SIMULATION OF TRUCK SAFETY INSPECTION PROCEDURES AT THE TEXAS/MEXICO BORDER

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ABSTRACT

The transportation funding bill approved by the US Congress in November 2001 makes specific reference to additional inspection procedures to be carried out at key high volume crossings at the border between the United State and Mexico. These inspections will ensure full implementation of North American Free Trade Agreement (NAFTA) regulations on international trucking. As a result, eight truck inspection facilities are now under implementation at major Ports of Entry in Texas.

In order to successfully choose the site, plan, design, and operate these inspection stations, the concerned agencies needed to develop a basic, or prototype, design, test it, and adapt it to local traffic conditions at the eight Ports of Entry along the Texas-Mexico border. Planning and design of the basic prototype layout was done for Laredo, Texas, because it is the busiest commercial Port of Entry on the U.S.-Mexico border, currently serving over 9,000 trucks per day. Once the basic Border Safety Inspection Facility (BSIF) prototype was defined and validated for the highest traffic demand in the U.S.-Mexico border, it was necessary to select sites for the future inspection stations, making sure that there were no impacts of adjacent traffic, or traffic controls that would affect inspection efficiency.

The concerned agencies decided to analyze these issues using animated simulations of the system comprised by the inspection station and the adjacent roadway infrastructure. They needed not only the analysis results, but also the animated simulations, which are powerful tools to visualize the performance of a particular system.

This paper discusses how the authors developed computer simulations for the prototype, as well as one of the eight sites, where interaction with the existing road infrastructure was analyzed in detail. Since there is no commercial simulation platform that integrates traffic maneuvers (such as yielding and merging), controlled intersections, and staffed inspection points, the authors used an industrial simulation platform combined with customized programming. These simulation programs were then used to: (a) Estimate the current and future size and capacity of each inspection component, such as parking lots and inspection bays, and develop a prototype layout; (b) Test the proposed prototype layout under different traffic scenarios, developing recommendations to prevent traffic snarls and ensure efficient operations; (c) Estimate the traffic impacts of different proposed station sites, and use those as one of the site selection criteria; (d) Develop recommendations to use in the facilities' detailed schematics and construction plans; (e) Estimate the current and future staffing requirements for each station, and (f) when applicable, develop recommendations for scheduled implementation of the inspection components.

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KEY WORDS

Computer Simulation, International Trucking, US-Mexico Border Inspections.

BACKGROUND AND OBJECTIVES

The transportation funding bill approved by the US Congress in November 2001 makes specific reference to additional inspection procedures to be carried out at key high volume crossings on the border between the United State and Mexico. These inspections will ensure full implementation of North American Free Trade Agreement (NAFTA) regulations on international trucking. As a result, eight truck Inspection facilities are now under implementation at major Ports of Entry in Texas.

Planning and design of the station prototype started in Laredo, Texas, the most critical area because it is the busiest commercial Port of Entry on the U.S.-Mexico border (Bureau of Transportation Statistics, 2001, and Weissmann, 2000). Once the basic Border Safety Inspection Facility (BSIF) prototype was defined and validated for the highest traffic demand in the U.S.-Mexico border, it was necessary to select sites for the future inspection stations, making sure that there were no impacts of adjacent traffic on inspection operations (AHS Architects, 2001, Weissmann, 2002). In order to successfully choose the site, then plan, design, and operate these inspection stations, the concerned agencies needed to:

- Estimate the current and future size and capacity of each inspection component, such as parking lots and inspection bays, and develop a prototype layout;
- Test the proposed prototype layout under different traffic scenarios, and develop and test recommendations to prevent traffic snarls and ensure efficient operations;
- Estimate the traffic impacts of different proposed station sites, and use those as one of the criteria to select the best site,
- Develop recommendations to use in the facilities' detailed schematics and construction plans,
- Estimate the current and future staffing requirements for each station, and
- When applicable, develop recommendations for scheduled implementation of the inspection components.

The hurdle? There is no commercial simulation platform that integrates traffic features, such as controlled intersections, yielding and merging, with inspection points and staffing schedules.

PROBLEM DEFINITION AND PROGRAMMING APPROACH

Modeling of a truck inspection facility combines characteristics of two distinct simulation approaches. It consists of a traffic analysis problem, since it has roadways, as well as controlled and uncontrolled intersections. On the other hand, it also has assembly line characteristics, such as service times, staffing requirements and schedules, and inspection points. All characteristics need to be modeled in the same program; otherwise, the interactions between traffic impacts, staffing availability and station utilization could not be analyzed. The solution was to combine customized programming with an industrial simulation platform that allows reprogramming as needed (SIMUL8 Corp, 2002).

The authors developed 22 animated models representing site alternatives for the future inspection stations, successfully simulating conditions not covered by any commercially available simulation platform. These models required extensive input data that included traffic volumes, hourly distributions, turning movements at nearby intersections, service times and staffing requirements at each component, regulation compliance, and traffic signal cycles (Weissmann, 2000, 2002).

Figure 1 shows the traffic circulation in one of the most complex sites, the Bridge of the Americas in El Paso, Texas. International trucks exiting the Federal inspection site first go over weigh-in-motion devices (1), whose results are relayed to the officer in the observation room (2). They proceed to the front of the observation room (2), where there are variable message signs directing trucks to either enter the facility for further inspections (routes B or C), or to continue on their way towards (in this specific site) the Paisano Drive traffic signal. Inside the facility, there are the following staffed inspection areas: static scales (3) for trucks flagged by the weigh-in-motion (1); a short-term parking area for inspecting the vehicle and/or the driver credentials (4); a long-term parking for out-of-service trucks or those completing paperwork (5); and inspection bays (6) for thorough vehicle inspections.

It is clear that the local traffic (SH54 exit and Paisano Drive signal) has the potential to interfere with inspection operations. In order to use only the built-in commercial simulation platforms' features, these impacts would have to be ignored, thus rendering all results of facility utilization and staffing requirements inaccurate. The simulation approach described in this paper avoids these shortcomings.

MODEL INPUTS AND ASSUMPTIONS

The inputs common to all inspection station models consist of: traffic demand, service times and staffing requirements at each inspection component, speeds and distances between system components, traffic operations inside the facility, and regulation compliance rates. Compliance rate (in percentage) is defined as the rate between the number of trucks pulled over to a particular type of inspection / station component in a certain period, and the total truck demand in the same period.

Compliance-related assumptions control how many trucks enter or bypass the facility, how many use each component, and how long they stay inside. As such, they affect station utilization and staffing requirements results, but have less impact on the number of trucks using the facility main lanes (route A), since the vast majority of trucks are pre-inspected and are not pulled over to the station for inspections. Local traffic conflicting with the facility lanes, however, has potential to block them and affect the facility operation.

The traffic demand is input as distributions fitted to 24-hour traffic counts (adjusted to the busiest month and day), and their projections. Therefore, the number of trucks entering the facility, as well as the number of vehicles on the adjacent infrastructure, are randomized.

Since the simulations were developed during the planning stage, service times and traffic operations data came from other truck inspection facilities in California and New Mexico, and truck weigh stations in Texas. Site-specific inputs referred to the adjacent roadway infrastructure (e.g., ramps, traffic signals, and conflicting local traffic). Traffic data for the models came from traffic counts taken during the project, in addition to existing sources (Bureau of Transportation Statistics, 2000, Texas A&M, US-CBP Service, US-ITC).

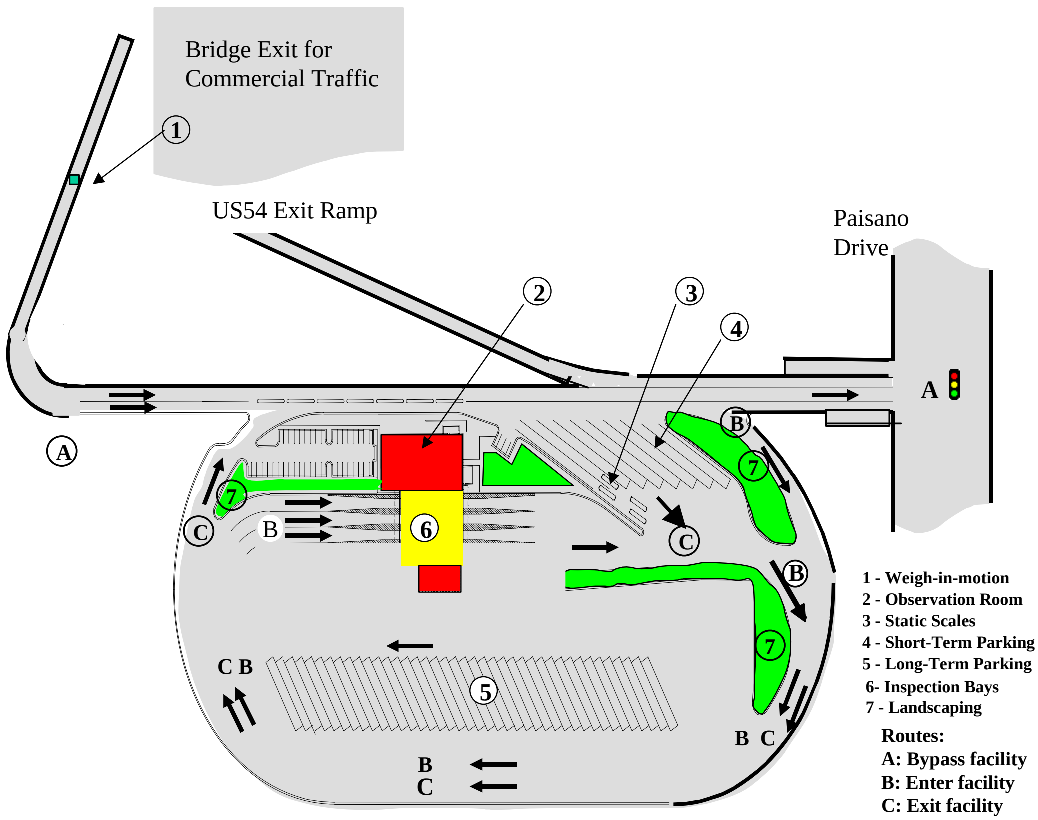

Figure 1 Layout and Location of a Planned Truck Inspection Station in El Paso, Texas

CASE STUDY: TRUCK INSPECTION STATION IN LOS TOMATES, TEXAS

Among the 34 site alternatives modeled in this study, the authors selected for discussion in this paper the inspection station in Los Tomates, Texas, near the Veterans International Bridge. There were two site alternatives, as shown in Figure 2. In terms of traffic operations, the main difference between the two sites is in the turning movements at the facility exit, and in storage capacity. Site A exit requires a right turn move into northbound US77/83, with approximately 75m (250 ft) space between the facility exit and the T-intersection with US77/83. Site B exit is a T-intersection with East Loop, where most trucks would turn left. The space between the facility exit and the T-intersection is only about 30m (100ft), which means there is space for only one truck when the planned signal is red. Both models start where the international trucks leave the federal inspection area, and end after clearing the signal at the US77/83 and East Loop intersection. The models simulate one full working day of operations, capturing the hourly fluctuations and traffic peaks observed at the exit of the Veterans Bridge, and at the nearest major intersections.

Veterans Bridge is open to commercial traffic from 7:00Am to 11:00PM Monday through Friday. Based on 24-hour vehicle classification counts at U.S. Customs exit gate and at US77/83 and East Loop intersection, hourly traffic distributions and their respective turning movements, for the baseline year 2002 and the target year 2012 were established. The totals were, respectively, 840 and 1,430 trucks per day. Total peak traffic on the US77/83 and East Loop intersection was about 2,000 vehicles per hour.

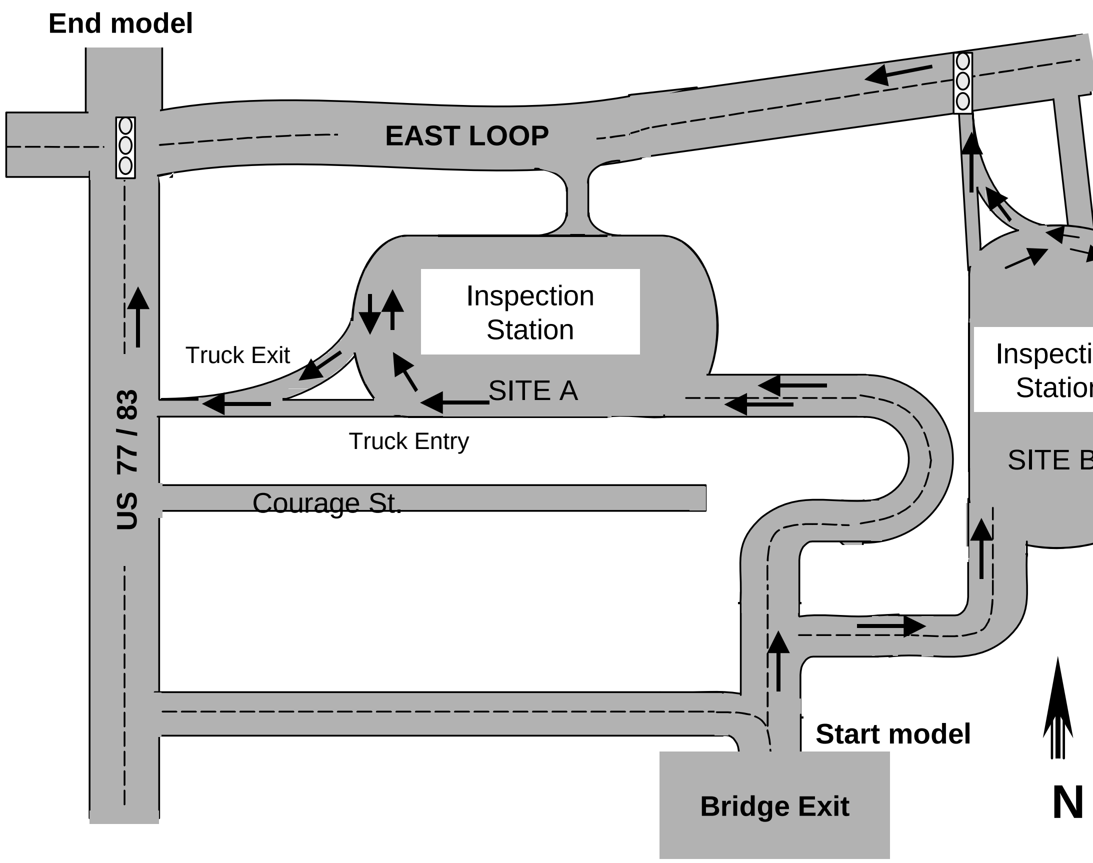

Figure 2 Site Alternatives for Veterans Bridge Inspection Station

SIMULATION RESULTS

The model was programmed to calculate the average, maximum and minimum times compliant and non-compliant trucks take from the bridge exit gates until clearing the US77/83 and East Loop intersection (see figure 1). Times in system include clearing all signalized intersections. This result is depicted in table 1, and it shows that truck delays caused by the facility presence are negligible for compliant trucks. Compliant trucks flagged by the weigh-in-motion alarm, which have to go through a multi-platform static scale, take an additional 55 to 75 seconds, still a negligible delay. Trucks subject to inspections have more substantial delays, spending times that range from 13 to nearly 24 minutes for the short-term inspections, up to 40 minutes for the complete inspection done at the bays. The most significant delays are for out-of-service trucks, which may take several hours to correct the condition. Compliant trucks average only about 20 additional seconds for site B, since the added distance is compensated by faster speed.

Table 1 Baseline Scenario Times to East Loop and US77 Intersection
(hours:minutes:seconds)

Site Alternative	**Facility Usage**	**Minimum Time**	**Average Time**	**Maximum Time**
A	*Compliant*	*0:02:18*	*0:02:21*	*0:03:00*
	Bypass component	---	---	---
	Static scales	0:03:13	0:03:26	0:04:15
	Short term parking	0:12:58	0:18:01	0:23:40
	Long term parking	0:18:40	2:34:08	5:04:49
	Inspection bays	0:32:58	0:34:24	0:40:05
B	*Compliant*	*0:02:22*	*0:02:40*	*0:03:39*
	Bypass component	---	---	---
	Static scales	0:03:17	0:03:45	0:04:54
	Short term parking	0:13:02	0:18:20	0:24:19
	Long term parking	0:19:01	2:33:23	5:20:32
	Inspection bays	0:31:54	0:34:47	0:37:40

The models also output the utilization status of each facility component, as well as officers on inspection duties, at five-minute intervals, throughout the simulated day. This output was summarized and reported as illustrated in figure 3. The horizontal axis is the number of spaces (or officers), and the vertical axis is the percent of time a certain number of spaces was in use (or officers were inspecting). For example, figure 3, which summarizes the number of spaces, indicates that, under the baseline traffic demand and assumed compliance rates, only one short term parking space is enough over 75 percent of the time, while five are needed during 1.5 percent of the time. In the target year, utilization increases: one space is enough only 17 percent of the time, while seven spaces are needed 2.5 percent of the time. Analogous results are output for every station component.

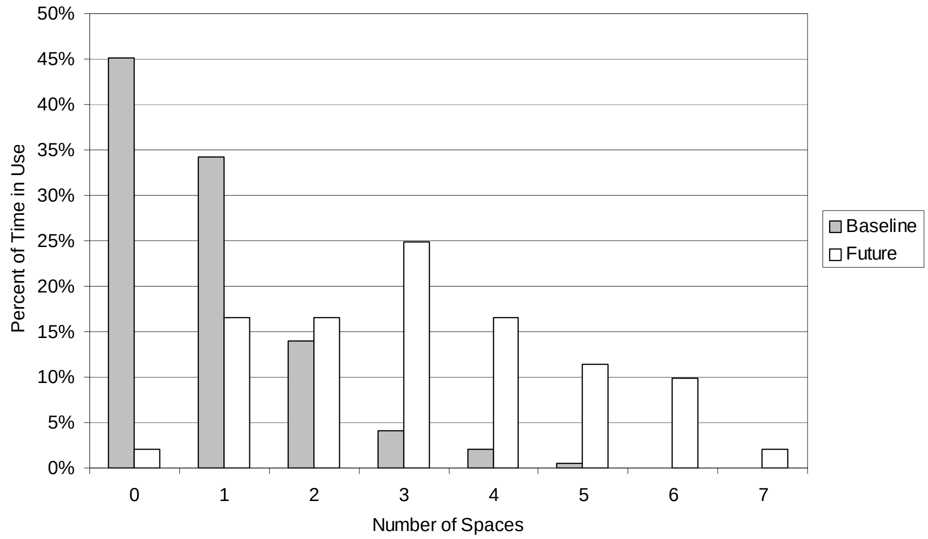

Figure 3 Utilization of Short Term Parking

The average staffing requirements to ensure that no truck waits for an officer were also calculated by the model. For the baseline scenario, only three officers will be necessary about 75 percent of the time. Four officers will be able to inspect trucks without any wait in the baseline year, while 10 will be necessary in the target year to make sure that trucks wait for an officer less than 5 percent of the time. The median number of inspecting officers is 6 in the target year and 2 in the baseline year.

At the end of nine consecutive simulation runs, the model automatically writes on a table the confidence intervals for all relevant results: number of trucks using and/or bypassing each system component; number of trucks queuing on the main lanes; and percent of time trucks were queuing. In this case study, the results indicate full facility efficiency, i.e., there was no need to release trucks because a facility component was full. Results also indicated that there was no congestion on the facility main lanes due to impacts of the nearest intersection delays (zero queues). This result was also obtained for the 2012 target year traffic, indicating no traffic impacts in the next 10 years.

CASE STUDY CONCLUSIONS AND RECOMMENDATIONS

The results indicate that, under the assumed traffic demand and compliance rates, only one static scale would be enough up to the target year 2012. The proposed seven short term parking spaces will not be fully utilized before the target year 2012, when full utilization occurs only 2.5 percent of the time.

Two inspection bays would handle the baseline traffic 80 percent of the time. With two bays, there was no overflow, but 74 percent of the trucks going to the bays had to wait in line, 62 percent of them for more than 10 minutes. The average (non-zero) queuing time was 40 to 45 minutes.

Three bays would handle the target year traffic 74 percent of the time, without bay overflow. Fifty-five percent of the trucks pulled over to the bays had to wait in line, 69% for less than 10 minutes. The average (non-zero) queuing time was 13 to 14 minutes, and the maximum queuing time was 38 to 40 minutes.

The 40-space long-term parking area is unlikely to be fully utilized, if all model assumptions are met. About half of its full capacity will be utilized for the baseline traffic, while simultaneous utilization of 35 or more spaces occurs less than 1 percent of the time for the target year.

Staffing requirements are high only during the traffic peaks for all scenarios. The median number of inspectors was 2 for the baseline year and 6 for the target year; the maximum number required for no wait during the peaks is 4 in the baseline year and 11 in the target year.

The times required for compliant trucks to go through the facility are under three minutes for both sites. Site B takes a little longer on the average, basically due to the signalized left turn into East Loop. Apparently, the intersections have enough capacity to handle the current and target year traffic because the Federal inspections exit gates are "metering" the trucks at a rate that is less than the intersection capacity. If the exit gates procedures are expedited, the nearest intersection may work over capacity for the target year.

SITE A

The intersection impacts on the facility were modeled assuming free right turns into US77/83. In addition, the turning movement patterns observed in June 2001 were assumed to remain the same in the target year. Traffic counts indicated over 90 percent through and right turn movements for these trucks, which precludes weaving in more than one lane. Intermediate model runs indicated that the right turn and merge into US77/83 would start to affect the inspection operations at 3,500 trucks per day, and 360 autos per hour per lane on northbound US77/83. In order to verify these results, the authors developed Synchro models of two sequential intersections: the station exit with US77, and US77 with East Loop. These Synchro models validated the simulation results.

Two low-investment options are possible to improve the flows, and both need to be carefully studied before implementation. Widening the exit lane allows more storage space at the exit, but it cannot change the time required to complete the right turn and merge into US77/83. Signalizing the intersection of US77/83 and the facility may require actuation to prevent the signal queues to impede international auto traffic exits and/or the facility lanes for truck traffic.

A high investment option is the grade separation of US77 and East Loop intersection. This would eliminate signal queues that have potential to reach the US77 intersection with the facility exit. However, it is recommended to carefully model this improvement implementation, to ensure that the facility exit and US77 intersection are working efficiently in combination.

SITE B

Site B layout has one exit lane for truck traffic, ending in a T-intersection. The facility exit lane length can accommodate only one large truck at a time. Every time the signal is not green for the facility, trucks cannot exit from inside the facility. The facility entrance, however, was not blocked for the baseline or target year 2012 traffic levels.

The intersection impacts started to impede the facility entry around years 2014-2015, at the assumed (5 percent) traffic growth level. When the trucks reach about 2,200 per day, the red light queue would impede the facility entry for 40 to 50 percent of the trucks. There are two options to be considered, alone and/or in combination: widening the intersection to allow two trucks to turn left at the same time, and actuating the signal when the truck queue impacts the facility entry. These options must be carefully modeled at the network level before implementation. This model should include at least two additional East Loop intersections in each direction, since actuating the facility signal will affect signal coordination on East Loop.

East Avenue (future East Loop) is only two lanes wide at this point, but there are plans to make it either a four-lane, or a five-lane boulevard; however, the environmental assessment for this project has not yet started. If site B is selected for this facility, it is recommended to secure right-of-way to increase the intersection capacity.

FINAL RECOMMENDATION AND ACTION TAKEN

Both sites are relatively near intersections whose signal queues may interfere with the facility operations. Site A requires a yield-controlled right turn move, while site B requires a signalized intersection. Site A is easier than B to mitigate future impacts of flow interruptions on the facility lanes. Site A's estimated impacts start to occur later than they do for site B, whose exit lane is rather too close to the nearest major traffic interruption. From the point of view of intersection impacts on facility efficiency, site A strongly is recommended over site B. Based on these recommendations, site B was dropped from consideration by the concerned agencies.

CONCLUSIONS

The simulation models reported in this paper were instrumental in developing and planning border inspection facilities at eight international Ports of Entry on the U.S.-Mexico border. The simulation results were used to design the facility size and its traffic flows; develop current and future staffing schedules; and select sites based on traffic impacts. The unique approach reported in this paper of combining assembly-line-type micro-simulations with the simulation of traffic control devices and traffic flows enabled the concerned agencies to make site selection decisions such as those explained above. The animations were helpful when making such decisions in concert with stakeholders unfamiliar with the technical aspects of this project.

None of these applications would have been possible without a pioneering modeling approach capable of accurately integrating staffed inspection operations and the nearby traffic network. The simulations' animations and results were presented in several public meetings and hearings, as well as presentations to stakeholders at private, local, state and federal levels. They were instrumental in answering the three most commonly voiced public concerns, clearly demonstrating that: (1) the inspection stations can be successfully operated within a reasonable staffing budget, (2) without impeding international commerce or blocking local traffic, and (3) while providing adequate accommodations for inspections and correction of most out-of-service conditions on-site.

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