader may also refer to figure 3.12 (animation window) while reading this section.

The first inspection component consists of the U.S. Customs flashing beacon, at which point U.S. Customs inspectors select trucks to undergo export inspection (US1 in figures 2.4 and 2.6). According to conversations with U.S. Customs officials, the percentage of trucks undergoing export inspections, as well as the duration of such inspections, are subject to seasonal as well as legal changes, and they do not keep historical records of such data. However, it was observed at other border crossings—and confirmed by U.S. Customs in Laredo—that fewer than 1 percent of southbound trucks undergo inspections and that the time it takes to decide is between 5 and 10 seconds. These inspections are not carried out every day. On some days, there is no export inspection activity; on others it may occur sporadically, while on still other days requires a full day's activity. These situations were modeled as sub-scenarios, as described in chapter 4.

Trucks not undergoing U.S. export inspections go to the tollbooths (US5 in figures 2.4 and 2.6). Most trucks take advantage of prepayment. Times for paying toll observed at Laredo II varied between 5 and 12 seconds, with more trucks taking shorter than longer times. These observations tallied with those from El Paso (see the first report of this project, 1800-1), where sufficient data were collected to fit a skewed Erlang distribution of mean 14.7 seconds and a shape parameter of two. The El Paso distribution was used in this case study. Toll prices depend on truck weight, and for that reason there are scales upstream of the tollbooths. Researchers assumed a continuous weighting operation in which trucks are weighted while driving at speeds between 8 and 28 km/h (5 and 17 mph) over the scales.

After vehicles pay toll, they proceed through the bridge (US6 in figures 2.4 and 2.6) to the Mexican Police station, where, according to the Mexican consultant, they undergo a preliminary check of the documentation and a brief safety inspection (M3 in figures 2.5 and 2.6). When something is seriously wrong, trucks can be impounded or returned to the United States. Drivers may also be selected for a drug test. Service times for this station are based on ad-hoc estimates provided by the Mexican consultant, compared to data collected in El Paso, where more modern traffic operations are in effect. Data from El Paso indicate less than 0.25% of impounded and/or returned trucks. Service times were found to approximately follow an exponential distribution of mean 20 seconds.

From the Police station, drivers proceed to the signals that select trucks for primary inspection (M5 in figures 2.5 and 2.6). According to the data obtained by our Mexican consultant, 10 percent are selected and go to the primary inspection module, while the rest proceed directly to the final document check and exit the system. Service times at the signals were assumed to follow a normal distribution of mean of 60 seconds and a standard deviation of 15 seconds.

The trucks selected for primary inspection go to the inspection docks (M6 in figures 2.5 and 2.6). Service times were assumed uniformly distributed between 15 minutes and 2 hours. Ten percent of the trucks that underwent primary inspection can be selected for secondary. The selection procedure is analogous to the primary inspection and was modeled as a binary choice between either 45 seconds or zero. The latter is necessary because trucks that were not selected for primary inspection will pass through this area without stopping. See M7 and M8 in figures 2.5 and 2.6 for locations of the secondary inspection signals and docks.

The five exit gates are a mandatory stop for all trucks (M9 in figures 2.5 and 2.6). The service times were represented by a normal distribution with mean of 16 seconds and a standard deviation of 4 seconds. These figures were based on information provided by the project's Mexican consultant, who interviewed officials on the Mexican side.

In the absence of data for staffing schedules at the different inspection points and toll collection, researchers assumed all of them fully staffed at all times. Moreover, all service times used in the model are ad-hoc values based on data from existing bridges and information from border crossing officials. The Project 0-1800 team strongly recommends collection of actual data and recalibration of the model as well as of all the scenarios six or more months after the World Trade Bridge is open to traffic.

SUMMARY AND DISCUSSION OF MODEL ASSUMPTIONS

Assumptions Regarding Model Components

Table 3.1 shows a summary of service times assumed for each model component. Every inspection and toll collection facility was assumed fully staffed. In other words, researchers assumed no delay anywhere due to unmanned booths or inspection docks. They also assumed that eight U.S. Customs drop boxes would be located at the tollbooths, eliminating one stop and streamlining the traffic on the U.S. side.

Table 3.1 Assumptions for Model Components

Component	Delay	Percent trucks delayed	Capacity**
Flashing beacon on the U.S. side (US3)	Normal distribution with mean 8 seconds and standard deviation 2 seconds	Varies with scenario	3
U.S. export inspection docks (US4)	Triangular distribution with lower limit of 10 minutes, mode of 45 minutes, and upper limit of 3 hours.	1% of those delayed at beacon	10 queue = 6
U.S. drop boxes (US5)	Zero*	100%	8
Tollbooths (US5)	Erlang distribution with shape factor of 2 and mean 15 seconds	100%	8
Mexican Police M3)	Exponential distribution with mean 20 seconds	Varies with scenario	4
Signals for Mexican primary inspection (M5)	Normal distribution with mean 60 seconds and standard deviation 15 seconds	100%	17
Mexican primary docks (M6)	Uniform distribution with lower limit 15 minutes and upper limit 2 hours.	10%	110
Mexican signals for secondary inspection (M7)	Normal distribution with mean 60 seconds and standard deviation 15 seconds	10%	12
Mexican secondary docks (M8)	Uniform distribution with lower limit 15 minutes and upper limit 2 hours.	1%	12
Exit gate (M9)	Normal distribution with mean 16 seconds and standard deviation 4 seconds	100%	5

* Assumed located at the tollbooths.

** Number of trucks simultaneously served.

Assumptions Regarding Traffic Demand

The model assumes that traffic grows 10 percent each year and that the weekly, monthly and hourly distributions observed in the Laredo area prior to the opening of the World Trade Bridge would remain valid throughout the analysis period of 10 years. These assumptions were thoroughly discussed in the previous sections of this chapter. Additional assumptions, such as amount of traffic diversion from Colombia, were analyzed as scenarios (discussed in chapter 4).

It is very important to stress that the traffic data used in the model were obtained both from Colombia Bridge, which works considerably under capacity and from Laredo II, which was very congested. Hourly distributions for Colombia reflect a non-congested situation, while those of Laredo II reflect hourly distributions affected by heavy congestion; the model assumed hourly factors similar to those observed in Colombia, throughout the analysis period. This assumption was necessary for the model to reflect an arrival rate consistent with non-congested conditions. It is important to verify these assumptions with data from the World Trade Bridge as soon as its demand stabilizes.

The capacity of the adjacent roadway network was assumed to always be enough to carry the peak hours assumed for the future. For the year 2010, the peak hour is still about half the theoretical capacity of Loop 20. Loop 20 output may be limited by conditions of the network feeding it. Analysis of the Laredo network feeding the World Trade Bridge is beyond the scope of this research, but as both the city and the international traffic grow, this network output may affect hourly distributions at the facility entrance.

The model assumes that all trucks queued would remain there and cross the border (no balking), and it does not include the local traffic on Loop 20. Queues predicted by the model consist strictly of trucks trying to enter the World Trade Bridge. In reality, there would be some trucks postponing the crossing, and the queue would consist of local traffic plus the international trucks.

Assumptions Regarding Traffic Operations

On the Mexican side, the speed limits are known to be posted at 20km/h (12mph) throughout the facility. On the U.S. side speed limits were undecided when the model was being developed. They were assumed as 20mph throughout the facility and as 30 mph on the bridge itself. The project staff observed some speed conditions on congested conditions on the existing bridges. These averaged 9km/h (5.5mph).

The simulation program utilized does not support continuous speed changes. Only one speed was programmed on segments too short to allow for significant acceleration or deceleration between stops. On longer segments, the model assumes two possible speeds: speed limit if traffic is light and 9 to 10km/h if traffic is heavy. This assumption is a good approximation for the hourly distribution patterns discussed in this chapter, which show a rather sudden increase in demand. This approach was verified in a sensitivity analysis, which indicated very little sensitivity of crossing times to speed adjustments of this magnitude. Nevertheless, if the hourly distribution of traffic changes, or if the posted speeds are very different from those assumed, the researchers recommend reprogramming all segment speeds to allow for as many intermediate values as indicated by a new sensitivity analysis.

The model assumed that the loop leading to the U.S. export inspection docks (see figure 2.4) would always be used as additional queuing area as soon as one of the following conditions occurred:

(1) More than 3 trucks per lane are queued at the entrance, or

(2) Traffic is slow on the bridge deck, or

(3) Traffic is queuing at the toll collection.

The model assumed that the additional loop on the Mexican side (see figure 2.5) would be built during the year 2000 and would always be used as additional queuing area as soon traffic slowed down on the Mexican bridge egress.

The model also assumes that the World Trade Bridge will remain a commercial-only facility throughout the analysis period. This assumption needs to be verified in a sensitivity analysis if the bridge is open to non-commercial traffic and the volumes of that traffic become significant.

All intersections and junctions inside the facility were assumed to operate as a four-way stop, with 100 percent compliance with the first-in, first-out rule Additional assumptions regarding traffic operations, such as hours of operation of the U.S flashing beacon, were considered as model scenarios and are discussed in chapter 4.

ANIMATION

The animation window shows a schematic layout of the facility, with the Mexican and U.S. sides separated. The bridge is represented in the middle of the picture, with its simulated capacity increased to include that of the area right in front of the tollbooths, which could not fit into the animation screen. This arrangement was necessary to fit both sides of a large facility in an average computer window. Figure 3.11 depicts a picture of an animation window frozen during an actual model run. It shows the trucks entering the facility, paying toll, and being inspected. The next chapter discusses the model scenarios and results.

The flashing beacon of the U.S. export inspections was animated with a small icon of a beacon. It is gray when not in service. When flashing, it changes to red and yellow, and displays the number of trucks stopping at the beacon at the same time. The Mexican primary and secondary signals were assumed in full service all day and were animated with a small icon of a traffic light, with the number being serviced shown next to it. The Mexican signals have several booths, represented by yellow areas next to the traffic light icons.

The tollbooths, inspection docks, Mexican Police, and exit gates are represented by yellow areas. The numbers inside each yellow area represent the number of trucks being serviced. In figure 3.12, there are two trucks in the export docks and none at the waiting area. There is one truck paying toll. There are 4 trucks in the Mexican Police shed, 11 at the Mexican signals for primary inspection, 38 at the Mexican primary inspection docks (17 on one side and 21 on the other), one at the secondary signals, none at secondary inspection, and 5 at the exit gates.

In order to ensure easy visibility, each truck was represented by a small circle, changing colors depending on inspections, as listed below. The color code is as follows:

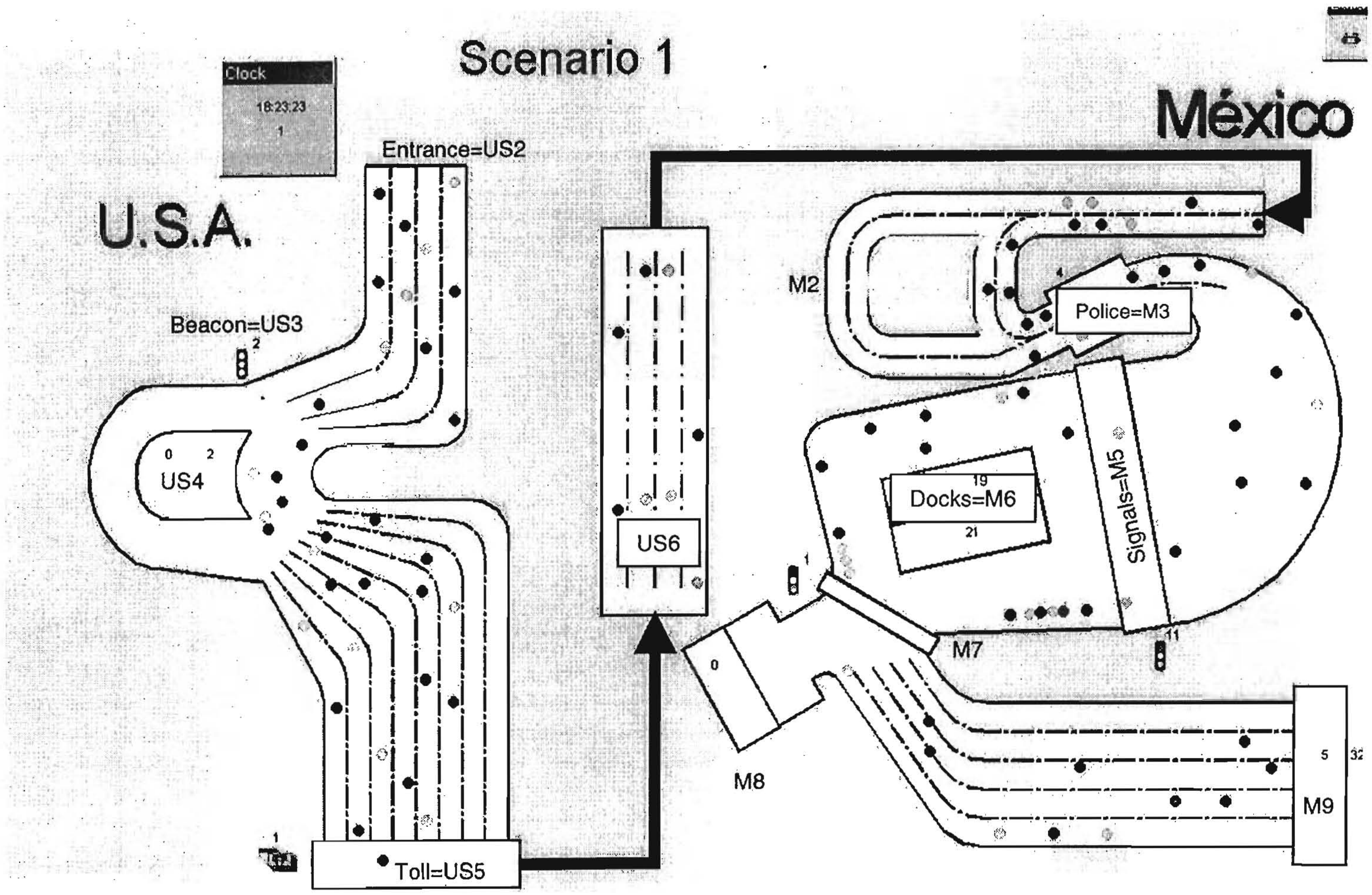

Figure 3.11 Animation Window

Green: empty

Blue: loaded, not inspected

Red: underwent export inspection

Purple with White Center: underwent Mexican primary inspection

Purple with yellow center: underwent Mexican secondary inspection

Three-lane Loop 20 appears in the animation only when congested by trucks queuing at the facility entrance. In such situations, the animation screen depicts three stacks of circles at the facility entrance, each displaying a number representing the number of trucks queued on each one of Loop 20 three lanes adjacent to the facility.

The animation screen has a clock (also seen at the upper left of figure 3.12) to indicate the time of the day, as well as the number of days being simulated. It runs from 8:00AM to midnight. When the simulation is over, the clock resets itself to 8:00AM. The number below the time indicates the number of working days being simulated (1 in this case).

PRACTICAL MODEL USE

The model user does not need to have a background in programming to see the scenarios being animated. To run the program, open the software, open the file, then click on the "run" icon at the top bar and wait. The simulation clock will show times throughout the day. At the end of the run, the model will automatically display a summary of the results. When the results have been inspected, the user can close the dialog box, click on the reset arrow on the left side of the top tool bar, and close the file without saving it.

Changing the model inputs and inspecting graphical results in more detail requires moderate training on the software. Changing the model logic requires considerably more training. Should any untrained user decide to change the model, the researchers strongly recommend using the "save as" feature to create another file, and changing only the back-up file.

MODEL USE FOR CASE STUDY ANALYSIS

Using the model for a thorough analysis of the facility is more complicated and requires several changes in the programming and calibration to account for different scenarios. In this case, there are three questions of particular interest:

- Can the facility carry future traffic without problems? If not, when will it become congested?
- When it does become congested, what are the bottlenecks and what can be done to improve the situation?
- What types of inspection activities cause more problems to transborder traffic flow or cause congestion on Loop 20?

In order to answer these questions, it is necessary, first, to develop a combination of scenarios that represent combinations of traffic demand levels and traffic operations, and then to run them. The results provide enough information to identify traffic levels and/or inspection activities that cause congestion, as well as identification of which are the major bottlenecks.

Once the bottlenecks are identified, the possible solutions need to be tested. This means modifying the model to include the possible solution, running it, and verifying that the proposed modification is indeed capable of eliminating or drastically reducing congestion.

Chapter 4 documents the development and analysis of scenarios, the identification of bottlenecks, impacts of different inspection activities, and analysis of proposed solutions.

CHAPTER 4
CASE STUDY RESULTS

CASE STUDY SCENARIOS

Once the World Trade Bridge is open, the capacity utilization of its components can change for various reasons, such as: staffing, number of detailed inspections actually made, paperwork automation in Mexico and in the U.S., traffic distribution between the new Bridge and Colombia, and traffic growth rates. A model must have all these components programmed, requiring inputs for all these factors.

The study of traffic demand in Laredo, discussed in chapter 3, points to a combination of scenarios with 10 percent traffic growth rates and two different trip distribution rates between World Trade Bridge and Colombia. This assumption is based on a Presidential Permit stipulation that Laredo I and II would be closed to commercial traffic.

The other factors were analyzed as modified "sub-scenarios," as needed, to identify problems, analyze bottlenecks, and verify impacts on Loop 20. The scenarios are listed on table 4.1, and the sub-scenarios below it. The last column of table 4.1 indicates which sub-scenarios were addressed in the case study analysis.

Table 4.1 Case Study Scenarios

Scenario	Typical Day	Yearly Growth Rate	Attraction to New Bridge		Sub-Scenarios
			Empty	Loaded	
1: Base case (2000)	Busiest	10%	90%	65%	A, B
2: Base case (2000)	Average	10%	90%	65%	none
3: High attraction (2000)	Busiest	10%	95%	75%	A, B
4: High attraction (2000)	Average	10%	95%	75%	A
5: Year 2005	Busiest	10%	90%	65%	A, B, C
6: Year 2005	Average	10%	90%	65%	A, D
7: Year 2010	Busiest	10%	90%	65%	A, B, D, F
8: Year 2010	Average	10%	90%	65%	A, B, D, F

Sub-Scenarios

A Mexican Federal Police and U.S. inspectors stopping trucks all day long.

B Mexican Federal Police stopping trucks all day long, and U.S. inspectors stopping trucks at the facility entrance (flashing beacon on) during two peak hours.

C Mexican Federal Police stopping trucks all day long, and no U.S. inspection activity.

D Mexican Federal Police randomly stopping only 20 percent of trucks, and U.S. inspectors stopping trucks at the facility entrance (flashing beacon on) during two peak hours.

E Mexican Federal Police randomly stopping only 20 percent of trucks at an average of 20 seconds, and no U.S. inspection activity.

F Mexican Police and U.S. Customs inactive.

In addition to the scenarios and sub-scenarios described above, it was necessary to develop several scenario modifications to analyze causes of congestion and to test recommendations for managing future traffic. This was especially true for the year 2010, when it became clear that the current layout could no longer accommodate the future traffic at the assumed levels of growth, hourly peaks, percent empties, and diversion from Colombia. These scenario modifications are discussed later in this chapter.

Traffic Demand Inputs

Tables 4.2 through 4.5 present the hourly distributions for each scenario. The traffic data and the approach used to arrive at the model inputs were discussed on chapter 3. The model was formulated for two separate hourly distributions: one for empties and one for loaded trucks. For each assumed traffic growth rate and trip distribution rate, the numbers in these tables estimate the hourly number of trucks for the busiest weekday of the busiest month, and for the average weekday of the average month.

Table 4.2 Hourly Number of Trucks for Study Scenarios 1 and 2: Base Case

	Scenario 1: Busiest Day and Month		Scenario 2: Average Day and Month	
Hour	Empty	Loaded	Empty	Loaded
8	67	26	63	19
9	64	69	61	50
10	76	132	72	97
11	101	170	96	124
12	111	201	105	147
13	153	187	145	137
14	106	227	100	166
15	150	251	142	183
16	200	291	189	213
17	195	365	184	267
18	217	404	205	295
19	145	360	138	263
20	81	126	77	92
21	62	64	58	46
22	37	2	35	1
23	7	0	7	0
Total	1773	2874	1677	2102

Table 4.3 Hourly Number of Trucks for Study Scenarios 3 and 4: High Attraction

	Scenario 3: Busiest Day and Month		Scenario 4: Average Day and Month	
Hour	Empty	Loaded	Empty	Loaded
8	70	30	66	22
9	68	79	64	58
10	81	152	76	111
11	107	196	101	143
12	117	232	111	169
13	161	216	153	158
14	112	262	106	192
15	159	289	150	212
16	211	336	199	246
17	206	422	194	308
18	229	466	217	341
19	154	415	145	303
20	86	146	81	107
21	65	73	62	54
22	39	2	37	1
23	8	1	7	1
Total	1872	3317	1770	2426

Table 4.4 Hourly Number of Trucks for Study Scenarios 5 and 6: Year 2005

	Scenario 5: Busiest Day and Month		Scenario 6: Average Day and Month	
Hour	Empty	Loaded	Empty	Loaded
8	107	42	101	31
9	103	110	98	81
10	123	213	116	156
11	163	273	154	200
12	179	323	169	236
13	246	302	233	221
14	171	366	162	268
15	242	404	229	295
16	322	469	304	343
17	314	589	297	430
18	349	650	331	476
19	234	579	222	424
20	131	203	124	149
21	99	102	94	75
22	60	3	56	2
23	12	0	11	0
Total	2855	4629	2701	3385

Table 4.5 Hourly Number of Trucks for Study Scenarios 7 and 8: Year 2010

	Scenario 7: Busiest Day and Month		Scenario 8: Average Day and Month	
Hour	Empty	Loaded	Empty	Loaded
8	173	67	163	49
9	166	178	157	130
10	198	343	188	251
11	262	440	248	322
12	288	521	272	381
13	397	486	375	355
14	275	590	260	431
15	390	651	369	476
16	518	755	490	552
17	505	948	478	693
18	563	1048	532	766
19	377	933	357	682
20	211	327	200	240
21	160	165	151	121
22	96	4	91	3
23	19	0	18	0
Total	4598	7456	4349	5452

MODEL ASSUMPTIONS

In order to develop a model for the World Trade Bridge before it opened to traffic, it was necessary to make assumptions about inspections activities, traffic operations, and toll collection procedures and schedules. Most of these assumptions were discussed on Chapter 3 (model development), and they are summarized here for convenient referral.

Loop 20 Flow Rate and International Traffic Demand

The maximum theoretical capacity of a freeway lane is 2,800 passenger cars per hour per lane, with a truck equivalency factor of 4. Therefore, it is impossible for three-lane Loop 20 to output more than 2,100 trucks per hour. Since the maximum hourly demand estimated for the year 2010 is 1,611 trucks (see table 4.5), the research team assumed that all demand can arrive at the bridge entrance at the rates shown on table 4.5.

Inspections and Traffic Operations

All inspection and toll collection facilities were assumed fully operational and fully staffed all day long. Service times at each component were discussed in Chapter 3, as well as percent of trucks subject to each inspection.

An important assumption regarding traffic operations is that the World Trade Bridge will carry at most negligible amounts of auto traffic throughout the target year. If the number of autos becomes significant in the future, and the number of trucks is close to the number assumed in the model, all the results discussed here need to be updated, and the model logic itself needs to be reprogrammed to take the autos into account.

The case study analysis is limited to the World Trade Bridge and does not include local traffic on Loop 20. All discussions about queues spilling back onto Loop 20 refer to model results and, therefore, only to the number of international trucks. In reality, even if the World Trade Bridge remains a commercial-only facility throughout 2010, queues beyond Loop 20 and Mines Road will include local traffic going to other destinations.

In terms of traffic operations within the facility, researchers assumed the speeds discussed on Chapter 3. The bridge was assumed to open from 8:00AM to midnight on weekdays. The research team did not model weekends, as traffic demand is considerably lower.

Researchers also assumed that the loop leading to the export docks on the U.S. side (see figure 2.4) will always be open to through traffic every time:

- Traffic from the Mexican side is spilling back and slowing down the bridge, or
- Trucks are queuing upstream of the tollbooths, or
- Trucks are queuing at the facility entrance.

ANALYSIS APPROACH AND MODEL OUTPUTS

Each relevant scenario was run nine times in order to obtain 95 percent confidence intervals and average values for the model outputs. The simulated time was one working day of 16 hours (8:00AM to midnight). The results were analyzed at all locations in the model that are potential bottlenecks, as well as where traffic queues may spill back into Loop 20 ramps.

On the U.S. side, there are the following critical locations to analyze, from northeast to southwest (see figures 2.4, 2.6, 3.12, and 4.1):

- The two-lane segment of Loop 20 between Mines Road off-ramps and IH35 on-ramps.
- The two-lane segment of Loop 20 between Mines Road off-ramps and Mines Road on-ramps.
- The three-lane segment of Loop 20 between the facility access and Mines Road on-ramps.
- The flashing beacon used by inspectors to stop trucks and select some to undergo export inspections.
- The queuing loop leading to the U.S. export docks.
- The export inspection docks.
- The tollbooths.

On the Mexican side, there are the following critical locations (see figures 2.5, 2.6, 3.12, and 4.1):

- The queuing loops leading to the Federal Police inspection.
- The station for Federal Police inspection.
- The traffic lights at which trucks are selected for primary inspection.
- The primary inspection docks.
- The traffic lights at which trucks are selected for secondary inspection.
- Secondary inspection docks.
- The exit gate.

In addition to the above, the model was programmed to obtain the utilization of the area between the toll exit and the bridge exit on the Mexican side. The utilization can be compared to the capacity of the component, indicating bottlenecks. For service areas such as toll collection and inspections, capacity is the number of trucks being serviced at the same time, plus the number of trucks that can wait for service without hindering the rest of the traffic.

For the roadway links between service areas, such as the bridge lanes, the term "lane capacity" was used to indicate the maximum concentration. In border crossing facilities, traffic is naturally very slow, and it stops often. As a result, the traditional definition of lane capacity—related to maximum flow rates—has no practical application. Hence, this document uses "capacity utilization" to indicate the concentration, or the number of trucks on the lane at any given time.

Most scenario runs started with the busiest day, sub-scenario A. This scenario consists of Mexican Police active all day, and U.S. Customs inspectors stopping trucks at the facility flashing beacon all day causing an average delay of 8 seconds when trucks are selected to undergo export inspections. It is important to note that, according to U.S. Customs officials in Laredo, this will not be a common scenario. Nevertheless, given its potential to cause traffic congestion on Loop 20, it was always examined. When sub-scenario A indicated no problems, there was no need to examine other sub-scenarios. When it did indicate queues, a more thorough analysis was warranted.

SCENARIOS 1 AND 2: BASE CASE

The model indicates negligible potential for congestion during the opening year of this bridge. There was no queue anywhere during any of the model runs, even in scenario 1, sub-scenario A, which is the busiest day, with both Mexican Police and U.S. Customs inspectors active throughout the day.

All model elements worked at less than half-capacity, except the Mexican Federal Police booths, assumed manned all day long. Trucks undergoing no inspections crossed at an average time of less than 11 minutes, with a minimum of less than 10 minutes and a maximum of 15.

It is concluded that the facility will operate under capacity with the estimated year 2000 traffic, if all model assumptions are met, including the current levels of traffic distribution between Laredo and Colombia. The results also indicate that, as long as the model assumptions are met, Loop 20 will be unaffected by all-day inspection activity at the bridge entrance combined with all-day activity by the Mexican Police.

SCENARIOS 3 AND 4: HIGH ATTRACTION, YEAR 2000

Scenarios 3 and 4 examined a situation where traffic attraction to the new bridge would be higher than the levels observed in the recent past. The facility could still support a higher traffic diversion from Colombia without queues, even on the busiest day (scenario 3), sub-scenario A (Mexican Police and U.S. Customs stopping truck during the entire day). There was some queuing at the Mexican loops upstream of the Police booths, which spilled into the bridge, slowing down traffic flow between approximately 6:30PM and 7:50PM. The queue did not affect the tollbooth operations (U.S. side).

Sub-scenario B would be a more common situation, and it was therefore analyzed in more detail. Table 4.6 shows the amount of time to complete the border crossing process required by trucks undergoing different combinations of inspections. The results shown in table 4.6 summarize five random model runs (five days), with a total sample size of 25,893 trucks, averaging 5,178.6 per day. No trucks were subject to all three inspections in any random run, since the probability of the same truck undergoing all three inspections is very small.

Table 4.6 Time to Complete Border Crossing: Scenario 3, Sub-scenario B

	Number	Time	to	Cross	
Inspections	of Trucks	Minimum	Average	Maximum	Sd.Dev
Mexican Primary	1585	0:27:56	1:23:12	2:31:10	0:30:39
Mexican Primary and Secondary	74	1:00:37	2:23:57	3:50:31	0:47:06
U.S. Export	42	0:27:18	1:16:37	2:10:01	0:34:03
U.S. Export and Mexican Primary	6	1:09:25	1:54:12	2:49:34	0:41:43
None	24186	0:09:33	0:13:50	0:31:42	0:04:47
All trucks	25893	0:09:33	0:18:36	3:50:31	0:22:28
Average trucks per day	5178.6				

For trucks undergoing inspections, the average time to cross was around one hour and twenty minutes for one inspection, and two to two-and-a-half hours for two inspections. These times were determined primarily by the inspection times, not by the traffic flow conditions. All inspection docks on both sides worked at less than half capacity all the time. The Mexican signals also worked at less than half capacity. The only component working near capacity was the Mexican Police, assumed manned full-time. Under these conditions, traffic slowed to a "snail's pace" upstream of the Police lanes from 6:20PM to 8:10PM, affecting the speeds on the bridge lanes, but not spilling back into the tollbooths. This condition can be seen in Figure 4.1, which shows a screen capture of this scenario during the middle of the peak hours. Both loops leading to the Mexican Federal Police are full, and the queue is starting to spill back to the bridge lanes.

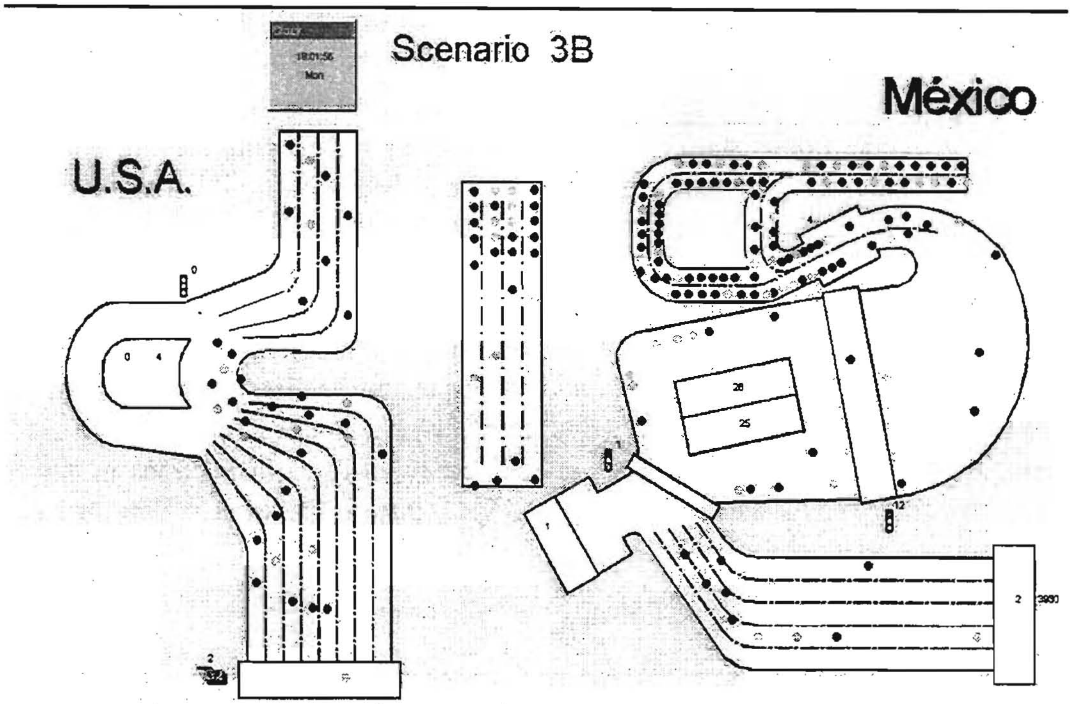

Figure 4.1 Scenario 3B: Screen Capture

Figure 4.1, captured at 7:00PM simulated time, clearly shows the tollbooths working under capacity, with only two booths in use, as indicated by the number on the booth icon. All four of the Mexican Police's booths are busy. Both queuing areas leading to the Police are full, spilling back into the bridge lanes. However, this slight spill does not hinder traffic on the U.S. side.

Figure 4.2 shows the distribution of times taken to cross the border for trucks undergoing no inspections. The average time was under 14 minutes, with a minimum under 10 minutes. The maximum time to cross was less than 32 minutes. These times are higher than those observed for scenarios 1 and 2, but they affected a small percentage of the demand. The distribution is clearly skewed to the left (shorter times more frequent than longer times). Over 77 percent of the non-inspected trucks crossed the facility in 15 minutes or less, and over 94 percent crossed it in

25 minutes or less. It is concluded that the facility can carry the traffic under capacity in all conditions in the year 2000, even if it diverts some traffic out of Colombia.

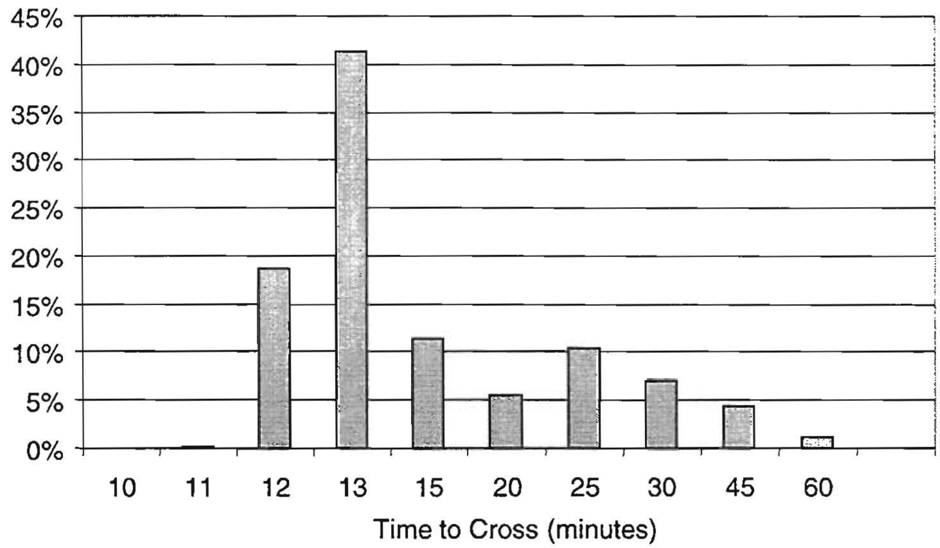

Figure 4.2 Time to Cross Without Inspections: Scenario 3B

SCENARIOS 5 AND 6: YEAR 2005

Scenarios 5 and 6 assume that there will no longer be high diversion from the Colombia Bridge. At a 10 percent yearly growth rate, traffic in the year 2005 will be 60 percent higher than in the year 2000, and any incentives to divert from Colombia that might have existed in the beginning were assumed to no longer apply. The current percentage of loaded trucks and the current shape of the hourly distribution were assumed to remain the same. The reader may want to refer to figure 2.7 to see three critical intersections on Loop 20 that may be affected by queues:

- Mines Road on-ramp (470m or 1,570ft from the facility entrance),
- Mines Road off-ramp (1,260m or 4,200ft from the facility entrance), and
- IH35 on-ramp (570m or 1,900ft from the facility entrance).

Scenario 5

With increased traffic, the facility no longer supports all-day inspections on the Mexican Police lanes on a busy day (scenarios 5A, 5B, and 5C). In these scenarios, the queue for Mexican Police booths will spill back into the bridge lanes around 4:15PM and into the tollbooths around 4:40PM. It reaches the facility entrance in the middle of the first peak hour (5:40PM), about 40 minutes after U.S. Customs' flashing beacon begins to stop traffic. After that, the queue reaches Mines Road on-ramps around 5:55PM, Mines Road off-ramps between 6:10 and 6:15PM, and

IH35 off-ramps at 6:20PM. The potential queue continues to block Mines Road on-ramps until 10:00PM, as shown in figure 4.3.

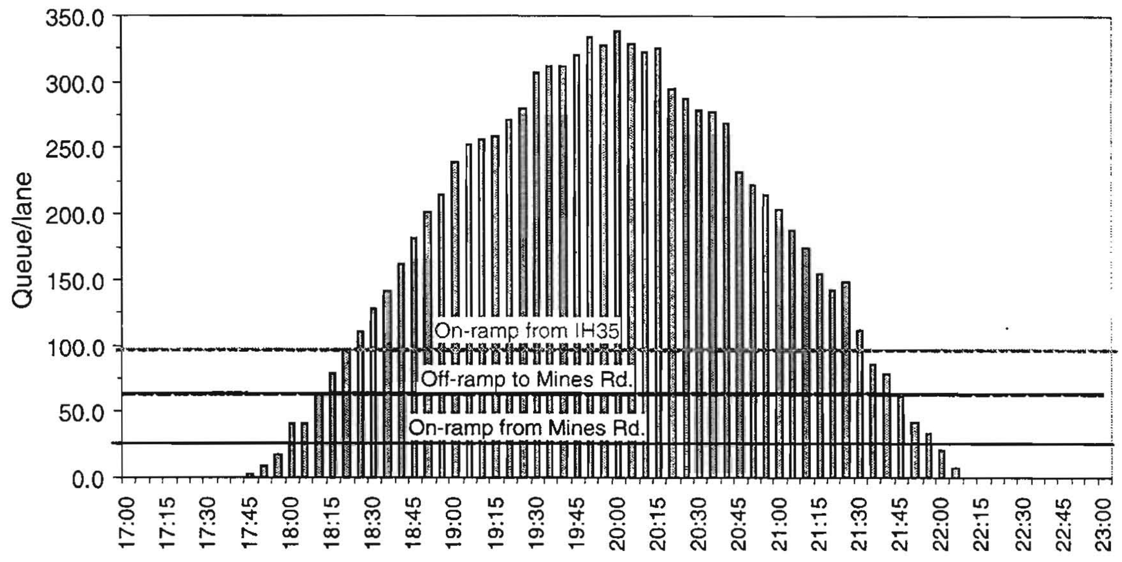

Figure 4.3 Average Queue per Lane on Loop 20 (Scenario 5, Sub-Scenarios A, B and C)

For scenarios 5A, 5B, and 5C, on the average, 67 percent of the trucks will be queued 10 seconds or less, and only half of them will be able to cross the facility in 30 minute or less. The average time to cross increases to about 46 minutes for trucks undergoing no inspections. The times to cross are shown in table 4.7 for different inspections. All inspection and toll components will be working under capacity, except the Mexican Police (assumed manned all day long). Therefore, the problem is lack of queuing area to store the peak hour traffic hindered by the Mexican Police stopping every truck, all day long. Under this situation, U.S. Customs works on a congested facility, and the effect of its further traffic stoppages is to increase an already significant congestion on Loop 20.

Table 4.7 Time to Complete Border Crossing: Scenarios 5A, 5B and 5C

Type of Inspections	Time to Cross		
	Minimum	Average	Maximum
None	0:10:05	0:45:55	2:45:04
Mexican Primary	0:29:06	1:59:08	4:07:08
Mexican Primary and Secondary	1:10:13	2:51:43	4:00:00
U.S. Export	0:28:24	1:42:25	3:35:09
U.S. Export and Mexican Primary	1:50:02	2:10:05	2:30:59

Next, researchers checked scenario 5D, which consists of a busy day when U.S. Customs export inspectors are active during two peak hours, and Mexican Police is stopping only 20 percent of the trucks, randomly throughout the day (a type of operation observed in some bridges). The average time to cross decrease a minute or two with respect to those observed in table 4.7, and the percent of trucks crossing in 30 minutes or less increases to 62 percent. The average and maximum potential queue decreases considerably, but Loop 20 is still very congested.

Figure 4.4 shows the queues developing on Loop 20. The queue starts forming at the Mexican Police and reaches the bridge at 5:10PM, when the U.S. Customs beacon is turned on. It reaches the facility entrance around 6:30PM and the Mines Road on-ramp around 6:45PM. At 7:05PM, the queue reaches Mines Road off-ramp, and it reaches the IH35 on-ramp 20 minutes later. The queue blocks the Mines Road on-ramp over two hours.

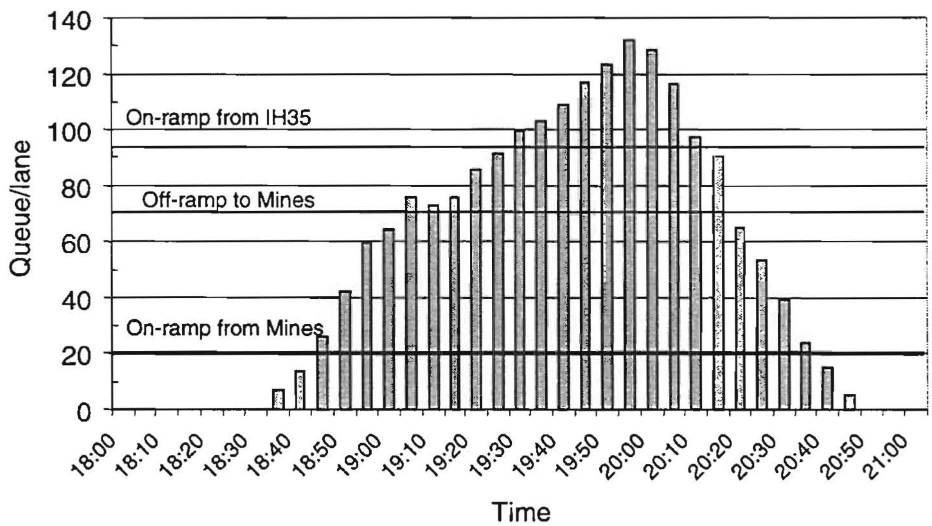

Figure 4.4 Average Queue per Lane on Loop 20 (Scenario 5D)

Scenario 6

In 2005, the World Trade Bridge will show instability in its ability to carry the average day demand on days with full-time inspection activity on the part of both U.S. Customs and Mexican Police (scenario 6A). The simulation indicates that there will always be some queuing at the entrance. The variability programmed in the model caused the maximum queue per lane to vary between 3 and 21 trucks, depending on the trial run. Figure 4.5 shows a comparison among four trial runs. In one run (trial 4), the queue reached Mines Road on-ramp and blocked it for about 15 minutes. In the other three trials, the queue barely reached halfway to Mines Road on-ramp. Shorter queues were more likely than longer queues.

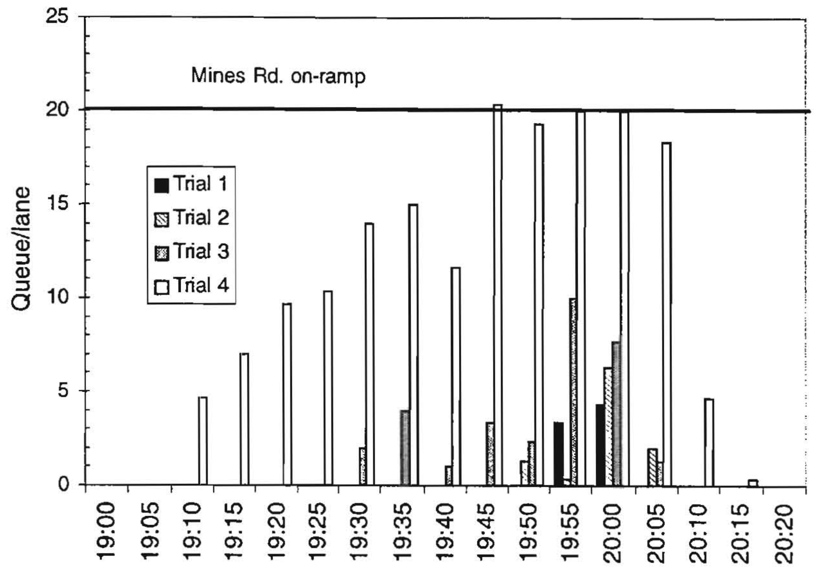

Figure 4.5 Average Queue per Lane on Loop 20 (Scenario 6A)

Table 4.8 shows the average times to cross for scenario 6A. For trucks undergoing no inspections, the average time was 22 minutes, a twofold increase with respect to the baseline scenario. The distribution of times to cross is skewed to the left, with over 70 percent of trucks crossing in less than 30 minutes. Figure 4.6 shows a screen capture of scenario 6A, with the queue at the facility entrance.

Table 4.8 Time to Complete Border Crossing: Scenario 6A

Inspections	Number of Trucks	Time to Cross Minimum	Average	Maximum
Mexican Primary	416	0:28:52	1:36:26	3:19:29
Mexican Primary and Secondary	18	1:08:02	2:45:17	4:16:51
U.S. Export	7	0:47:24	1:24:19	2:19:10
All three inspections	1		3:04:23	
None	7020	0:10:10	0:22:09	1:11:26
Average trucks per day	7461			

Table 4.9 depicts confidence intervals for the activity of each model component, calculated over nine trials. All components other than the Mexican Police worked under capacity. All inspection docks remained under capacity, even at the peak utilization. The tollbooths, exit gates, and Mexican primary inspection signals reached full utilization only during the peak hours. It is clear that the bottleneck is the two-lane access to the Mexican Police.

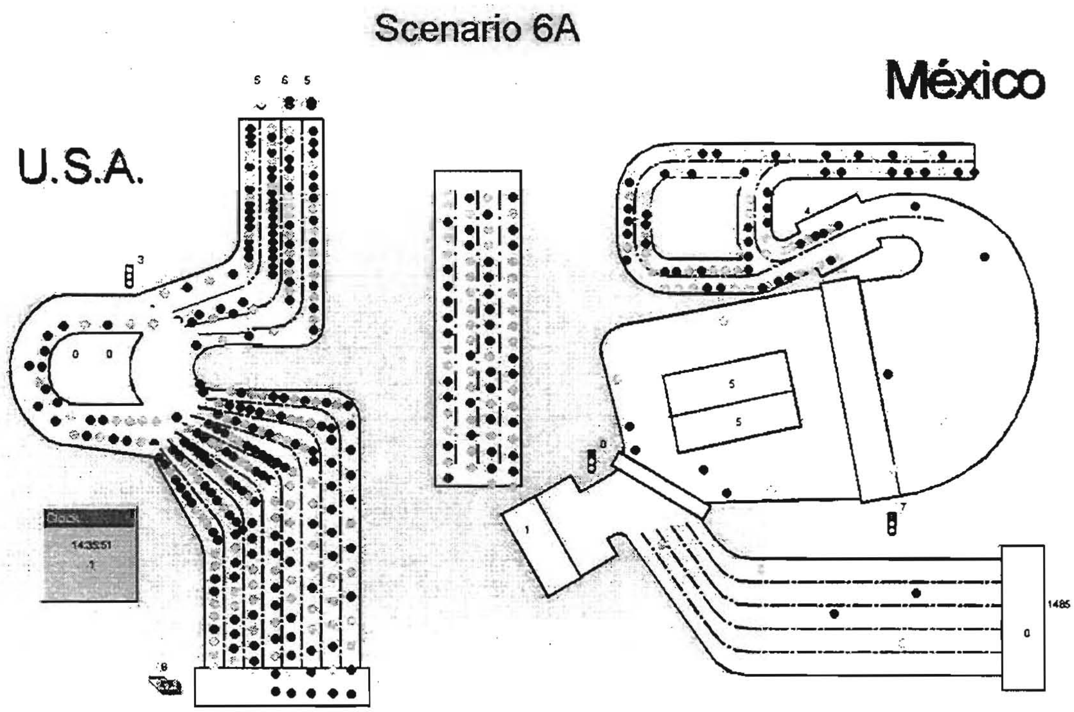

Figure 4.6 Scenario 6A Screen Capture

A trial run with scenario 6D was used in order to verify this bottleneck (Mexican Police stopping only 20 percent of the trucks). In this scenario, the facility could carry the demand without any problems or queues on the U.S. side, in spite of U.S. Customs activity during the peak hours. All components worked under capacity at all times, except the Mexican Federal Police lanes, which reached their full capacity before, during, and after the peak period.

It is concluded that the facility will be able to carry the year 2005 traffic, except during special circumstances, such as the busiest days of the year, and/or on days with full-time inspection activity. There will be some queuing on the average days when Mexican Police and U.S. Customs are stopping trucks all day. In this situation, the queue will not necessarily block the nearest ramps on Loop 20, but may do so.

SCENARIOS 7 AND 8: YEAR 2010

The simulation indicates that the facility will no longer be adequate for the average day demand, if the hourly distribution, percent of empties, and trip distribution patterns remain the same as those assumed for 2000. There was no need to run scenario 7 (busiest day), since the average day scenario 8F indicated that queues would block Mines Road on-ramp right after 5:00PM and continue blocking it for six hours. The potential queue would block Mines Road off-ramp from 5:15PM to 10:55PM, and IH35 on-ramp from 5:20PM to 10:50PM. This theoretical queue would peak at 8:00PM, with 715 trucks per lane. This means a potential queue

Table 4.9 Scenario 6A Results (Nine Trials)

Component	Capacity	Parameter	95% Lower	Confidence Middle	Interval Upper
Access queue, per lane	20*	Minimum Queue Size	0	0	0
		Average Queue Size	0	0.18	0.68
		Maximum Queue Size	0	7.2	20.1
Export docks	10	Minimum Utilization	0	0	0
		Average Utilization	1.4	1.7	2.0
		Maximum Utilization	4.4	6.2	8.0
		Total inspected	24.6	28.8	33.0
Tollbooths	8	Minimum Utilization	0.0	0.0	0.0
		Average Utilization	2.5	2.7	2.9
		Maximum Utilization	8.0	8.0	8.0
		Total served	6084.0	6084.0	6084.0
Bridge, per lane	19**	Minimum Utilization	0	0	0
		Average Utilization	4.4	4.7	5.0
		Maximum Utilization	19.0	19.0	19.0
Mexican Police	4	Minimum Utilization	0.0	0.0	0.0
		Average Utilization	2.2	2.3	2.5
		Maximum Utilization	4.0	4.0	4.0
		Total stopped	6082.7	6083.4	6084.1
Primary signals	17	Minimum Utilization	0.0	0.0	0.0
		Average Utilization	6.3	6.4	6.5
		Maximum Utilization	15.7	16.4	17.1
		Total served	6068.1	6071.8	6075.5
Primary docks	110	Minimum Utilization	0.0	0.0	0.0
		Average Utilization	21.0	23.2	25.5
		Maximum Utilization	48.4	54.0	59.6
		Total inspected	302.4	327.0	351.6
Secondary signals	12	Minimum Utilization	0.0	0.0	0.0
		Average Utilization	0.3	0.3	0.4
		Maximum Utilization	3.9	4.6	5.7
		Total	6067.4	6071.6	6075.8
Secondary docks	12	Minimum Utilization	0.0	0.0	0.0
		Average Utilization	0.8	1.1	1.4
		Maximum Utilization	2.8	4.2	5.6
		Total inspected	11.6	14.6	17.6
Exit gate	5	Minimum Utilization	0.0	0.0	0.0
		Average Utilization	1.6	1.7	1.8
		Maximum Utilization	5.0	5.0	5.0
		Total	6067.4	6071.2	6075.0

*Maximum concentration from facility entrance to Mines Road on-ramp

**Maximum concentration including area immediately after tollbooths

18km (11 miles) long, not counting local traffic. Figure 4.7 shows the development of this theoretical queue on Loop 20.

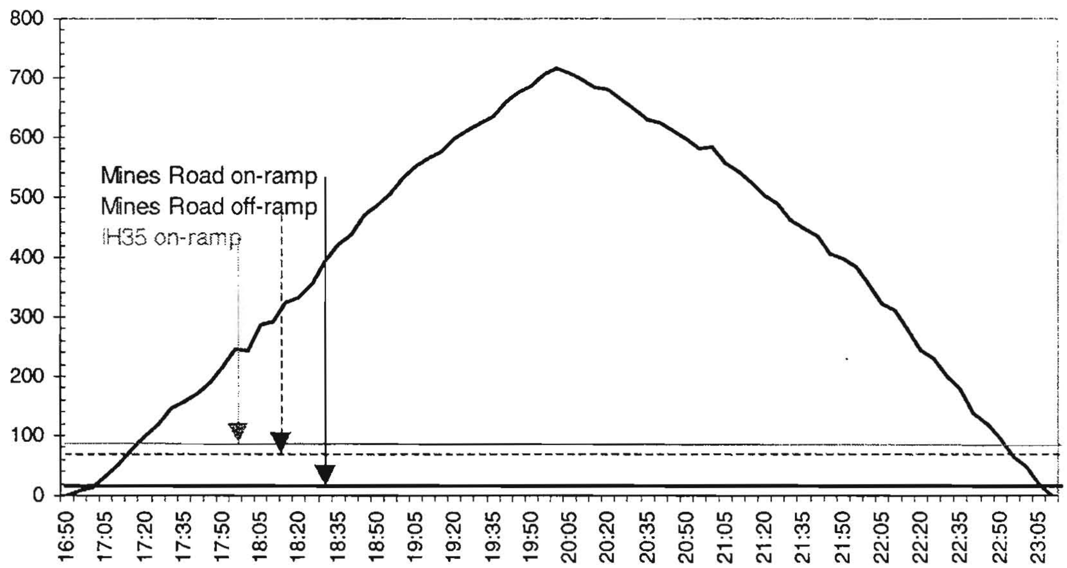

Figure 4.7 Potential Queue per Lane on Loop 20 (Scenario 8F)

The average time to cross without inspections was more than two hours, and the maximum was nearly three-and-a-half hours. The average (non-zero) queue time exceeded 51 minutes. Scenario 8F results indicated that the inspection docks were still working below capacity. The scenario result points to insufficient traffic circulation area as the main cause of congestion, since Mexican Police and U.S. Customs were both assumed non-operational, and all other inspection facilities were below capacity. Researchers ran several scenario modifications to identify locations and starting year of specific bottlenecks and to analyze impacts of possible solutions.

Scenario Modifications

There are two phases in the analysis of future traffic circulation on the World Trade Bridge: investigative phase and problem-solving phase. In the investigative phase, the project team used modified scenarios and layouts, to identify bottlenecks. In the problem-solving phase, the team members developed scenarios to test impacts of possible modifications of facility layout, traffic operations, and demand management. Some scenarios are hypothetical, developed to identify specific problems and/or analyze impacts of specific solutions.

The need for additional traffic circulation between the bridge and the Mexican Police was clear from the results of scenario 8F. Therefore, researchers ran several scenario modifications on a modified layout obtained by doubling the capacity of the queuing loops on the Mexican side. A modified scenario was built with two more lanes on each loop and four more lanes for the Mexican Police (figure 4.8). In addition, researchers built another modified layout consisting of figure 4.8 loop configuration on the Mexican side and analogous duplication on the U.S. side (loops leading to the export inspection docks, also used as queuing area). These modified layouts were tested for several scenario modifications, as discussed later in this section.

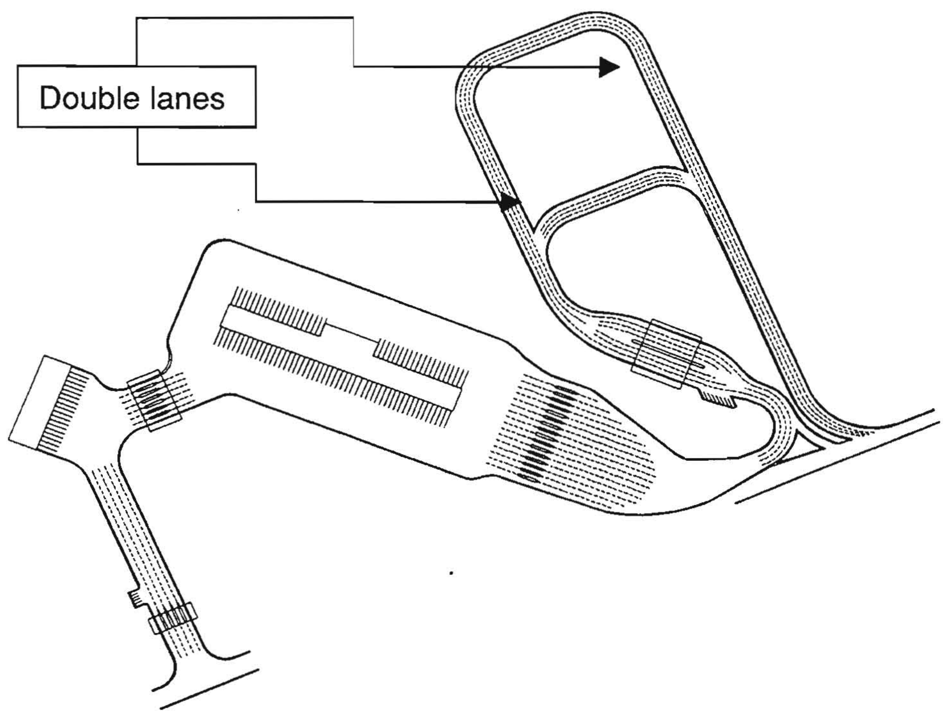

Figure 4.8 Double Capacity of Mexican Queuing Loops

The following basic scenario modifications were tested in the investigative and problem-solving phases:

- Double the Mexican queuing loop layout (see figure 4.8), in order to isolate the impacts of doubling the number of lanes.
- Hypothetical layout with infinite capacity on the Mexican side, and the U.S. side unchanged, in order to identify any bottlenecks on the U.S. side only.
- Double both queuing loops (U.S. and Mexico).

The following traffic demand modifications were tested for the target year, during the problem-solving phase:

- Eliminate empty trucks. Modification tested for different combinations of inspection activities by U.S. Customs and Mexican Police, and for different layouts.
- Eliminate peak hours, distributing traffic more evenly during the day. Modification tested for different combinations of inspection activities by U.S. Customs and Mexican Police, and for different layouts.

- Combinations of reducing empties and reducing peak-hour factors.

Investigative Phase

The investigative phase started by running the busy day for the year 2006 on the double-loop modification (figure 4.8), using sub-scenario F conditions (both Mexican Police and U.S. Customs inactive). The objective of sub-scenario F was to isolate Mexican traffic circulation as the cause of queues. The year 2006 demand was estimated by increasing year 2005 traffic by 10 percent.

The model indicated that the modified layout carries the 2006 busy day traffic with peak-hour queuing inside the facility, which spills into Loop 20 for only a few minutes, with a maximum queue per lane of 3.4 ± 2.6 trucks. Crossing times were comparable to those observed in the year 2000.

When the Mexican Police and U.S. Customs are active, traffic circulation becomes unstable. For sub-scenario A conditions (full-time activity), the maximum queue on Loop 20 increases to 6.4 ± 4.58 trucks per lane. The average time taken to cross was about 22 minutes, with 70 percent of the trucks crossing in less than 30 minutes.

These results indicate that the traffic circulation problem can be significantly improved by duplicating the Mexican Loop by the first half of 2006. Even the busy day, scenario A, conditions can be operated without blocking Mines Road on-ramps. In order to verify the recommendation to duplicate the loops by the year 2006, researchers ran the year 2007 busy day with full inspections. In this case, the maximum queue skyrocketed to over 190 trucks per lane, blocking Mines Road ramps during several hours, clearly indicating the year 2006 as the best to duplicate the loops.

The project team analyzed the target year 2010 in detail. For this year, the double-loop layout brought very little relief of afternoon and evening traffic congestion. Doubling the loop was not enough for the facility to withstand sub-scenario 8F conditions (Mexican Police and U.S. Customs inactive on an average day). With this expanded layout, the queues spilled into the bridge around 4:55PM, into the tollbooths at 5:20PM, and into the access at 6:05PM. Congestion on Loop 20 continued to be nearly as serious as with the current layout, as shown in figure 4.9. Nevertheless, all inspection and toll components were working under capacity most of the day, as shown in table 4.10.

The results clearly indicate that the Mexican loop will become a bottleneck in the future. However, the queue spill-back from the Mexican side masks any additional bottlenecks that may be occurring on the U.S. side. In order to analyze this phenomenon, researchers used a hypothetical scenario with infinite capacity on the Mexican side.

This scenario indicated that it would be impossible to have U.S. Customs activities all day in the busy day of the target year. The flashing beacon becomes a bottleneck in the target year, causing queues on Loop 20 that reach far beyond IH35 on-ramps, peaking between 260 and 300 trucks per lane.

Table 4.10 Scenario 8F, Double Loop Modification

Component	Capacity Utilization		
	Minimum	Average	Maximum
Tollbooths	0	47%	100%
Primary signals	0	59%	100%
Primary docks	0	33%	65%
Secondary signals	0	7%	50%
Secondary docks	0	15.6%	42%
Exit gate	0	56%	100%

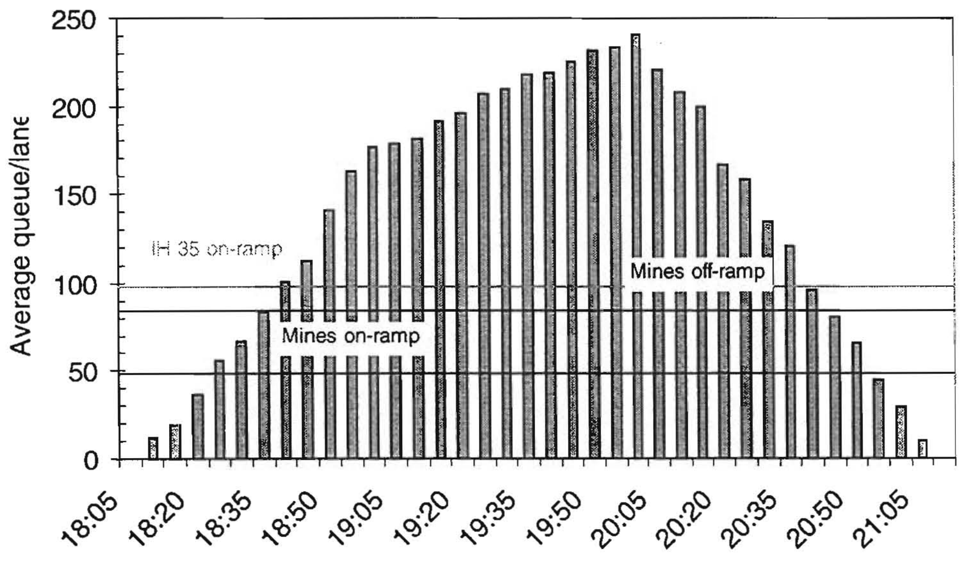

Figure 4.9 Queues for Scenario 8—Double Loop Modification

Next, researchers tried the average day demand (scenario 8), still with U.S. Customs active all day. In this case, the maximum queue had a 95 percent confidence interval of 13.6±4.39 trucks. This volume is not enough to block Mines Roads on-ramps, but it comes quite close, which means that there is a potential for blockages. The inspection docks were sometimes full during the peak hours, but their queuing area was enough for the waiting trucks. The 95 confidence interval for the maximum dock utilization was 9.8±1.6 trucks.

In order to identify when additional queuing and dock area would be needed on the U.S. side, the research team ran sub-scenario A for the busy day of the intermediate years, starting with 2006. According to the results, queuing area will become a problem on the U.S. side, on busy days with full-time export inspection activity in the year 2008. The docks are starting to work at full capacity, and, although their queuing area is not, it is becoming close to capacity (about 70%). The queuing loop on the U.S. side should be duplicated in the year 2008, and the export docks should be expanded about 50 percent.

Scenario 7F (no U.S. Customs activity) was then run for the target year, to isolate the tollbooths. Provided that the assumed service times and staff scheduling are accurate, the tollbooths will have enough capacity for the busy day traffic in the target year. They were full less than 3 percent of the time, and the queuing area upstream of them had enough capacity for these peaks.

It is important to realize that this "infinite capacity" scenario is impossible and should not be used in planning. One side cannot plan its size and number of lanes based on the assumption that the other side will have infinite capacity. Planning must make an allowance for the inevitable queues created by the series of inspection activities that will stop traffic.

In order to verify the impacts of doubling queuing areas on both sides of the border, the target year was run for sub-scenario A conditions, with both the Mexican and U.S. queuing loops doubled in capacity. Doubling these loops on both sides of the border provided little relief of congestion on average days at locations where inspections take place. Although queues decrease substantially, Loop 20 continued to be blocked for several hours. It is clear that traffic demand management strategies are needed to avoid future congestion in Laredo.

Conclusion. In 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 (1) the inspection docks on either side or (2) the tollbooths on the U.S. side. However, the model 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. The problem-solving phase examined these options.

Problem-Solving Phase

The problem-solving phase started by analyzing the current layout (no expansions) under two hypothetical scenarios: (1) traffic evenly distributed throughout the operating hours of the bridge and (2) no empty trucks. With uniformly distributed traffic, the World Trade Bridge could carry the demand for the average day of the year 2010, with the current percent of empties and current trip diversion from Colombia, under sub-scenario A conditions (Police and U.S. Customs active all day). The average crossing time (no inspections) was around 30 minutes. The busiest day demand could not be served without impacting Loop 20 intersections. The tollbooths and inspection docks, however, were enough for the busiest day demand. This means that the current traffic circulation area cannot support the year 2010 busy day, even without any peaks.

Another hypothetical scenario consisted of completely eliminating the number of empty trucks while maintaining the other unfavorable conditions. Under sub-scenario A conditions, the year 2010 average day traffic would circulate easily, with average crossing times of 20 minutes (no inspections). There was some queuing inside the facility, spilling into the tollbooths from

6:30 to 8:30PM, but never reaching the entrance. The busiest day traffic, however, could not use the facility without congestion. Around 6:30PM, the queue would already be blocking the IH35 on-ramps. All model components (docks, toll, etc.) worked considerably below capacity on the average, and served the maximum demand well, without queues.

These results suggest that reducing peaks and decreasing empties are strategies worth of further analysis, in conjunction with infrastructure expansion. The scenario combinations are depicted in table 4.11, which also shows one important result of each scenario: whether or not the queue blocks Mines Road's on-ramp, the first important point on Loop 20 upstream of the bridge. Blank cells on table 4.11 indicate that the particular combination was not analyzed.

The first combination analyzed was doubling the loops on both sides, and totally eliminating peaks (traffic uniformly distributed during the day). In this case, the facility could serve the year 2010 busiest day demand without any queues, under sub-scenario A conditions (Mexican Police and U.S. Customs active all day). The average times to cross (no inspections) were about 30 minutes.

In order to test a more realistic peak-hour reduction, researchers developed another scenario modification distributing the daily traffic according to the adjusted hourly factors depicted in figure 4.10. This figure also depicts the observed hourly factors for comparison. Hourly factors were calculated for total traffic (empty and loaded trucks) and were applied to the total daily loaded and total daily empties to obtain model inputs.

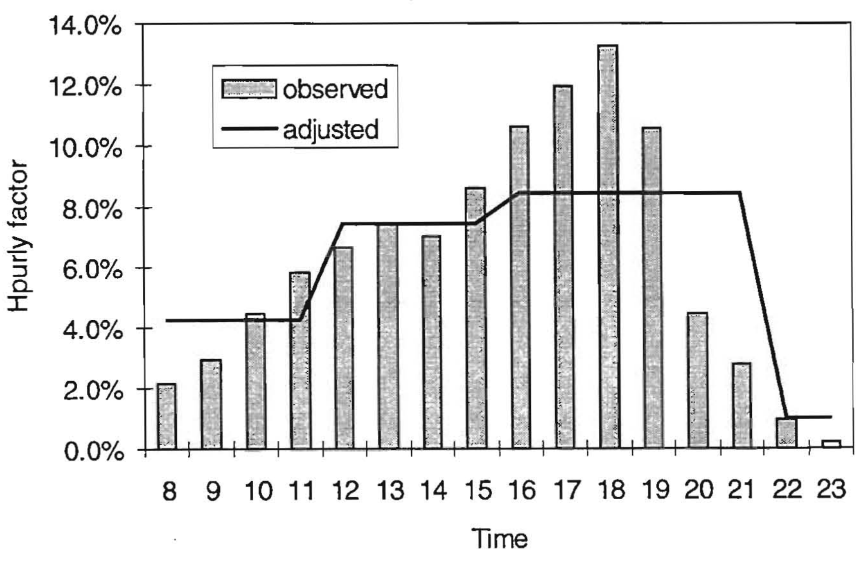

Figure 4.10 Hypothetical Hourly Distribution

The next scenario modification consisted of combining the peak reduction, as shown in figure 4.10, with doubling the loops. This was not enough to allow full-time inspection activities on Mexican Police and U.S. Customs on a busy day. The queues reach Mines Road on-ramps at

6:15PM, and remain blocking this intersection almost until closing time (11:00PM). The queues increase until they pass IH35 on-ramps at 7:00PM. The results indicate a clear need to combine approaches to solve the problem. Removing the empty trucks on the busy day eliminated all congestion, zeroing the queues and allowing crossing times of the same magnitude as those observed in 2000.

On an average day, however, the facility could support all traffic demand without queues, under sub-scenario A conditions. The crossing times were comparable to those observed in the year 2000. The outer loop on the Mexican side was never used. All docks worked below capacity, except the U.S. export docks, which reached maximum capacity and required use of about 80 percent of the queuing space. It is clear that decreasing peaks is a powerful strategy to manage future international traffic in Laredo.

The next option tested was removal of empties on the double-loop layout, for the busiest day. Under scenario A, the results were rather unstable, highly sensitive to the built-in variation in stopping times at the Mexican Police and flashing beacon. Out of seven trial runs, there were four without queues, one with queues reaching IH35 on-ramps, one with queues reaching Mines Road on-ramps, and the last one with queues spilling onto Loop 20 but remaining downstream from Mines Road on-ramps. The average day traffic, however, could cross without any queues. Eliminating empties will therefore eliminate congestion for the average day. On busy days, traffic will be unstable, very sensitive to variability.

Table 4.11 Year 2010: Impacts on Loop 20 / Mines Road On-Ramps

		Loops Layout	
Day	Sub-scenario A	Current	Doubled
Average	No Empties	No	No
	No peaks	No	No
	Adjusted peaks		No
Busy	No Empties	Yes	Sometimes
	No peaks	Yes	No
	Adjusted peaks		Yes
	Adjusted peaks and no empties		No

CONCLUSIONS AND RECOMMENDATIONS

Under the model assumptions, the World Trade Bridge will operate below capacity on all of its components for the year 2000, in all sub-scenarios, including additional diversion out of Colombia Bridge. In the year 2005, the facility may still support an average day with full-time inspection activity by both the Mexican Police and U.S. Customs, but the conditions are unstable and there will always be some queuing which may or may not block Mines Road on-ramps. On the busy day, however, the facility could not support any scenario requiring stoppages at the Mexican Police and U.S. Customs, without queues hindering Mines Road on-and off-ramps. The facility could easily serve an average day without U.S. Customs activity and with Mexican Police activity limited to 20 percent of the trucks.

In year 2010, the facility will no longer carry the estimated demand, in any situation. The traffic circulation within the facility was hindered, although the toll plaza and the inspection docks were working under capacity (caveat: as long as fully staffed and service times are as assumed).

This result required a detailed analysis to identify bottlenecks and analyze possible solutions. The analysis indicated that the solution for international traffic demand in Laredo cannot depend entirely on infrastructure expansions. The solution will require a combination of strategies to modify demand patterns as well as to decrease and/or reroute empty trucks. The strategies analyzed included only facility expansion and traffic operations, which are achievable at the local and state levels. The research team did not analyze strategies requiring inspection streamlining or other measures that would require changes either in federal legislation, or on international commerce practices.

The following strategies can control future congestion in Laredo (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. Verify the feasibility of enforcing this strategy using a 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, to encourage voluntary re-routing to other facilities, especially if the World Trade Bridge is open to private vehicles.
- Double the Mexican queuing loop by 2006.
- Double the U.S. queuing loop and increase by 50 percent the export docks capacity by 2008.

A very important caveat: all case study conclusions and recommendations are based on a model developed while the World Trade Bridge was under construction. For this reason, the model uses ad-hoc data for all inputs, including, but not restricted to, traffic demand, inspection times, staff scheduling, traffic operations, and speed limits within the facility. The Project 0-1800 research team strongly recommends an implementation phase to check all model assumptions, and, if necessary, recalibrate the model and rerun scenarios. Ideally, this data collection and recalibration should be done periodically after the implementation, since calibration conditions may change.

CHAPTER 5

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

This report discussed the characteristics of current and future traffic flows through the World Trade Bridge in Laredo, which opened to traffic in April 2000. The focus of this research effort was the southbound international traffic in Laredo's World Trade Bridge. The facility was under construction during the development of Project 0-1800.

The study approach was to develop an animated simulation of the entire southbound facility and to run the model for different scenarios. The results identify bottlenecks, test possible solutions, and estimate future impacts of traffic on crossing times and on Loop 20 traffic.

MODEL ASSUMPTIONS

The model starts at the facility entrance. Local traffic on Loop 20 is not simulated. Only traffic queuing at the entrance (and therefore on Loop 20) is represented. After that, the model simulates all border crossing components on both sides of the border. Model inputs include (but are not restricted to) delays, percent stopped, and staffing schedules. None of these data was available because the facility was under construction. They were determined based on architectural plans, interviews with inspection and city officials on both sides of the border, and data collected for other border crossings in Texas.

Assumptions Regarding Model Components

Chapters 2 and 3 discussed the model assumptions in detail. Table 3.1 from chapter 3 shows a summary of delay times assumed for each model component. It is important to stress that these times and percent delayed were obtained from other facilities and may not be the same for the World Trade Bridge. The researchers strongly recommend a thorough implementation phase to collect data, verify these assumptions and recalibrate the model, after the traffic stabilizes on the new bridge.

Every inspection and toll collection facility was assumed fully staffed. In other words, the research team assumed no delay anywhere due to unmanned booths or inspection docks. It was also assumed that eight U.S. Customs drop boxes would be located at the tollbooths, eliminating one stop and streamlining the traffic on the U.S. side.

Assumptions Regarding Traffic Demand

The model assumes that the traffic grows 10 percent a year and that the weekly, monthly, and hourly distributions observed in the Laredo area prior to the opening of the World Trade Bridge will remain valid throughout the analysis period of 10 years. These assumptions are thoroughly discussed in chapter 3. Tables 4.2 through 4.5 in chapter 4 depict the hourly distributions used in the model scenarios.

The issue of traffic diversion from Colombia was analyzed as an additional scenario for the year 2000 only. It was assumed that, as demand increases in the subsequent years, diversion from Colombia will return to 1999 levels.

It is very important to stress that the traffic hourly distributions used in the model were based on those observed at the Colombia Bridge, which worked considerably under capacity, and at Laredo II, which was very congested. The assumed hourly distributions should be checked against actual data from the World Trade Bridge as soon as its demand stabilizes.

The capacity of adjacent roadway network was assumed to always be enough to output the peak hours assumed for the future. For the year 2010, this capacity is still considerably less than the theoretical capacity of Loop 20, but Loop 20 output may be limited by conditions of the network feeding it. Analysis of the Laredo network feeding Loop 20 is beyond the scope of this research.

Assumptions Regarding Traffic Operations

On the Mexican side, the speed limits were assumed as 20 km/h (12mph) throughout the facility. On the U.S. side, they were assumed as 20 mph throughout the facility, and as 30 mph on the bridge itself.

Only one speed was programmed on segments too short to allow for significant acceleration or deceleration (the same as the speed under congestion). On longer segments, the model assumes two possible speeds: speed limit for light traffic, and 9 to 10 km/h for heavy traffic. This assumption was verified by a sensitivity analysis, which showed very little sensitivity to speed adjustments in between these two magnitudes.

The model assumes that the loop leading to the US export inspection docks (see figure 2.1) would always be used as additional queuing area as soon as one of the following conditions occurred:

- More than 3 trucks per lane are queued at the entrance, or
- Traffic is slow on the bridge deck, or
- Traffic is queuing at the toll collection.

The model assumes that the additional loop on the Mexican side (see figure 2.2) would be built during the year 2000 and would always be used as additional queuing area as soon traffic slowed down on the Mexican bridge egress.

The model also assumes that the World Trade Bridge will remain a commercial-only facility throughout the analysis period. This assumption needs to be verified in a sensitivity analysis if the bridge is open to non-commercial traffic. If auto traffic becomes significant, the model logic will no longer be valid.

Each intersection and junction inside the facility was assumed to operate as a four-way stop, with 100 percent compliance with the first-in, first-out rule. Additional assumptions regarding traffic operations, such as hours of operation of the U.S. Customs' flashing beacon, were considered as model scenarios.

SUMMARY OF RESULTS

It is important to remember that the queues predicted by this model consist of the potential number of trucks trying to enter the facility. The model has no provision for queue balking, since no reliable data on this behavior is available for international border crossings in Texas. The study does not include an analysis of local traffic on Loop 20. Actual queues on Loop 20 would be different from those predicted by the model, due to the mix of local traffic and international trucks. However, the number of queued trucks still gives an excellent measure of the facility's ability to serve the traffic demand, as well as of its impacts on Loop 20.

Year 2000

The model indicates that the World Trade Bridge will work under capacity and without any queues for the year 2000 traffic, even if there is higher diversion from Colombia. This result happened for the worst sub-scenario: both U.S. Customs and Mexican Police selecting trucks for inspection during the busiest day.

Trucks not subject to inspections crossed the border at an average of 14 to 15 minutes for the high diversion scenario, and 10 to 12 minutes for the levels of traffic distribution observed in 1998 and 1999.

Year 2005

In 2005, the facility no longer supports inspections on the Mexican Police lanes on a busy day, regardless of the amount of activity of U.S. Customs. (scenarios 5A, 5B, and 5C). In these scenarios, the queue for Mexican Police booths will spill back and reach Mines Road on-ramps, continuing to block Mines Road for several hours, depending on the sub-scenario. All inspection and toll components are working under capacity, except the Mexican Police. Therefore, the problem is lack of queuing area to store the peak hour traffic hindered by the Mexican Police stopping every truck, all day long. Under this situation, U.S. Customs works on an already congested facility, and the effect of its further traffic stoppages is to increase congestion on Loop 20.

For the average day, the World Trade Bridge will show instability on days with full-time inspection activity on the part of both U.S. Customs and Mexican Police (scenario 6A). The maximum queue per lane varies between 3 and 21 trucks, depending on the trial run. Shorter queues are more likely than longer queues, and only the longer one reached Mines Road on-ramp. All components other than the Mexican Police work under capacity. It is clear that the bottleneck is the two-lane access to the Mexican Police.

It is concluded that the facility will be able to carry the year 2005 traffic on most days. There will be queues on Loop 20 during special circumstances, such as the busiest days of the year and/or days with full-time inspection activity. There will be some queuing on the average days when Mexican Police and U.S. Customs are stopping trucks all day. In this situation, the queue will not necessarily block the nearest ramps on Loop 20, although it may do so.

Year 2010

The simulation indicates that the facility will no longer be adequate for the average day demand, if the hourly distribution, percent of empties, and trip distribution patterns remain the same as those observed in 2000. For an average day, the queues would block the Mines Road on-ramp right after 5:00PM and would keep blocking it for six hours. This theoretical queue would peak at 8:00PM, with 715 trucks per lane. This means a potential queue 18km (11 miles) long, not counting local traffic. These queues were observed without any activity of U.S. Customs and Mexican inspections, and with all inspection and toll components working under capacity. This result indicates insufficient traffic circulation area inside the facility.

A thorough analysis was conducted, including two phases: an investigative phase and a problem-solving phase. In the investigative phase, the research team identified bottlenecks. In the problem-solving phase, team members tested modifications of facility layout, traffic operations, and demand management, until they arrived at cost-effective solutions, implementable at state and local levels.

Analysis of Potential Bottlenecks-U.S. Side

In order to isolate the U.S. side, researchers used a scenario with all-day U.S. Customs activities and a hypothetical Mexican side with infinite capacity.

This scenario indicated that it would be very difficult to sustain U.S. Customs activities all day in the busy day of the target year. The flashing beacon becomes a bottleneck in the target year, causing queues in Loop 20 that reach far beyond the IH35 on-ramps, peaking between 260 and 300 trucks per lane, depending on the trial run.

For the average day demand (scenario 8), the maximum queue had a 95 percent confidence interval of 13.6 ± 4.39 trucks. The queue lenght is quite close to Mines Road on-ramps, which means that there is a potential for Loop 20 blockages. The inspection docks were sometimes full during the peak hours.

In order to identify when additional queuing and dock area would be needed on the U.S. side, researchers ran the busy day of the intermediate years, starting with 2006. According to the results, queuing area will become a problem on the U.S. side, on busy days with full-time export inspection activity in the year 2008. The docks are starting to work at full capacity, and, although their queuing area is not, it is approaching capacity (about 70%). The queuing loop on the U.S. side should be duplicated, and the export docks should be expanded about 50 percent in the year 2008.

Another hypothetical scenario to isolate the tollbooths indicated that they will have enough capacity for the busy day traffic in the target year. They were full less than 3 percent of the time, and the queuing area upstream of them had enough capacity for these peaks.

Analysis of Potential Bottlenecks-Mexican Side

In order to analyze traffic circulation on the Mexican side, the Project 0-1800 research team developed a scenario with a doubled queuing loop (see figure 4.8), using sub-scenario F conditions (both Mexican Police and U.S. Customs inactive), and year 2006 busy day traffic. The results indicated that the traffic circulation problem can be significantly improved by duplicating the Mexican Loop by the first half of 2006. Even the busy day, scenario A, conditions can be operated without blocking Mines Road on-ramps.

Researchers analyzed the target year 2010 in detail. For this year, 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 model 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.

Analysis of Traffic Demand Management Strategies

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 peak hour reduction included two scenarios: a hypothetical one, with traffic uniformly distributed throughout the operating hours of the bridge, and another with flatter peaks (see figure 4.9). A third scenario consisted of eliminating empty trucks. These scenarios were tested on two different layouts: the current layout and the "double-loop" layout (see discussion in previous section). The scenario combinations are depicted in table 5.1, which also shows one important result of each scenario: whether or not the queue blocks Mines Road's on-ramp, the first important point on Loop 20 upstream of the bridge. Blank cells in table 5.1 indicate that the particular combination was not analyzed. All scenarios assumed the worst-case situation: both Mexican Police and U.S. Customs active all day.

Totally eliminating either the peaks or the empties resulted in congestion-free operations for the average day of the year 2010, in the absence of infrastructure improvements and in the presence of full-time inspections by both U.S. Customs and Mexican Police. On the busy days, however, infrastructure expansion was also needed to eliminate congestion.

A more realistic peak reduction (see figure 4.9) combined with doubling the loops assured congestion-free operations on the average day, but not on the busy day. Analogous results were observed for eliminating empties.

The results indicate a clear need to combine approaches to solve the problem. Removing the empty trucks on the busy day eliminated all congestion, zeroing the queues and resulting in crossing times of the same magnitude as those observed in 2000.

Table 5.11 Year 2010: Impacts on Loop 20 / Mines Road On-Ramps

		Loops Layout	
Day	Sub-Scenario A	Current	Doubled
Average	**No empties**	**No**	**No**
	No peaks*	No	No
	Reduced peaks		No
Busy	**No empties**	**Yes**	**Sometimes**
	No peaks*	Yes	No
	Reduced peaks		Yes
	Reduced peaks and no empties		No

* Hypothetical scenario with a perfectly uniform distribution throughout the day.

For all scenarios, all Mexican inspection docks worked under capacity. The booths for signals and toll worked at an average capacity of less than half, except during the peak hours, when they were fully utilized.

CONCLUSIONS AND RECOMMENDATIONS

In 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 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 both sides. Such expansions, however, will not be enough. Maintaining the current types of inspections without causing serious congestion in Laredo will require modifying hourly distribution, percent of empties, and/or diversion from Colombia.

Recommendations for Traffic Demand Management

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

The following strategies can control congestion in Laredo in the next 10 years, provided that the assumptions used in Project 0-1800 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 a 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 queuing loops upstream of the tollbooths on the U.S. side by the year 2008.

Recommendations for Traffic Operations

To ensure smooth operation as predicted by the model, researchers recommend meeting all model assumptions listed in chapter 3. On the U.S. side, the most important of these recommendations are:

- Fully staff all components.
- Ensure that the U.S. Customs inspectors stationed at the beacon take less than 8 to 10 seconds to select trucks to be routed to export inspections, and that inspectors 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 the shippers export declaration drop-off box at 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, in a manner similar to that already implemented in some California stations.

On the Mexican side, the recommendations are:

- Fully staff all components.

- Federal Police inspections should take an average time of 20 seconds or less, and the number of trucks requiring more than a cursory inspection should always be less than the capacity of the parking area provided for more complete inspections.
- Make sure that all trucks take an average of one minute at the primary signals. Any activity other than waiting for the signal should be located outside the traffic flow.
- If the signals are manually activated by the driver, make sure no driver has to get off the truck to do so.
- Make sure that all trucks that bypassed primary inspection are able to drive by the signals for secondary inspection without any additional delays.
- The final document check at the exit gate should take an average time of 16 seconds.

Recommendations for Research Implementation

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 uses ad-hoc information in conjunction with data from the Laredo bridges existing up to 1999. For this reason, researchers strongly recommend the following steps as an implementation plan:

- Collect traffic data at the new bridge, especially demand and diversion from Colombia, after the traffic demand stabilizes.
- Collect data on the service points: service times, staffing scheduling (if not fully staffed), and details of traffic operations, after these variables, parameters, elements are fully established.
- Count traffic at the facility entrance and estimate the actual inter-arrival times daily and hourly.
- 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.

Project 0-1800 researchers strongly recommend this follow-up study to check all model assumptions, and, if necessary, recalibrate the model and rerun scenarios. Ideally, this data collection and recalibration should be done periodically, since calibration conditions may change, and thus invalidate the results.

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

This is not to be understood as meaning that such strategies either are not valid or should not be pursued or that they will be needed only in a remote future. The research results clearly indicate that the only way to prevent congestion in the near future is by rather aggressive demand 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 the potential to drastically decrease the number of empties. Reducing empties is a 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.