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Regional Freight Capacity Management: Free and Secure Trade (FAST) Program Optimization at the Pacific Highway, Northbound Crossing

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by

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Introduction

This study is the latest in a series of studies examining issues with and possible enhancements to the FAST program at the Pacific Highway Crossing (PHC) in Blaine, WA. The FAST, or Free and Secure Trade program (USCBP, 2005), was designed to increase the security of commercial freight crossing the Canada – U.S. border. To qualify for FAST, carriers, drivers, and shippers are required to follow certain security procedures which aim to enhance the safety and security of supply chains. In the "model" configuration, FAST-qualified trucks are then allowed to use a dedicated approach lane and inspection booth, thus minimizing border wait-times. The FAST program was therefore designed to encourage participants of the trans-border commercial freight supply chain to enact greater security measures. At PHC, the "model" configuration had actually been achieved in both the north- and southbound directions by 2008. In each direction, one of the available three booths was dedicated solely to FAST traffic, with the remainder of trucks handled by the other two booths. Each of the two traffic streams (FAST and non-FAST) received simple "First Come, First Served" (FCFS) treatment within its respective queue. However, concerns emerged following a field study in 2009 (WCOG, 2007; Davidson, 2009). The proportion of FAST vehicles was well under a third of the total commercial freight traffic, which resulted in underutilization of the FAST booth and unnecessarily long lines in the general-purpose (GP) approach lane.

Regional stakeholders first focused upon the *southbound* PHC, undertaking studies (Springer, 2010; Davidson, 2011; Springer, 2011a; Springer, 2011b), simulation modeling and pilot testing of alternatives configurations in 2010 and 2011. In the fall of 2011, the most recent of those studies recommended using a new priority rule for processing commercial freight traffic through the inspection process (Springer, 2011c). This new rule, dubbed the "FAST 1st" configuration, gave arriving FAST-qualified vehicles priority access to any of the three available southbound inspection booths. Since FAST vehicles had a separate approach lane to the inspection booths, the new configuration enabled arriving FAST vehicles to bypass trucks waiting in the typically longer queues in the general purpose (GP) lane. If no FAST-qualified trucks were waiting for inspection, however, *all three* inspection booths would be available for GP trucks. The study found that implementing the FAST 1st priority rule could dramatically lower wait-times for GP trucks at the price of only a small increase in wait-times for FAST trucks—i.e., simulation analysis predicted that under then-current traffic volumes, average wait-times for GP trucks could be cut by more than two-thirds (from 52.8 minutes to 15.2 minutes), while average FAST wait-times would increase from 3.0 to a still-modest 7.4 minutes. Seven other configurations were examined in the study, but none were seen to yield as large a benefit for the GP trucks at such a small cost to the FAST trucks. Consequently, the FAST 1st configuration was implemented at the southbound PHC in early 2012.

This study uses simulation analysis to investigate the effectiveness of using a FAST 1st configuration at the *northbound* PHC. Currently, the northbound PHC uses a booth configuration similar to that used previously by the southbound PHC: one dedicated FAST approach lane and booth, one GP approach lane and two GP booths, and a FCFS priority rule for each type of booth. Compared to the southbound PHC, northbound wait times are significantly lower: a 2011 survey found average northbound wait times for GP vehicles to be slightly over seven minutes, while a southbound survey conducted at the same time found GP waits of approximately fifty-two minutes. (Davidson et al., 2011; BPRI/WCOG, 2011). Nonetheless, the results for the southbound PHC suggest that the FAST 1st configuration could cut the northbound GP waits further with little adverse effect on the

FAST waits, and this could become a particularly desirable option as northbound commercial traffic increases and GP waits increase.

The remainder of the paper is organized as follows. First, data on northbound PHC traffic collected in 2011 and 2012 will be briefly reviewed. Next, the differences between the alternative booth configurations will be outlined; while the focus will be on the differences between current northbound PHC operations and the proposed FAST 1st system, similarities and differences with the southbound PHC will also be noted. Finally, the parameter settings used in the simulation experiment will be discussed, followed by an analysis of the results and recommendations.

The Northbound PHC: Current and Past Conditions

Over four days in the summer of 2011 and two days in the summer of 2012, a team of researchers observed the arrival and inspection of commercial freight vehicles at the northbound PHC. Details of the 2011 data collection effort can be found in Davidson et al. (2011); researchers recorded the license plates and timestamps of trucks as they arrived in the appropriate approach lane, began inspection at a booth, and left the booth. Since license plates were recorded along with timestamps, arrivals and departures at different points in the system could be matched for each truck, facilitating the calculation of waiting time. The waiting time for a truck was defined as the time that elapsed from the truck's arrival at the end of the line in the approach lane to the truck's arrival at the inspection booth. As discussed in Davidson et al. (2011), the waiting times for the northbound trucks were relatively low: using the above definition of waiting time, no waiting was observed for FAST trucks, while GP trucks had average waits of less than five minutes on three of the four observation days.

	2002	2006	2009	2011	2012
% Empty	35%	24%	19%	NA	NA
% FAST	NA	NA	2%	NA	NA
% FAST or Empty	NA	NA	NA	9.6%	12.7%
Arrivals/Hour	78	71	51	69	78
Arrivals/Hour as % of 2011 Baseline	114%	102%	74%	100%	113%
Inspect Time-FAST or Empty (Sec)	NA	NA	69	37	45
Inspect Time-GP (Sec)	49	63	76	67	66
Inspect Time-Avg (Sec)	49	63	76	64	64
Inspect Time as % of 2011 Baseline	76%	98%	118%	100%	99%
Transition Time (Sec)	NA	NA	NA	28	29

Table 1: Summary Data from Five Studies of Northbound PHC Freight.

The two days of data collection in 2012 have not been documented elsewhere and were undertaken primarily to confirm the 2011 observations. License plates were not recorded during these observations, and therefore waiting times could not be calculated. Arrival times and inspection times were recorded, however, allowing the 2012 data to serve as a check on the 2011 observations[1]. Summary results from the 2011 and 2012 observations, as well as results from previous data collection efforts at the northbound PHC (USDOT, 2003; WCOG, 2007; WCOG, 2010), are included above in Table 1. Note that not all types of data were available and/or collected in each year that a survey was conducted.

Before examining the numbers in detail, it is first necessary to clarify how the criteria used to qualify vehicles for the FAST approach lane and booth have changed over the years of the five studies. At the time of the 2002 and 2006 studies, there was no FAST program for northbound traffic. There was a FAST program in 2009, and at that time only those fully qualified FAST vehicles were given access to the FAST approach lane and booth. With only two percent of the traffic FAST-eligible, however, this resulted in a dramatic underutilization of one-third of the inspection resources. Consequently, at the time of the 2011 and 2012 studies, empty trucks as well as FAST-eligible trucks were allowed to use the FAST approach lane and booth. The dramatic jump in FAST booth usage, from 2.0% to 9.6% and then 12.7%, is likely due almost entirely to use of the FAST booth by empties; no separate recording of FAST and empty trucks was recorded in 2011 and 2012, so we cannot however be certain. Interestingly, FAST and empty trucks were recorded separately in the 2009 data survey, and taken together 21% of the northbound traffic in 2009 was FAST-eligible or empty.

Focusing in greater detail on the comparison between the 2011 and 2012 data, one sees that the average GP inspection times are quite close. The average transition time, which is defined as the time required for a truck to pull up to the booth after the previous vehicle has left, is also quite consistent between 2011 and 2012. The average inspection time for FAST or empty trucks is about twenty percent higher in 2012 than in 2011, but given the relatively small number of FAST/empty trucks, and the unknown mix of FAST and empty trucks in the data, it is difficult to say if this observation reflects an underlying change in the inspection time. There appear to be about thirty percent more trucks using the FAST booth in 2012 than in 2011, and the hourly arrival rate – as measured between the times of 8:15 and 4:45 – is more than ten percent higher in 2012 than in 2011.

A closer examination of the changes in the hourly arrival rate throughout the day is shown below in Figure 1. For each of the 2011 and 2012 studies, the hourly arrival rate, averaged across all days in each study, is plotted against the time of day. The hourly arrival rate for 2012 is clearly more variable throughout the day than that for 2011, although since the 2012 observations include only two days of data, averaging across all six days from both years yields a profile which is more similar to that of 2011.

[1] Inspection time, transition time, and % FAST or empty calculations do not include data collected on Monday, July 25, 2011, when standard booth operations were suspended and all trucks were allowed access to all booths.

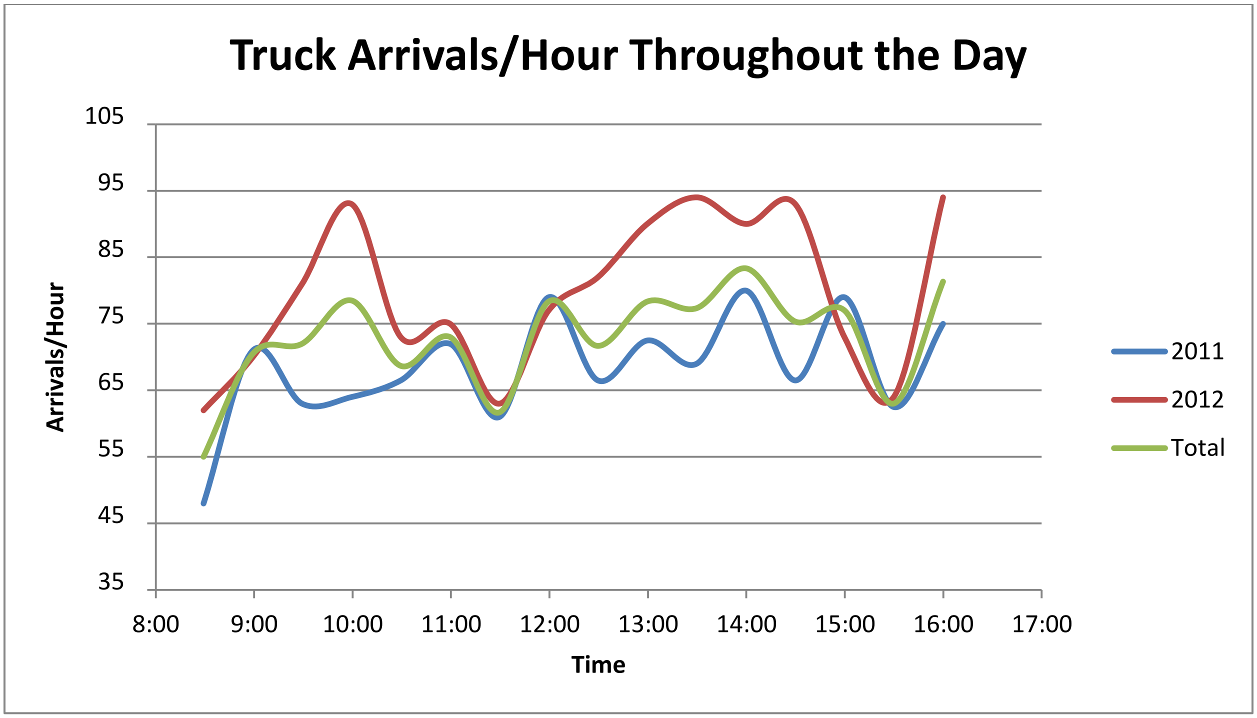

Figure 1: Average and 99th Percentile Waiting times for FAST and GP Lanes (From Springer, 2011).

On the whole, the northbound PHC appears to have been operating in a very similar manner in 2011 and 2012. GP inspection and transition times were virtually identical, and the small number of FAST/empty inspection times differed perhaps by twenty percent, although this difference may be a byproduct of the small sample of FAST/empty trucks observed. The biggest difference in the operation appears to have been in the trucks that were arriving: there were more empties and FAST trucks for the FAST booth, and the overall traffic levels had reached levels not recorded since 2002.

The Northbound PHC: Baseline and FAST 1st Configurations

The baseline configuration for the northbound PHC is similar to that described elsewhere (Springer, 2011c) for the baseline southbound PHC configuration, with a few important differences. Similar to the baseline southbound PHC, the northbound PHC configuration includes one approach lane and booth reserved for FAST/empty vehicles, and one approach lane and two booths for GP vehicles. Unlike the southbound PHC, however, there is no radiation portal monitor (RPM) at the northbound PHC that trucks must pass through before approaching the inspection booth. In addition, the southbound PHC had a more complex waiting area feeding RPMs and inspection booths: the GP approach lane broke into six feeder lanes, which were then regulated to feed the two GP inspection booth lanes. For the northbound PHC, the GP approach lane feeds directly into the two GP inspection booths. When a GP booth becomes available, the next truck waiting in the GP approach lane moves forward to that booth. The baseline northbound configuration is therefore simpler than the original baseline southbound configuration. In addition, as mentioned above, the southbound PHC FAST lane was reserved for fully-compliant FAST vehicles, while in 2011 and 2012 the northbound PHC FAST lane was open to FAST-qualified and empty trucks.

The FAST 1st configuration proposed for the northbound PHC is identical to that proposed for the southbound PHC, but the simpler existing baseline physical configuration of the northbound crossing requires less physical re-layout. In the proposed FAST 1st configuration, the FAST/empty and GP approach lanes would remain as currently positioned. An additional signal would be needed at the current stopping point for each approach lane. Since each inspection booth in the FAST 1st configuration would be capable of handling both GP and FAST/empty traffic, trucks from either approach lane would need the ability to pull up at any inspection booth. Once an inspection booth became available, if a truck was waiting in the FAST approach lane it would be signaled to approach the empty booth; otherwise, the truck waiting in the GP booth would be signaled to advance[2]. With this configuration, FAST/empty trucks would have their expected wait times increased very modestly – they would no longer arrive to an empty booth unless no GP trucks were waiting – but the previously unused capacity of the FAST/empty booth could now be used to reduce the wait times of GP trucks.

Parameter Settings and Reported Statistics

For each of these two border configurations, certain parameters were systematically varied across multiple simulated days, and other parameters were held constant. The traffic volumes were varied from ten percent below the average levels recorded in the 2011 and 2012 surveys to seventy percent above those same levels. As can be seen from Table 1, 2012 northbound traffic levels are relatively high compared to prior study years, so picking a maximum level seventy percent above the average of the 2011 and 2012 levels should cover any likely near-term traffic volume changes.

The 2011 and 2012 studies also yielded different estimates of the fraction of trucks using the FAST/empty booth; the fraction increased from 9.6% to 12.7% over the course of the year. While this may just represent a case of small sample bias, each border configuration was simulated under each FAST/empty fraction. In addition, looking back to 2009 suggested an even wider range of possible FAST ratios. If only FAST-qualified trucks were permitted access to the FAST approach lane, Table 1 suggests that only two percent of arriving trucks would qualify. However, if the ratio of empty trucks increased to what it was in 2009, and FAST and empty trucks were allowed access to the FAST approach lane, twenty-one percent of all trucks could be expected to qualify. Since this wider range, based on the 2009 data, could have a significant impact on system performance, each border configuration was also tested for "FAST" ratios of 2% and 21%.

The remaining parameters needed to define the system were held constant across all simulations. This includes the distributions for inspection times and the time needed for trucks to move from the approach lane to the inspection booth. For each type of time, 2011 and 2012 data were pooled to yield a single data set which was fitted to a log-logistic distribution[3]. As discussed earlier, there was

[2] Some signal coordination would be necessary to ensure that two trucks don't receive closely-timed signals to advance to booths at opposite corners, i.e., to ensure that trucks aren't signaled to occupy the same space at the same time. Such coordination could result in a slight increase in mean transition time. Alternatively, moving the stopping point for each approach lane farther south could free up space for three short (one or two truck-length) booth lanes, one in front of each inspection booth. Trucks would then be signaled to progress from the main approach lanes to one of the three booth lanes when there was space in the booth lane. Once in the booth lane, trucks would proceed to the booth in front of them when it became available. This would likely shorten the transition time by an unknown but possibly significant amount.

[3] As noted earlier, data from 7/25/2011 was excluded from these calculations.

very little discernible difference between either the 2011 and 2012 transition times or the 2011 and 2012 GP inspection times. There was a difference between the 2011 and 2012 FAST/empty inspection times, but given the small sample size in each year it was considered prudent to combine both years into a single sample.

For each combination of border configuration, traffic volume level, and FAST/empty arrival ratio, twenty-five eight-hour days of border operation were simulated. Random day to day variations result in different average and maximum waiting times for each of the twenty-five days, mimicking the actual situation where waiting times can differ between two days even though the underlying system parameters haven't changed. Thus, averaging across twenty-five simulated days gives us a better estimate of the "typical" daily performance than just using the result of a single simulated day. In addition to the twenty-five day average, two other waiting time measures are reported to assess the variability inherent in each configuration. To determine how "bad" the waiting time could get under the different traffic levels, we report the *maximum average waiting time* across all twenty-five days for each traffic level; this number represents the "worst" day observed for that traffic level out of all twenty-five simulated days. This is roughly equivalent to the expected waiting time on the most congested day of the month. In addition, within each simulated day we can determine the *average maximum wait*: this is the average, across all twenty-five simulated days for a given set of conditions, of the "worst" wait experienced by a truck each day. This is therefore an estimate of the longest wait experienced each day by a single truck. We also report the average booth utilization under each parameter combination; this is simply the fraction of the time that the three booths are busy inspecting trucks.

As a final step before running the experiment, the simulation model for the baseline configuration of the northbound PHC was run using the arrival rate profiles and FAST/empty percentages for the three days of the 2011 data survey where the northbound PHC was in standard operation. Twenty-five repetitions of each of these three days were simulated, and the distribution of average wait times from each batch of twenty-five simulations were compared to the actual average wait times recorded for that day. In each case, no significant difference was detected between the simulated and observed averages, confirming the validity (logical accuracy) of the simulation model.

Results for the 2011-2012 FAST/Empty Ratios

We first compare the two border configurations when the proportion of FAST and empty vehicles arriving at the northbound PHC is either 9.6% or 12.7%, the levels observed in the 2011 and 2012 studies. The average waiting times for FAST and GP trucks under the different border configurations and FAST/empty ratios are shown in Figures 2 and 3; Figure 4 shows the overall average waiting time for all FAST and GP trucks combined. All average waiting times are reported for nine different levels of traffic volume under the baseline configuration[4]; the vertical axis is the same scale for each of the three charts, ranging from 0 to 80 minutes, to facilitate comparison.

The results of the two different configurations for each FAST/empty ratio are shown on each chart: the baseline configuration with 9.6% and 12.7% FAST/empties, and the FAST 1st configuration with 9.6% and 12.7% FAST/empties. The numerical results behind the graphs are provided in

[4] The nine levels are those labeled across the horizontal axis of the chart. The results are presented as continuous lines to facilitate viewing.

Appendix A. Several important observations can be made when examining Figures 2 through 4. First, note that under any of these parameter combinations and for any level of simulated traffic, average wait times for FAST/empty trucks are effectively zero; Table A1 in the appendix confirms that the average FAST/empty wait times under all these scenarios is less than one minute. Second, the average waiting time for GP trucks improves dramatically, especially at higher traffic levels, when a FAST 1st configuration is used instead of the baseline configuration. With demand levels at the 2011/2012 level, average wait times drop from 4.5 minutes to .5 minutes when the FAST/empty percentage is 9.6%; increasing that percentage to 12.7% results in a lesser drop from 3.5 minutes to .5 minutes.

Everything else being equal, a higher FAST/empty percentage yields a smaller GP wait time since it means fewer trucks in the GP approach lanes; an additional, but smaller benefit, results from the smaller processing time for FAST/empty trucks. But the big difference is not between scenarios with different FAST/empty ratios, but between the baseline and FAST 1st configurations. At higher traffic levels the results are more dramatic: at traffic levels fifty percent higher than the 2011/2012 average, average GP waits in the baseline configuration are over fifty minutes but approximately five minutes in the FAST 1st configuration. Finally, Figure 4 shows the average waiting times of all trucks. Since the fraction of FAST/empty trucks in all scenarios is relatively small, this chart appears quite similar to the average waiting times of GP trucks in Figure 3; and as in Figure 3, the FAST 1st configuration outperforms the baseline configuration for all traffic levels and across both FAST/empty ratios.

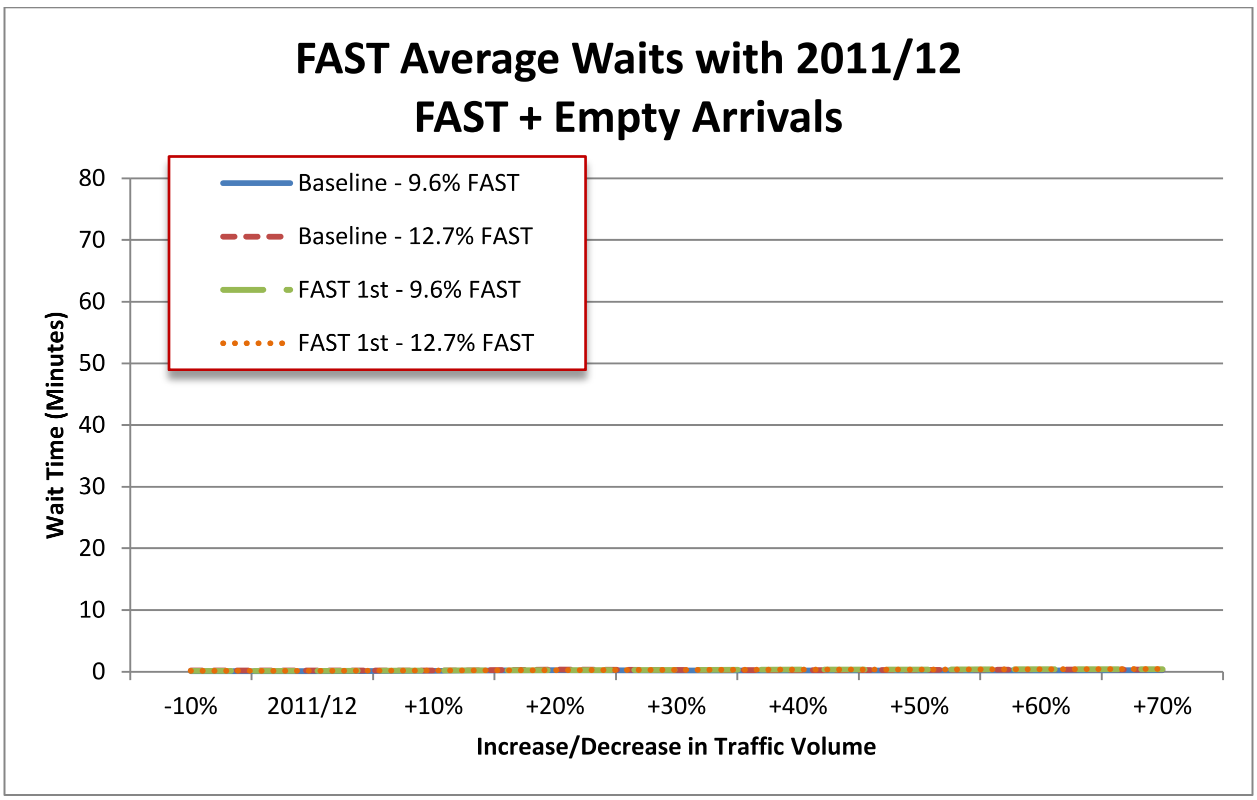

Figure 2: FAST average waiting times with FAST/empty arrival ratio = 9.6% and 12.7%.

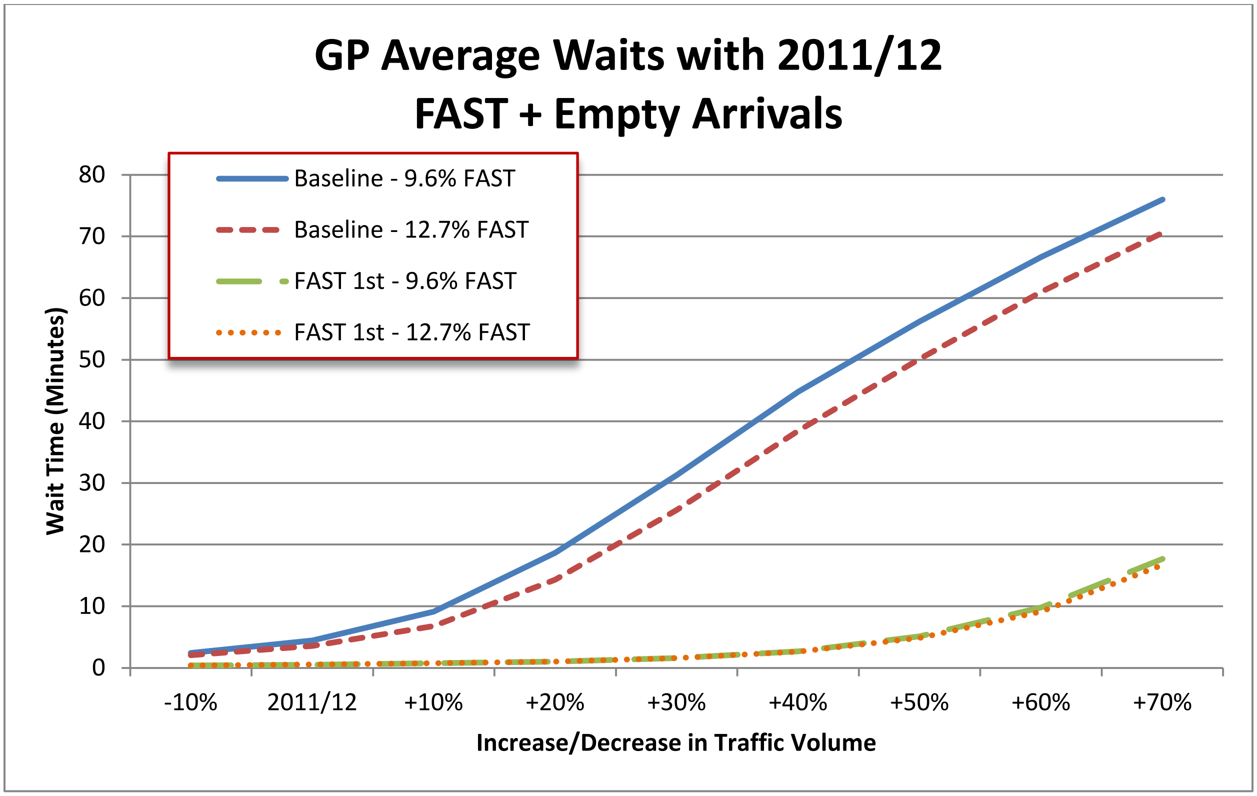

Figure 3: GP average waiting times with FAST/empty arrival ratio = 9.6% and 12.7%.

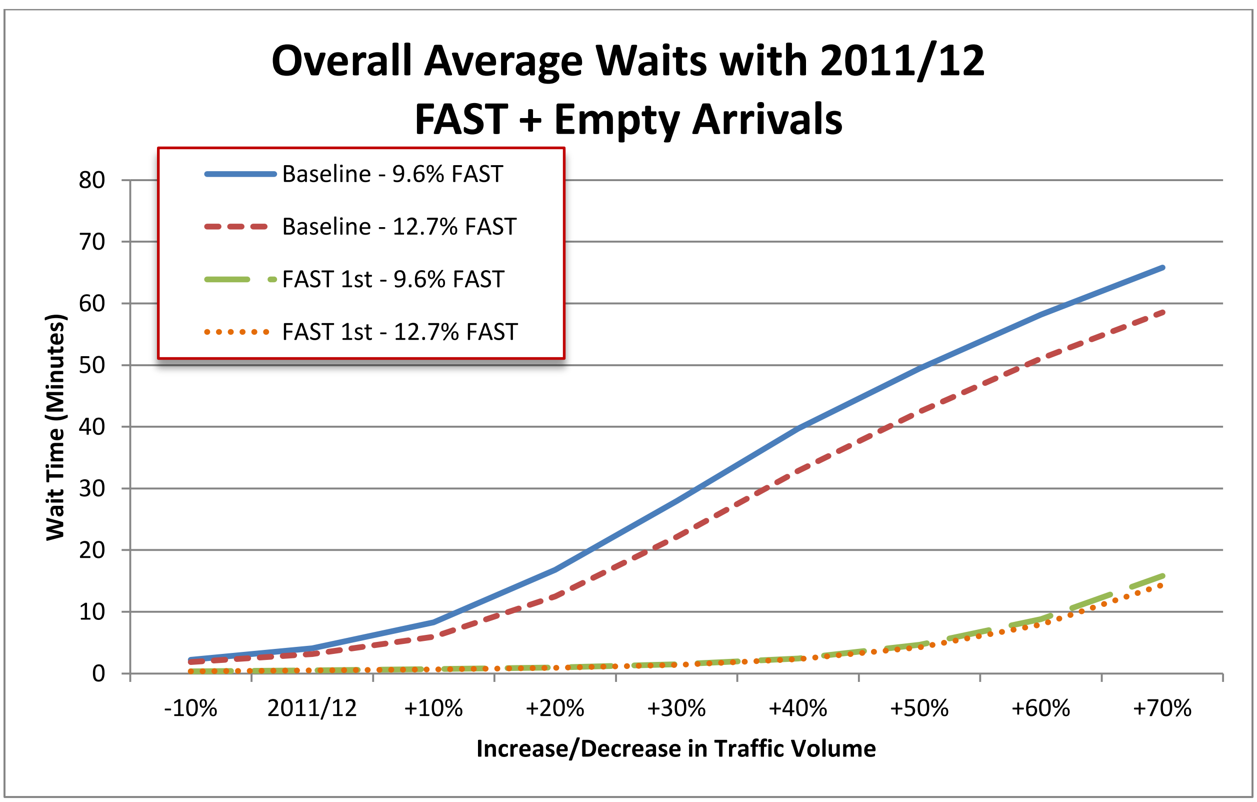

Figure 4: Overall average waiting times with FAST/empty arrival ratio = 9.6% and 12.7%.

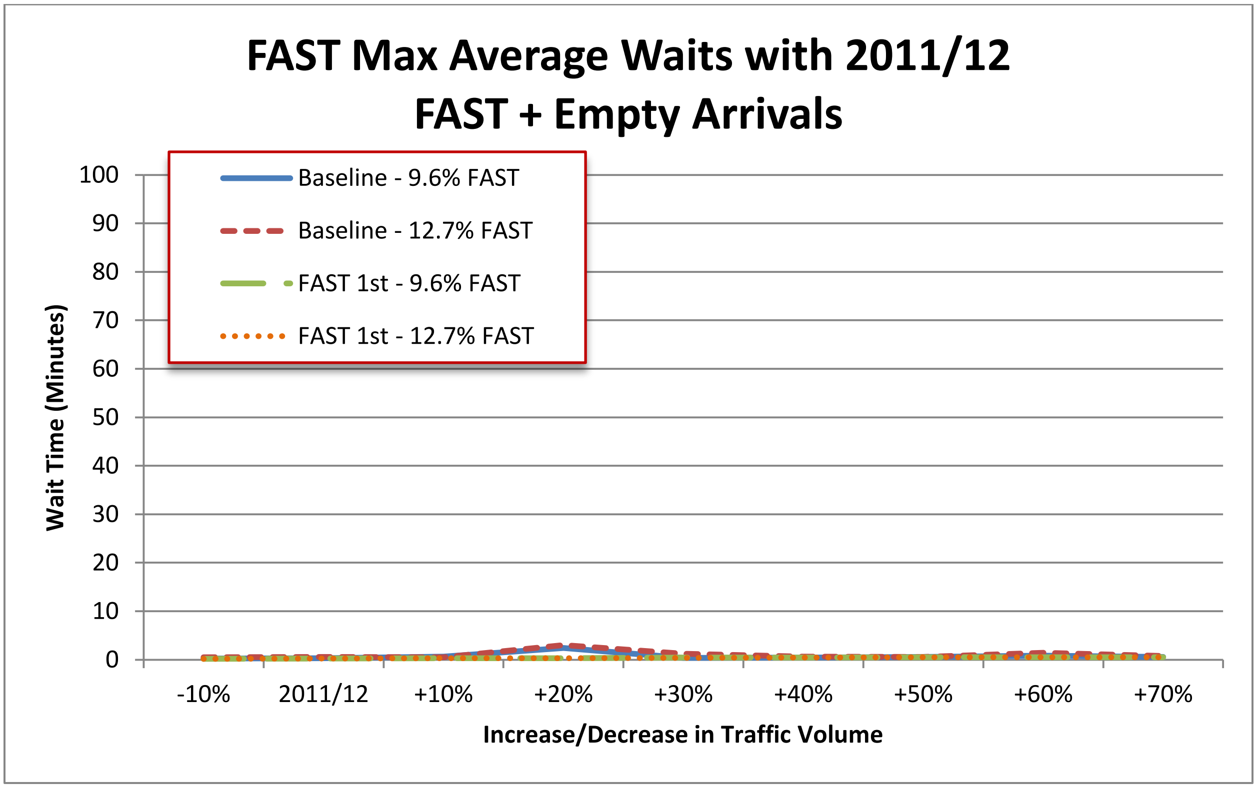

Figure 5: FAST max average waiting times with FAST/empty arrival ratio = 9.6% and 12.7%.

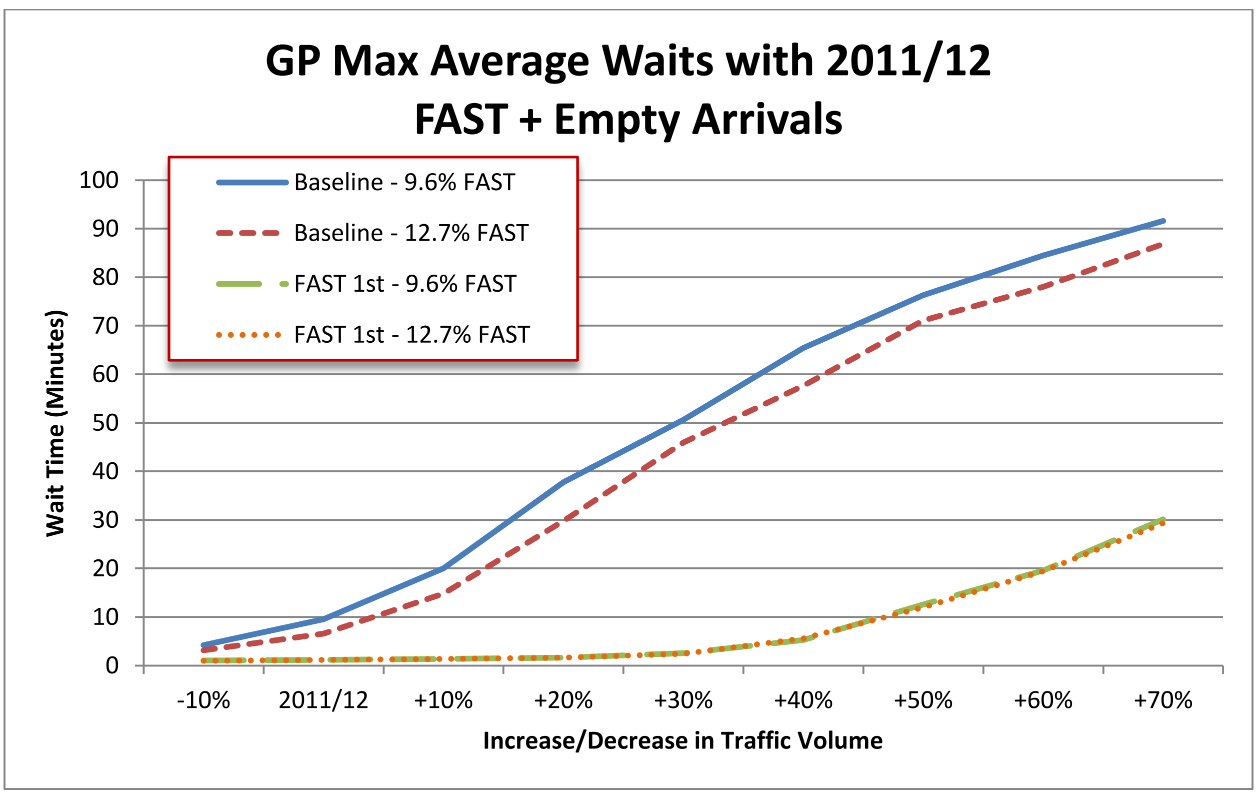

Figure 6: GP maximum average waiting times FAST/empty arrival ratio = 9.6% and 12.7%.

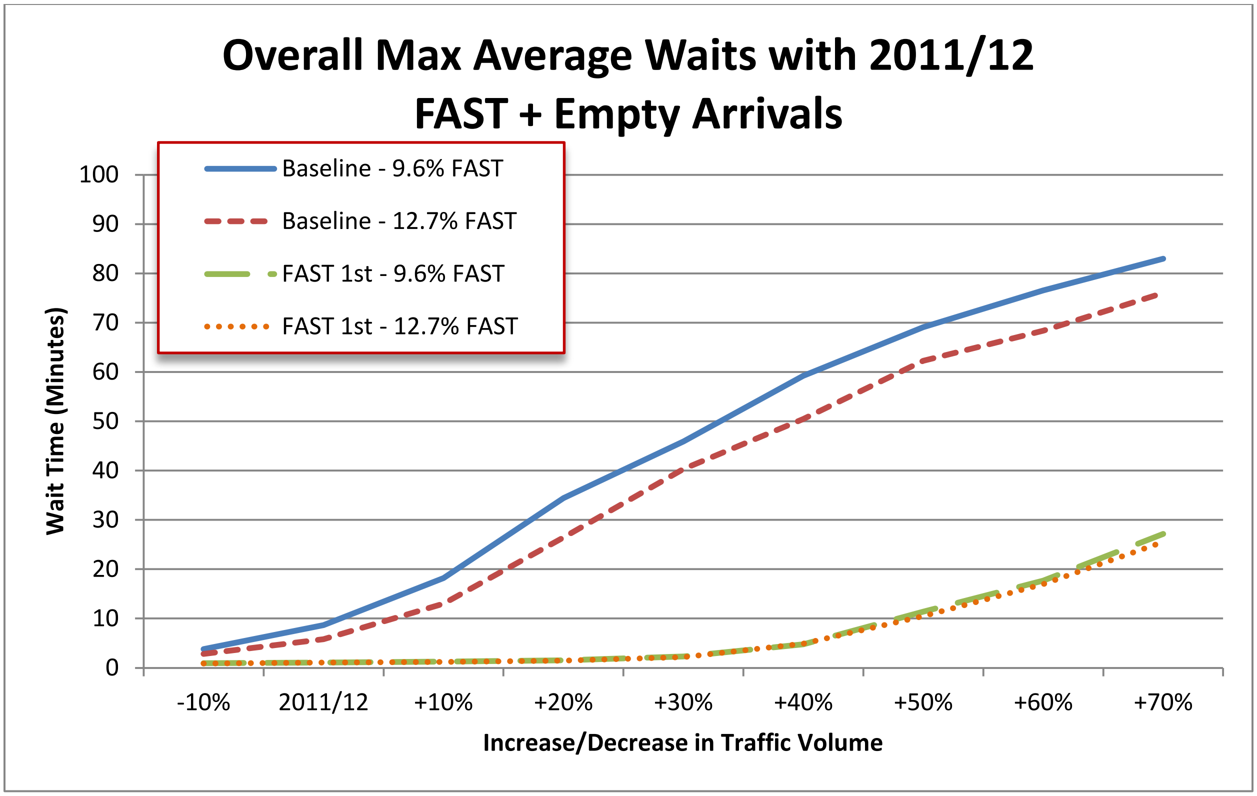

Figure 7: Overall max average waiting times with FAST/empty arrival ratio = 9.6% and 12.7%.

The same pattern occurs with regards to the maximum average waiting time (average times from the worst day of the month) and average maximum waiting time (average of the worst waiting time every day for a month). Figures 5 – 7 show the maximum average waiting times for the same configurations and FAST/empty arrival ratios; the numbers for all the configurations appear in Appendix B. Note that the vertical axis for Figures 5 – 7 is scaled from 0 to 100 minutes. Once again, the trucks using the FAST/empty approach lane have extremely small maximum average waiting times for all scenarios; switching from the baseline system to the FAST 1st configuration will not noticeably increase waiting times for FAST or empty vehicles. The benefits for the GP trucks, however, and therefore for the system as a whole, of switching to the FAST 1st system is dramatic: the "worst day of the month" average wait times are cut by more than three-quarters at 2011/2012 traffic levels, and by roughly two-thirds as traffic volumes rise to seventy percent above their current 2011/2012 levels.

Figures 8 – 10, and Appendix C, show the average maximum waiting times for the different configurations. As discussed above, these are averages of the worst daily waiting times experienced under each different configuration; since, for some configurations, these times tend to be larger than the maximum average waiting times, the vertical axis extends from 0 to 160 minutes. The relative performance of the different configurations is similar to that evidenced by the charts of maximum average waiting times, except that under baseline conditions the average longest wait for FAST approach lane users is generally greater than one minute. More specifically, under baseline conditions, the average worst-case daily wait is between two to three minutes for 2011/2012 traffic levels, and grows to approximately four minutes with a seventy percent increase in traffic. Switching to FAST 1st actually improves the average worst-case daily wait times, as in the FAST 1st configuration this average never exceeds two minutes. For GP trucks, as with the other performance measures, the benefits are clear: the average maximum daily wait is cut in half at 2011/2012 levels, while as traffic increases it is cut by twenty-five percent or more.

Finally, consider the overall utilization of the three inspection booths under the different configurations. Figure 11 shows that the baseline and FAST 1st configurations exhibit two different patterns: at low traffic levels, both configurations start out at around 40% utilization of all three booths, but as traffic levels increase, the baseline configurations top out at around 52%, while the FAST 1st configuration seems to be approaching close to 70% utilization. As discussed earlier, one hundred percent utilization is not possible because of the transition times between trucks; the time it takes the truck to move from its waiting position to the booth will result in slack time that puts an upper bound on booth utilization. In addition, for the baseline systems, the booth dedicated to FAST vehicles is underutilized: only 9.6% or 12.7% percent of the arrivals use it, even though it represents one third of the system capacity. This underutilization of the FAST booth represents "lost" capacity, since the GP trucks cannot access it even when there are no FAST/empty trucks waiting. The FAST 1st configuration avoids this possibility, since the GP trucks can access all three booths when no FAST/empty trucks are waiting. Making use of this extra capacity is what enables the FAST 1st configuration to offer lower waiting times for GP trucks with a very small penalty for FAST trucks.

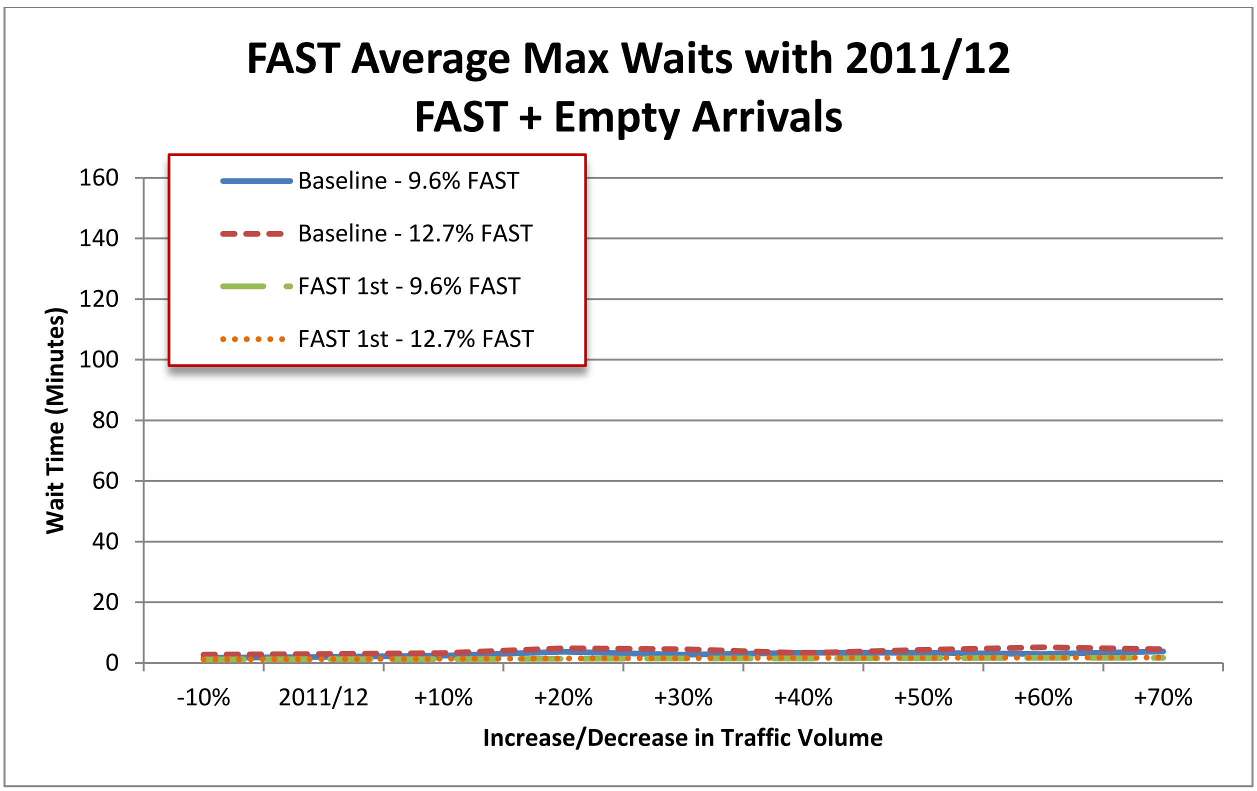

Figure 8: FAST average max waiting times with FAST/empty arrival ratio = 9.6% and 12.7%.

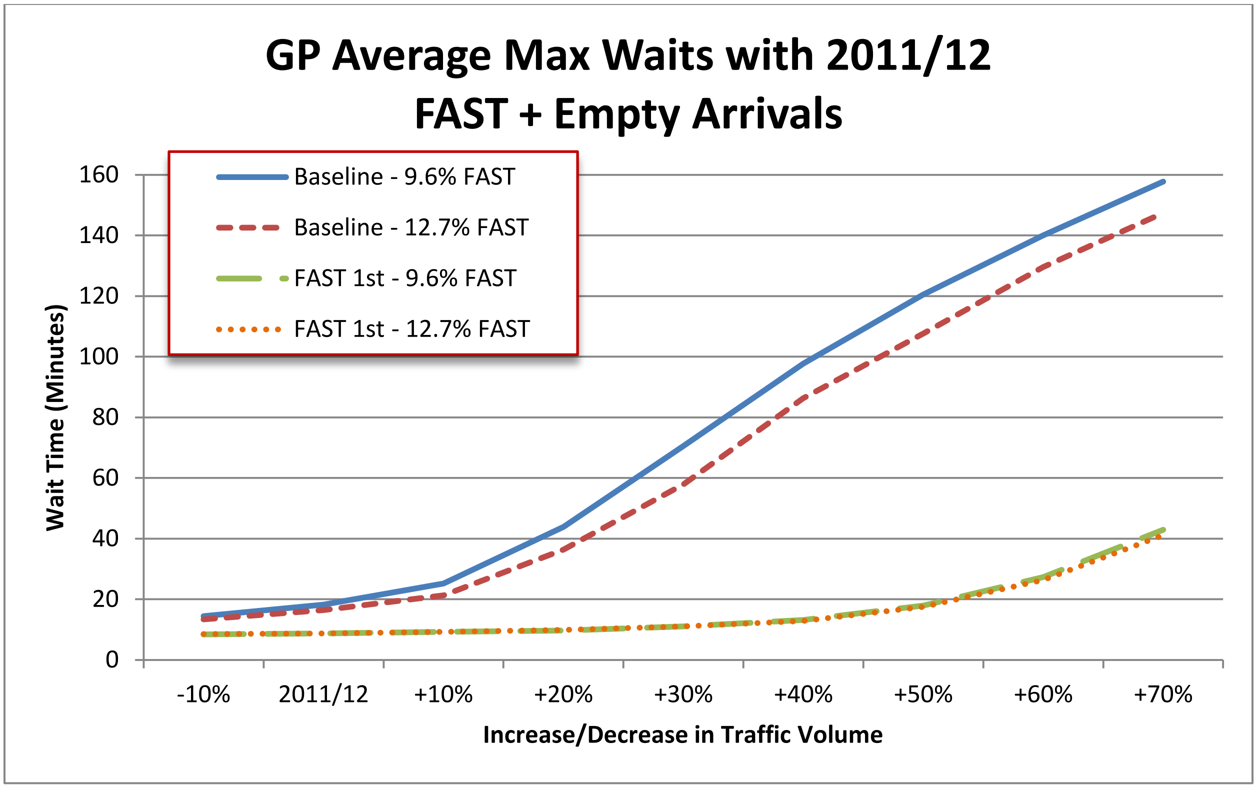

Figure 9: GP average max waiting times with FAST/empty arrival ratio = 9.6% and 12.7%.

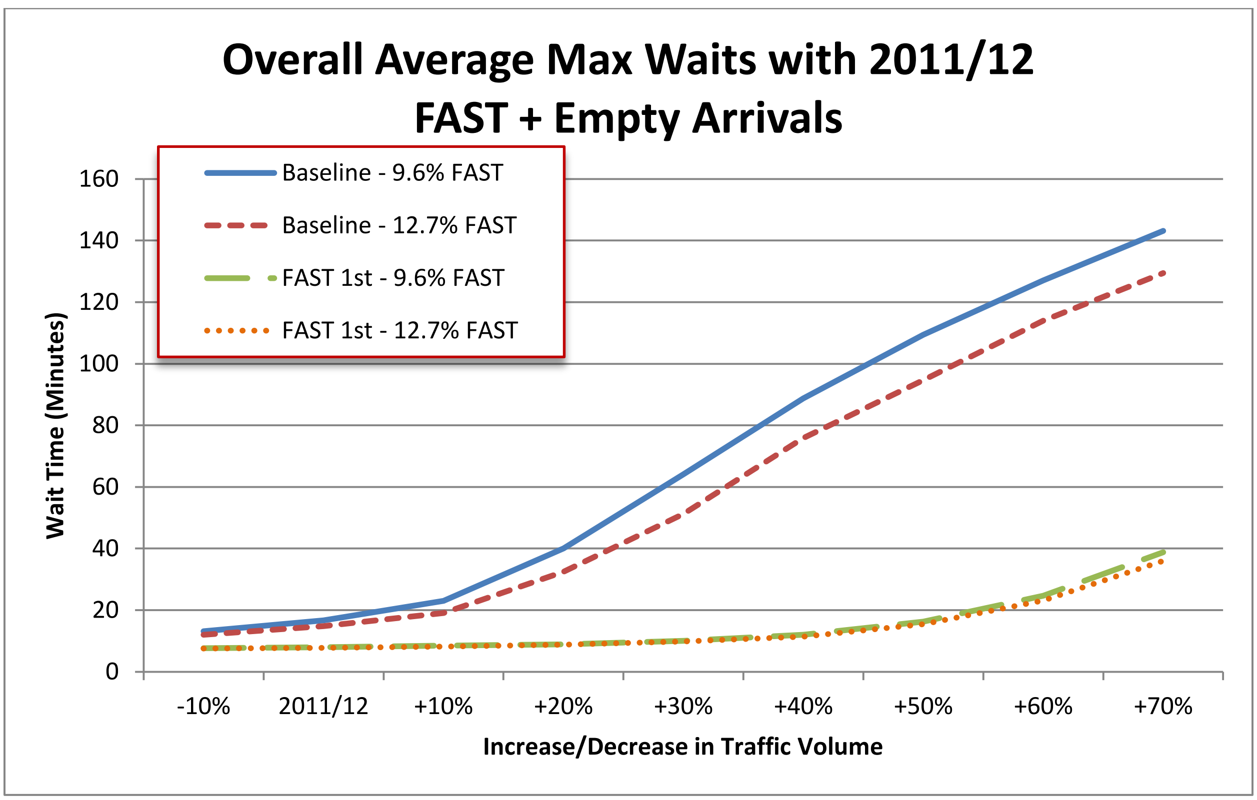

Figure 10: Overall average max waiting times with FAST/empty arrival ratio = 9.6% and 12.7%.

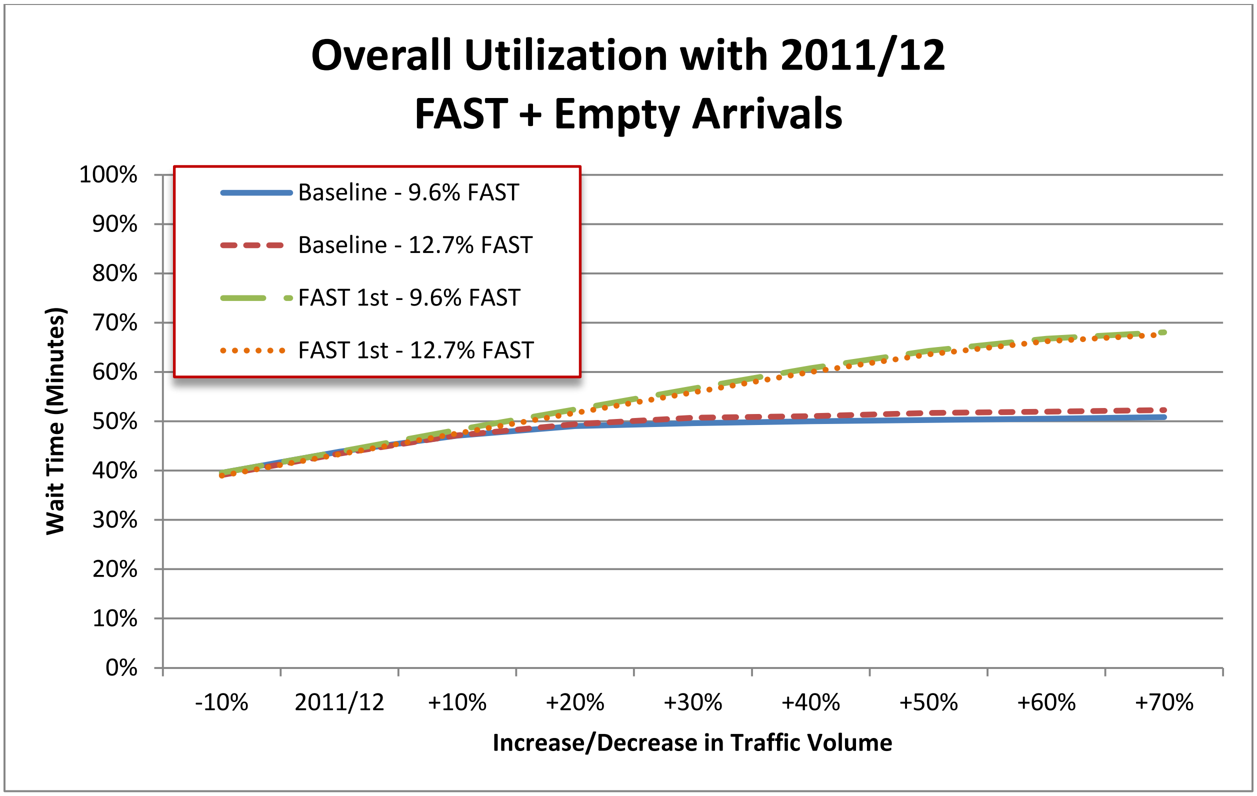

Figure 11: Overall booth utilization with FAST/empty arrival ratio = 9.6% and 12.7%.

Summing up, one can reach the following conclusion for border configurations when the FAST/empty ratio is expected to be in the range of 9.6% or 12.7%: switching from the baseline configuration to a FAST 1st configuration will not noticeably lengthen the waiting times of FAST or empty trucks, and can dramatically reduce the waiting times for GP trucks. At the relatively low FAST/empty utilization rates found in the 2011 and 2012 studies, freeing up some of the unused FAST booth capacity can cut the GP waits without negatively impacting FAST or empty vehicle waiting times.

Results for the 2009 FAST/Empty Ratios

To examine the robustness of our conclusions in the previous section, we consider the performance of the configurations under a wider range of FAST ratios. First, we consider a situation where only FAST-eligible trucks are allowed to use the FAST approach lane; based on the data from 2009, which is the last year in which this ratio was observed, this corresponds to a FAST ratio of only two percent. Second, in recognition of higher rates of empty vehicles in the past, we consider a FAST/empty ratio of 21%, which corresponds to the FAST/empty ratio observed in 2009. We examine the same set of waiting time and utilization statistics as in the previous section.

Consider first the average waiting time per vehicle for FAST, GP, and all trucks shown in Figures 12-14 and Appendix D. Comparing Figures 4 and 14, we see that for both configurations, an increase in the FAST/empty ratio to 21% lowers the overall average wait times; a decrease in the FAST ratio to 2%, on the other hand, raises the overall average waiting times. This is not unexpected, since the FAST and empty vehicles have a smaller inspection time; the greater the fraction of FAST/empty vehicles, therefore, the less time needed for inspection overall, and the shorter the wait times. The impact of these FAST/empty ratio changes, however, is much greater on the baseline configuration. Under 2011/2012 traffic levels, dropping the FAST ratio from 9.6% to 2% increases the overall average wait time from 4.5 minutes to 7.8 minutes in the baseline system, while the same change in the FAST ratio increases the average wait in the FAST 1st configuration from 0.5 minutes to 0.6 minutes. Similarly, increasing the FAST ratio from 9.6% to 21% under the same traffic conditions decreases the average baseline wait to 1.7 minutes and the FAST 1st average wait to 0.4 minutes. The results are much more dramatic when traffic volume increases. Clearly, the FAST 1st configuration is also much more robust to changes in the FAST/empty ratio.

Examining the maximum average waiting times in Figures 15 – 17 and Appendix E, one sees a similar pattern as exhibited with the average wait times. Increasing the FAST/empty rate decreases maximum average waiting times at all traffic levels, just as decreasing the FAST/empty ratio increases maximum average waiting times. These changes are much greater under the baseline system than under the proposed FAST 1st configuration.

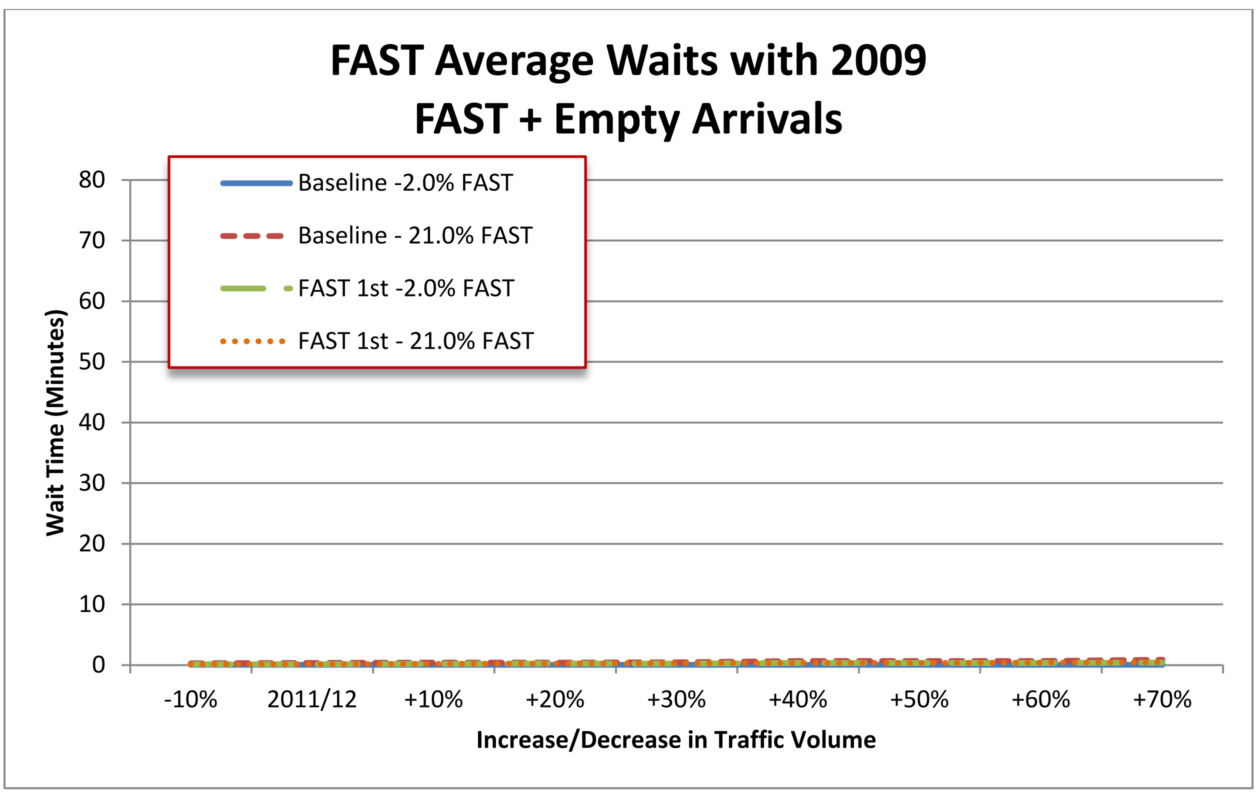

Figure 12: FAST average waiting times with FAST/empty arrival ratio = 2% and 21%.

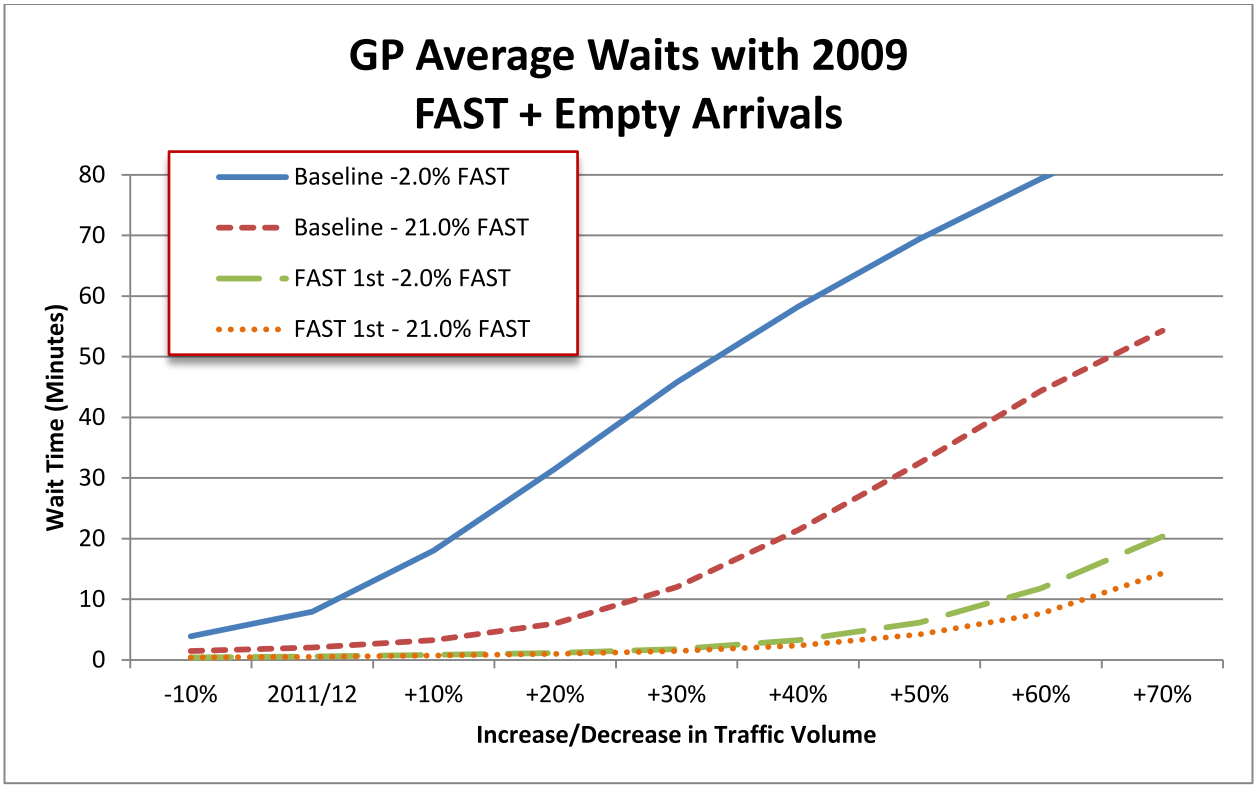

Figure 13: GP average waiting times with FAST/empty arrival ratio = 2% and 21%.

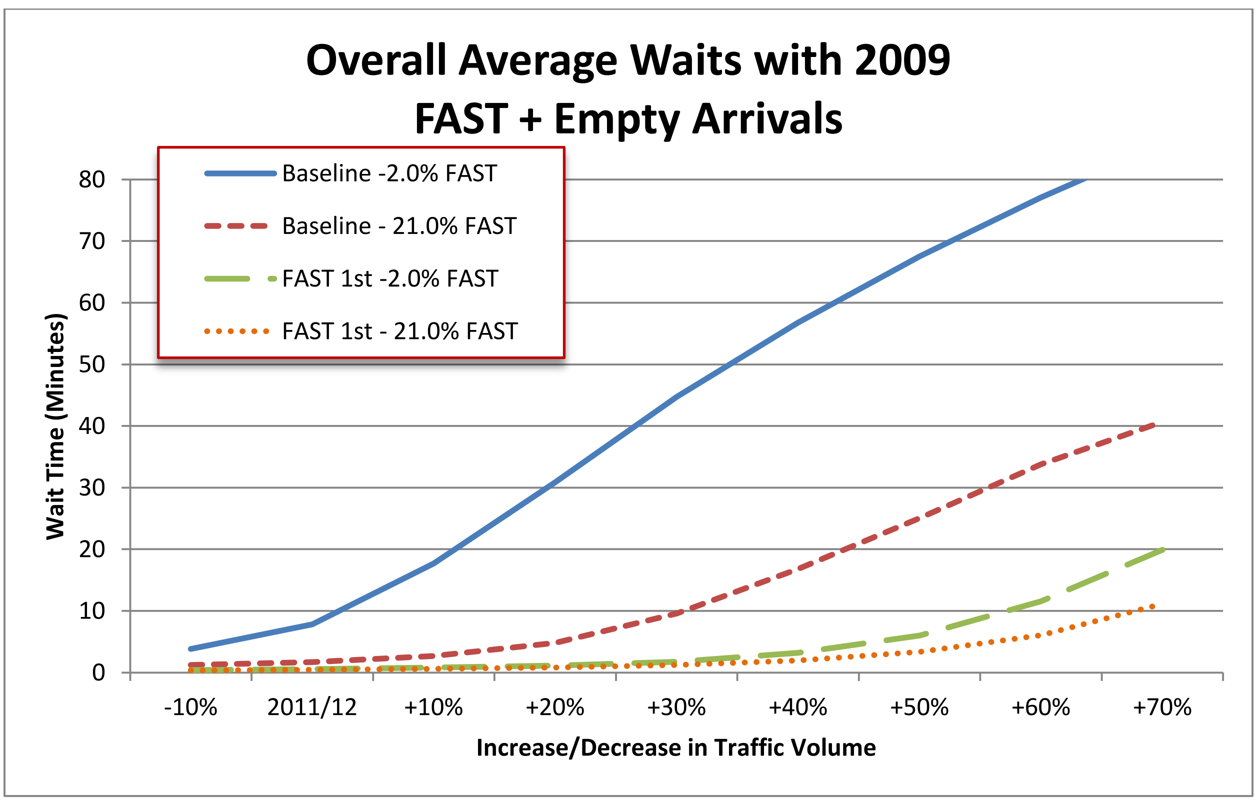

Figure 14: Overall average waiting times with FAST/empty arrival ratio = 2% and 21%.

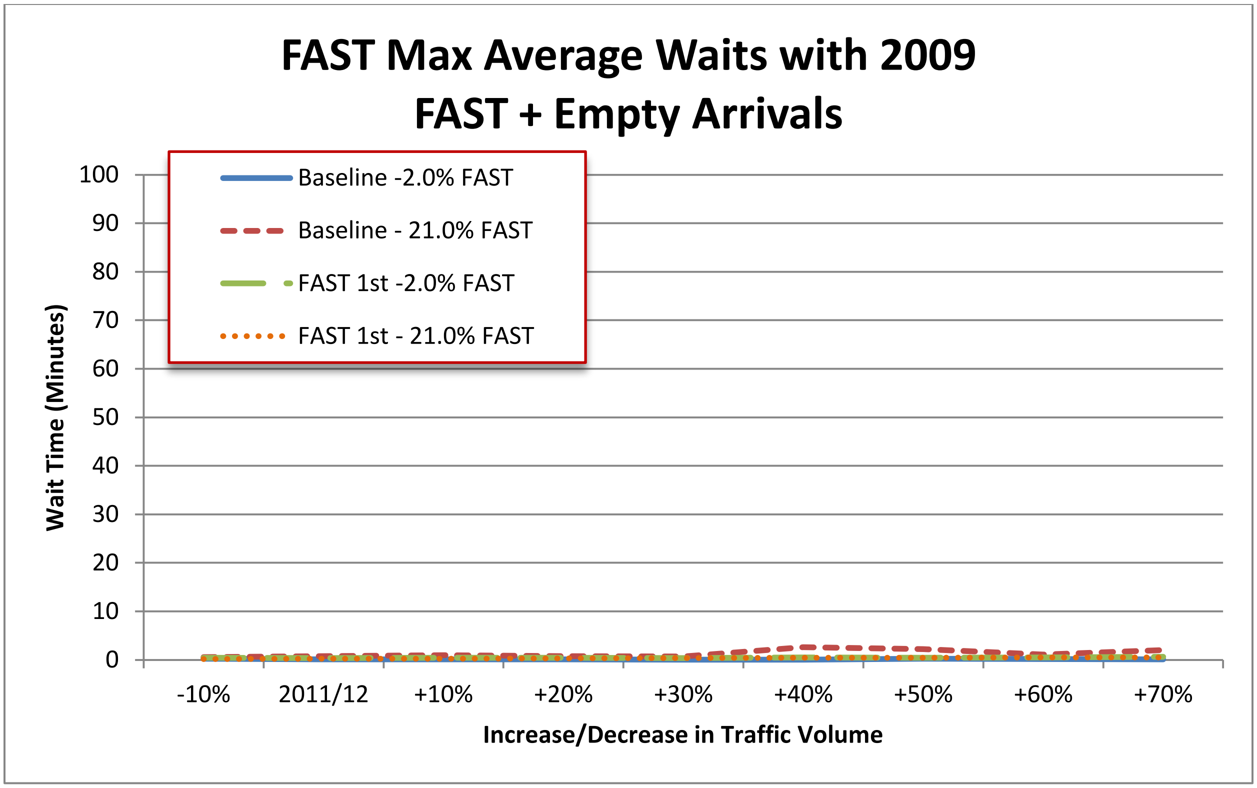

Figure 15: FAST max average waiting times with FAST/empty arrival ratio = 2% and 21%.

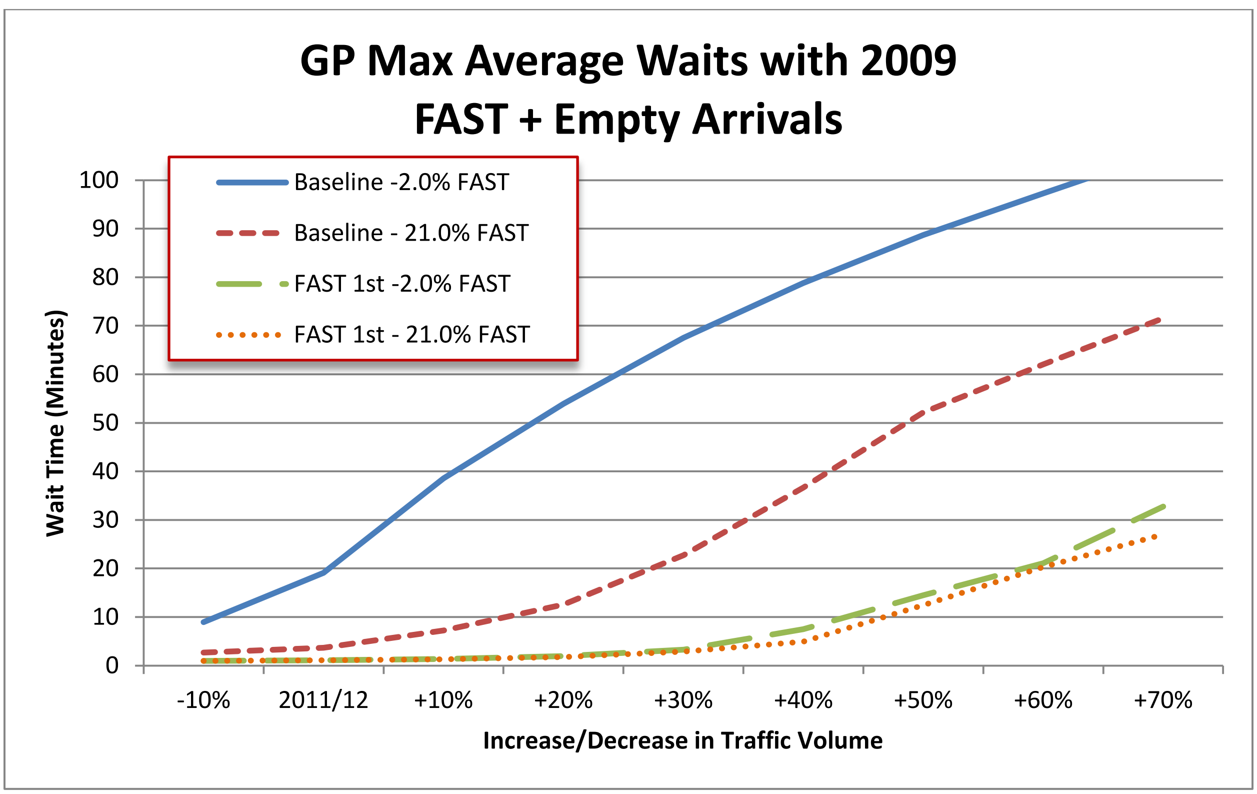

Figure 16: GP max average waiting times with FAST/empty arrival ratio = 2% and 21%.

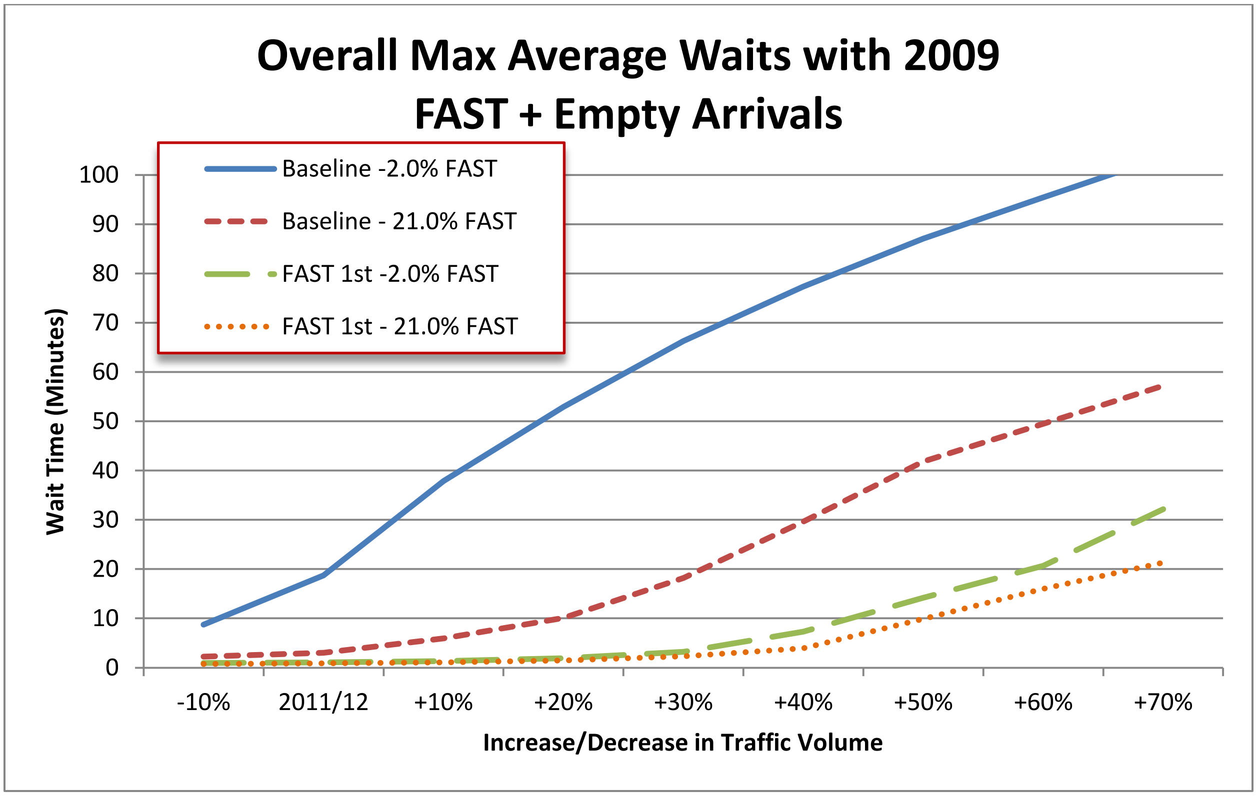

Figure 17: Overall max average waiting times with FAST/empty arrival ratio = 2% and 21%.

For the average maximum waiting times shown in Figures 18-20 and Appendix F, the narrative is mostly the same as for the average and maximum average waiting times at these more extreme FAST/empty ratios: the FAST 1st configuration outperforms the baseline configuration, and a higher FAST/empty ratio leads to lower overall average maximum waiting times. One slight difference from the other performance measures occurs for FAST/empty average maximum waiting times: for the baseline configuration at a FAST/empty ratio of 21%, the average daily worst case waiting times approach nine minutes as traffic intensifies. These are the worst values for FAST/empty trucks across all of the performance measures that we have considered. As with the overall system performance measures, however, the baseline performance is worse than the FAST 1st performance.

Finally, a quick examination in Figure 21 of the overall utilization of the three inspection booths at the higher FAST ratio shows some interesting phenomenon. For the baseline configuration, an increase in the FAST/empty ratio results in less underutilization of the FAST booth at higher traffic levels, and therefore a higher overall system utilization. For the FAST 1st configuration, the higher FAST/empty ratio results in less overall processing time being expended; this in turn slightly lowers the overall booth utilization for the traffic levels under consideration. Generally speaking, however, the FAST 1st configuration still obtains higher utilization of the booths than the baseline configuration.

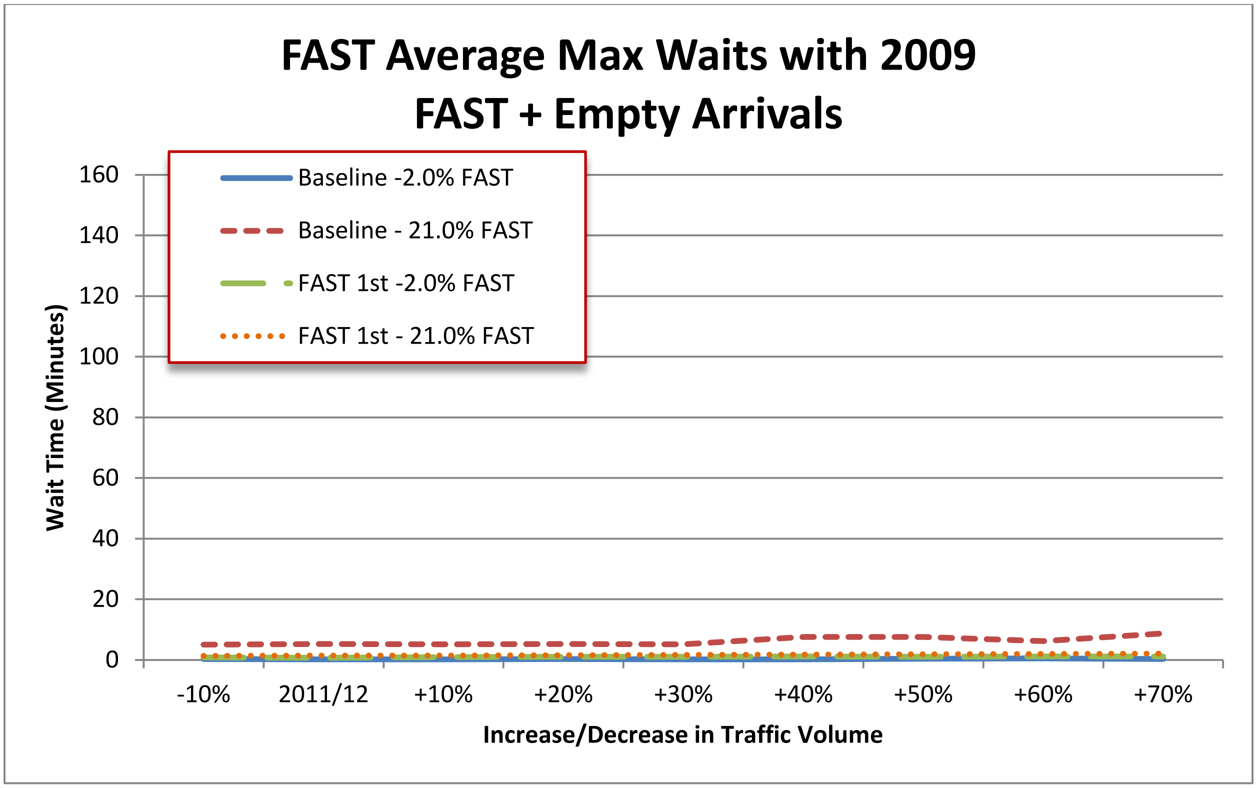

Figure 18: FAST average max waiting times with FAST/empty arrival ratio = 2% and 21%.

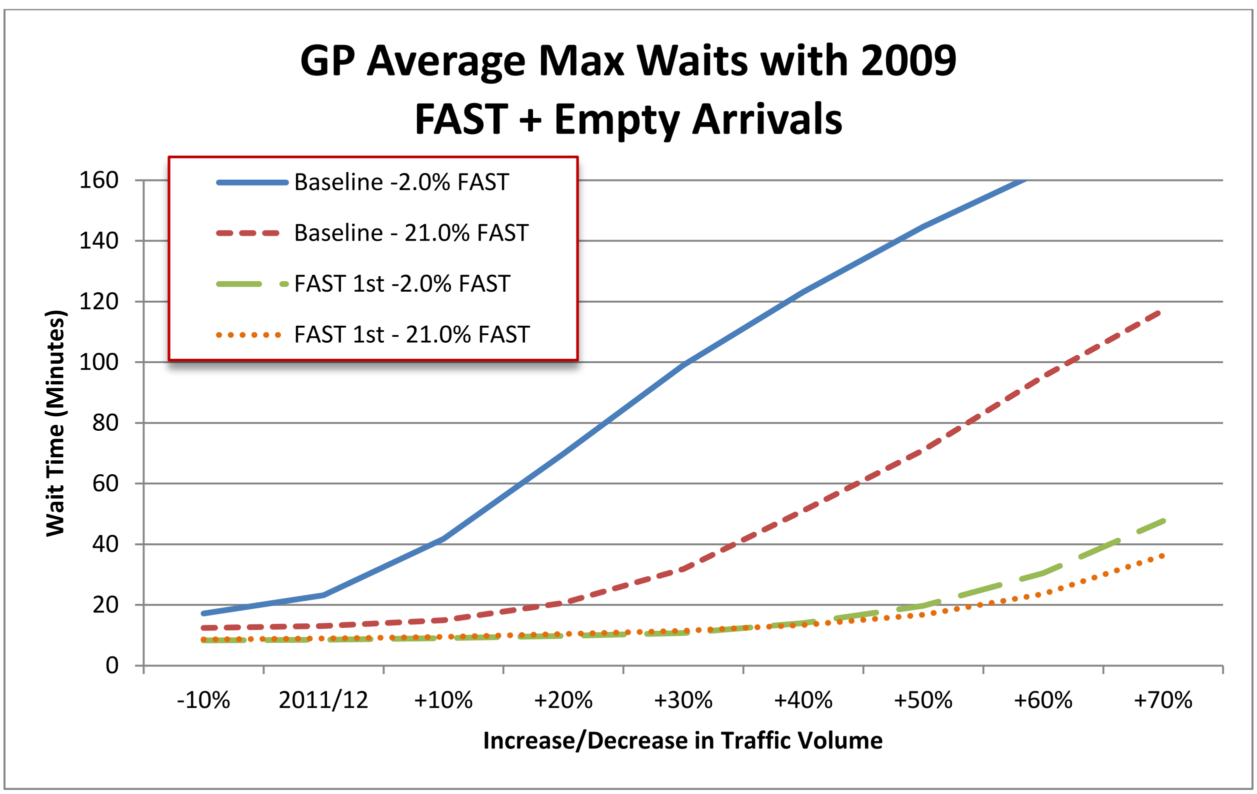

Figure 19: GP average maximum waiting times with FAST/empty arrival ratio = 2% and 21%.

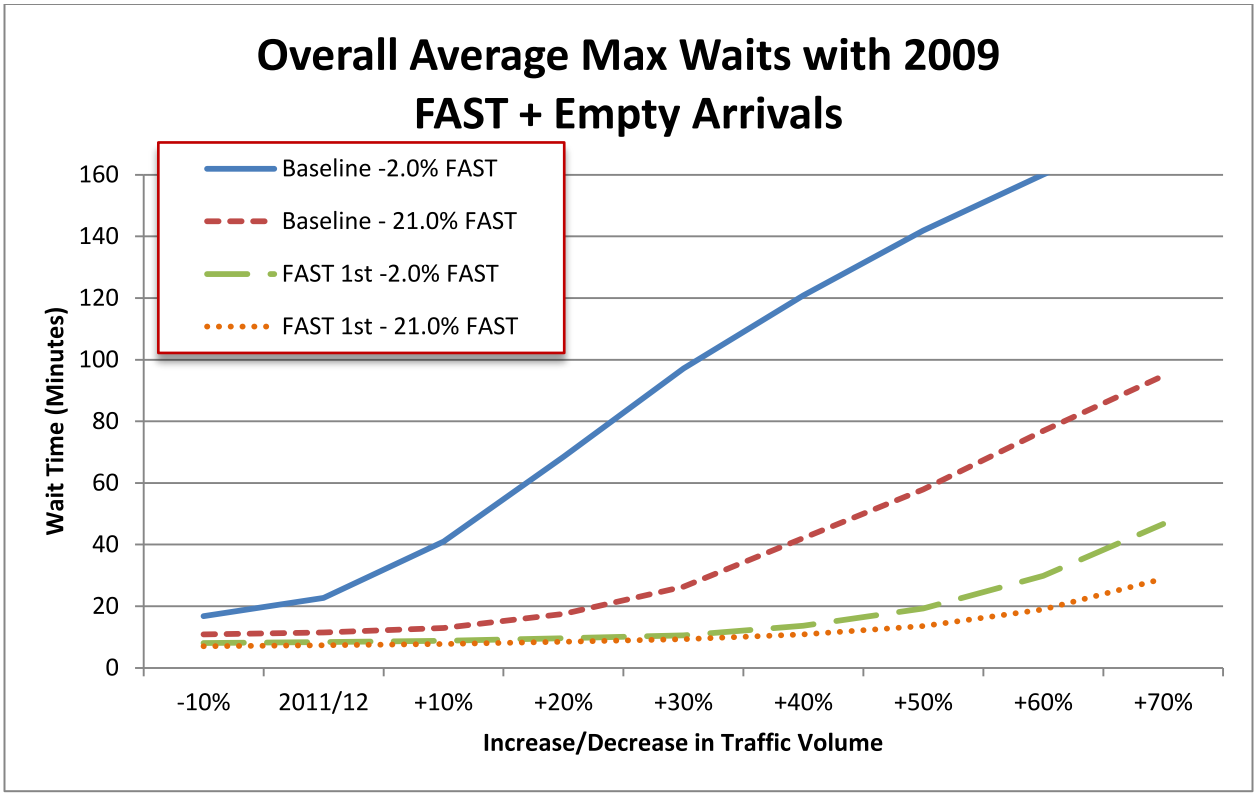

Figure 20: Overall average max waiting times with FAST/empty arrival ratio = 2% and 21%.

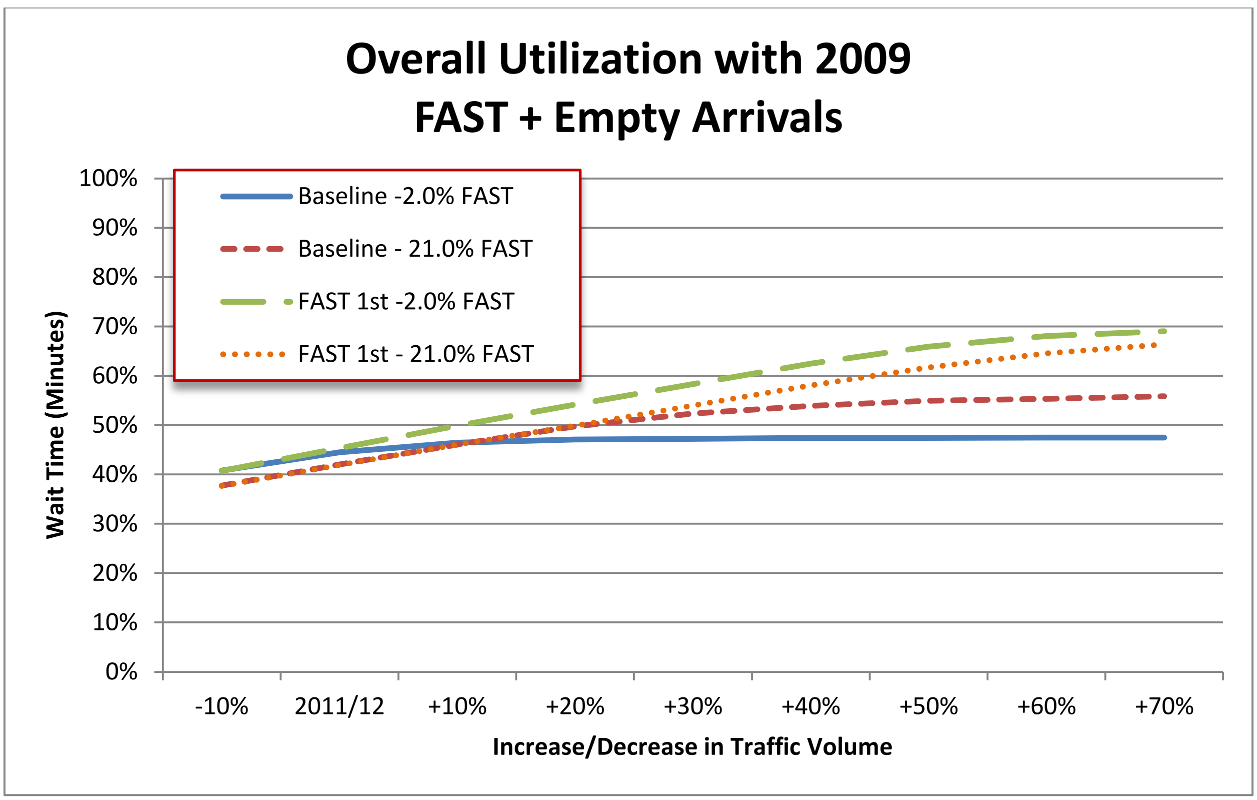

Figure 21: Overall booth utilization with FAST/empty arrival ratio = 2% and 21%.

Conclusion

The current baseline configuration of the northbound Pacific Highway Crossing bears much similarity to the baseline configuration used at the southbound PHC until this past year: one approach lane and one inspection booth are reserved for a small subset of arriving vehicles, leaving two inspection booths and one approach lane for all remaining general purpose truck traffic. For northbound traffic, this subset of vehicles has recently included both FAST-qualified and empty trucks. Since the sum total of these two vehicle types amounted to less than thirteen percent of northbound traffic volume this past year, this has resulted in an underutilization of the dedicated FAST booth and longer waiting times for GP trucks. Changing the northbound PHC to a FAST 1st configuration, similar to that recently adopted by the southbound PHC, promises to significantly cut the waiting times of GP trucks without noticeably increasing the waits of FAST or empty trucks.

Such a change would not entail as significant a physical re-layout of the northbound border area as was necessary for the southbound border area; adding a stop bar with signaling at a point not far upstream of the inspection booths would be the most significant physical change. Another possible requirement would be to create short feeder lines in front of each of the booths, which would likely require placing the stop bar and signal further south by an equal distance. In response to these small changes, however, GP waiting times can be reduced significantly, and the border crossing can be made more robust against possible future changes in overall traffic volume or FAST participation rates.

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APPENDIX A: AVERAGE WAITING TIMES, FAST RATIO = 9.6% & 12.7%

	Traffic Volume Level								
Border Configuration	-10%	2011/12	+10%	+20%	+30%	+40%	+50%	+60%	+70%
Baseline - 9.6% FAST	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.2
Baseline - 12.7% FAST	0.2	0.2	0.2	0.3	0.3	0.2	0.3	0.3	0.3
FAST 1st - 9.6% FAST	0.1	0.2	0.2	0.2	0.3	0.3	0.3	0.4	0.4
FAST 1st - 12.7% FAST	0.1	0.1	0.2	0.2	0.3	0.3	0.4	0.4	0.4

Table A1. FAST Average Waits with 2011/12 FAST + Empty Arrival Rates

	Traffic Volume Level								
Border Configuration	-10%	2011/12	+10%	+20%	+30%	+40%	+50%	+60%	+70%
Baseline - 9.6% FAST	2.4	4.5	9.1	18.7	31.3	44.8	56.2	66.6	76.0
Baseline - 12.7% FAST	2.1	3.5	6.8	14.3	25.6	38.5	50.1	61.0	70.6
FAST 1st - 9.6% FAST	0.4	0.5	0.8	1.0	1.6	2.7	5.1	9.8	17.7
FAST 1st - 12.7% FAST	0.4	0.5	0.7	1.0	1.6	2.6	4.8	9.1	16.7

Table A2. GP Average Waits with 2011/12 FAST + Empty Arrival Rates

	Traffic Volume Level								
Border Configuration	-10%	2011/12	+10%	+20%	+30%	+40%	+50%	+60%	+70%
Baseline - 9.6% FAST	2.2	4.1	8.3	16.8	28.0	39.7	49.5	58.2	65.8
Baseline - 12.7% FAST	1.8	3.1	6.0	12.5	22.2	32.8	42.5	51.1	58.6
FAST 1st - 9.6% FAST	0.4	0.5	0.7	0.9	1.5	2.4	4.6	8.8	15.8
FAST 1st - 12.7% FAST	0.4	0.5	0.7	0.9	1.4	2.3	4.2	7.9	14.4

Table A3. Overall Average Waits with 2011/12 FAST + Empty Arrival Rates

APPENDIX B: MAX AVERAGE WAITING TIMES, FAST RATIO = 9.6% & 12.7%

	Traffic Volume Level								
Border Configuration	-10%	2011/12	+10%	+20%	+30%	+40%	+50%	+60%	+70%
Baseline - 9.6% FAST	0.2	0.3	0.6	2.4	0.4	0.4	0.6	0.8	0.6
Baseline - 12.7% FAST	0.5	0.5	0.5	3.0	1.2	0.6	0.6	1.4	0.8
FAST 1st - 9.6% FAST	0.2	0.2	0.3	0.3	0.4	0.5	0.5	0.5	0.5
FAST 1st - 12.7% FAST	0.2	0.2	0.3	0.3	0.4	0.5	0.5	0.5	0.5

Table B1. FAST Maximum Average Waits with 2011/12 FAST + Empty Arrival Rates

	Traffic Volume Level								
Border Configuration	-10%	2011/12	+10%	+20%	+30%	+40%	+50%	+60%	+70%
Baseline - 9.6% FAST	4.2	9.5	20.0	37.8	50.7	65.4	76.3	84.5	91.6
Baseline - 12.7% FAST	3.1	6.6	14.8	29.8	45.9	57.6	71.1	78.0	86.8
FAST 1st - 9.6% FAST	1.0	1.2	1.4	1.6	2.5	5.3	12.6	19.6	30.1
FAST 1st - 12.7% FAST	1.0	1.2	1.4	1.6	2.4	5.6	12.0	19.5	29.4

Table B2. GP Maximum Average Waits with 2011/12 FAST + Empty Arrival Rates

	Traffic Volume Level								
Border Configuration	-10%	2011/12	+10%	+20%	+30%	+40%	+50%	+60%	+70%
Baseline - 9.6% FAST	3.8	8.7	18.2	34.4	45.9	59.2	69.1	76.5	83.0
Baseline - 12.7% FAST	2.8	5.8	13.0	26.4	40.3	50.5	62.3	68.4	76.0
FAST 1st - 9.6% FAST	0.9	1.1	1.3	1.5	2.3	4.8	11.4	17.7	27.2
FAST 1st - 12.7% FAST	0.9	1.1	1.2	1.4	2.2	4.9	10.5	17.0	25.6

Table B3. Overall Maximum Average Waits with 2011/12 FAST + Empty Arrival Rates

APPENDIX C: AVERAGE MAX WAITING TIMES, FAST RATIO = 9.6% & 12.7%

	Traffic Volume Level								
Border Configuration	-10%	2011/12	+10%	+20%	+30%	+40%	+50%	+60%	+70%
Baseline - 9.6% FAST	1.7	2.0	2.4	3.7	2.7	3.3	3.3	2.9	3.8
Baseline - 12.7% FAST	2.7	2.9	3.2	4.8	4.5	3.2	4.3	5.2	4.5
FAST 1st - 9.6% FAST	1.1	1.2	1.2	1.4	1.5	1.5	1.6	1.7	1.6
FAST 1st - 12.7% FAST	1.1	1.2	1.3	1.4	1.5	1.6	1.6	1.7	1.7

Table C1. FAST Average Maximum Waits with 2011/12 FAST + Empty Arrival Rates

	Traffic Volume Level								
Border Configuration	-10%	2011/12	+10%	+20%	+30%	+40%	+50%	+60%	+70%
Baseline - 9.6% FAST	14.4	18.2	25.2	43.9	70.6	97.7	120.5	140.1	157.8
Baseline - 12.7% FAST	13.4	16.5	21.3	36.4	57.9	86.3	107.7	129.6	147.4
FAST 1st - 9.6% FAST	8.4	8.7	9.2	9.7	11.0	13.1	17.9	27.3	42.9
FAST 1st - 12.7% FAST	8.5	8.7	9.3	9.8	11.1	12.9	17.5	26.3	41.2

Table C2. GP Average Maximum Waits with 2011/12 FAST + Empty Arrival Rates

	Traffic Volume Level								
Border Configuration	-10%	2011/12	+10%	+20%	+30%	+40%	+50%	+60%	+70%
Baseline - 9.6% FAST	13.2	16.7	23.1	40.1	64.1	88.7	109.4	127.1	143.2
Baseline - 12.7% FAST	12.0	14.8	19.1	32.4	51.2	75.9	94.7	114.0	129.5
FAST 1st - 9.6% FAST	7.6	7.9	8.4	8.8	10.1	12.0	16.3	24.7	38.8
FAST 1st - 12.7% FAST	7.5	7.7	8.2	8.7	9.8	11.4	15.4	23.1	36.0

Table C3. Overall Average Maximum Waits with 2011/12 FAST + Empty Arrival Rates

APPENDIX D: AVERAGE WAITING TIMES, FAST RATIO = 2% & 21%

	Traffic Volume Level								
Border Configuration	-10%	2011/12	+10%	+20%	+30%	+40%	+50%	+60%	+70%
Baseline -2.0% FAST	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Baseline - 21.0% FAST	0.3	0.4	0.4	0.4	0.5	0.7	0.7	0.6	0.9
FAST 1st -2.0% FAST	0.1	0.1	0.2	0.2	0.3	0.3	0.3	0.4	0.4
FAST 1st - 21.0% FAST	0.1	0.2	0.2	0.2	0.3	0.3	0.4	0.4	0.4

Table D1. FAST Average Waits with 2009 FAST + Empty Arrival Rates

	Traffic Volume Level								
Border Configuration	-10%	2011/12	+10%	+20%	+30%	+40%	+50%	+60%	+70%
Baseline -2.0% FAST	3.9	7.9	18.0	31.6	45.8	58.2	69.4	79.3	88.4
Baseline - 21.0% FAST	1.4	2.0	3.3	6.0	12.0	21.4	32.5	44.4	54.3
FAST 1st -2.0% FAST	0.4	0.6	0.8	1.1	1.8	3.3	6.1	11.8	20.4
FAST 1st - 21.0% FAST	0.4	0.5	0.7	1.0	1.5	2.4	4.2	7.6	14.3

Table D2. GP Average Waits with 2009 FAST + Empty Arrival Rates

	Traffic Volume Level								
Border Configuration	-10%	2011/12	+10%	+20%	+30%	+40%	+50%	+60%	+70%
Baseline -2.0% FAST	3.8	7.8	17.7	30.9	44.7	56.8	67.6	77.1	85.7
Baseline - 21.0% FAST	1.2	1.7	2.7	4.8	9.6	16.8	25.1	33.8	40.7
FAST 1st -2.0% FAST	0.4	0.6	0.8	1.1	1.7	3.2	6.0	11.5	19.9
FAST 1st - 21.0% FAST	0.3	0.4	0.6	0.8	1.2	1.9	3.4	6.1	11.1

Table D3. Overall Average Waits with 2009 FAST + Empty Arrival Rates

APPENDIX E: MAXIMUM AVERAGE WAITING TIMES, FAST RATIO = 2% & 21%

	Traffic Volume Level								
Border Configuration	-10%	2011/12	+10%	+20%	+30%	+40%	+50%	+60%	+70%
Baseline -2.0% FAST	0.2	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.1
Baseline - 21.0% FAST	0.6	0.7	1.0	0.8	0.7	2.6	2.2	1.1	2.0
FAST 1st -2.0% FAST	0.5	0.4	0.4	0.4	0.4	0.5	0.5	0.5	0.6
FAST 1st - 21.0% FAST	0.2	0.2	0.3	0.3	0.4	0.4	0.5	0.5	0.5

Table E1. FAST Maximum Average Waits with 2009 FAST + Empty Arrival Rates

	Traffic Volume Level								
Border Configuration	-10%	2011/12	+10%	+20%	+30%	+40%	+50%	+60%	+70%
Baseline -2.0% FAST	8.9	19.1	38.6	53.9	67.6	78.8	88.7	97.3	105.7
Baseline - 21.0% FAST	2.7	3.6	7.2	12.5	22.7	36.7	52.2	62.1	71.5
FAST 1st -2.0% FAST	0.9	1.1	1.4	2.0	3.3	7.5	14.5	21.1	32.8
FAST 1st - 21.0% FAST	0.9	1.1	1.3	1.8	2.9	4.9	12.5	20.3	27.0

Table E2. GP Maximum Average Waits with 2009 FAST + Empty Arrival Rates

	Traffic Volume Level								
Border Configuration	-10%	2011/12	+10%	+20%	+30%	+40%	+50%	+60%	+70%
Baseline -2.0% FAST	8.7	18.7	37.9	52.9	66.3	77.3	87.0	95.4	103.7
Baseline - 21.0% FAST	2.2	3.0	5.9	10.1	18.2	29.7	41.9	49.5	57.2
FAST 1st -2.0% FAST	0.9	1.1	1.3	1.9	3.2	7.3	14.2	20.7	32.1
FAST 1st - 21.0% FAST	0.8	0.9	1.1	1.5	2.3	3.9	9.9	16.0	21.3

Table E3. Overall Maximum Average Waits with 2009 FAST + Empty Arrival Rates

APPENDIX F: AVERAGE MAXIMUM WAITING TIMES, FAST RATIO = 2% & 21%

	Traffic Volume Level								
Border Configuration	-10%	2011/12	+10%	+20%	+30%	+40%	+50%	+60%	+70%
Baseline -2.0% FAST	0.2	0.2	0.2	0.3	0.2	0.2	0.3	0.5	0.3
Baseline - 21.0% FAST	5.0	5.3	5.1	5.2	5.1	7.6	7.5	6.2	8.7
FAST 1st -2.0% FAST	0.8	0.7	0.9	1.0	1.0	1.1	1.0	1.1	1.1
FAST 1st - 21.0% FAST	1.3	1.4	1.4	1.5	1.6	1.7	1.9	1.9	2.0

Table F1. FAST Average Maximum Waits with 2009 FAST + Empty Arrival Rates

	Traffic Volume Level								
Border Configuration	-10%	2011/12	+10%	+20%	+30%	+40%	+50%	+60%	+70%
Baseline -2.0% FAST	17.1	23.2	41.8	69.8	99.1	123.1	144.7	163.2	180.5
Baseline - 21.0% FAST	12.4	13.1	15.0	20.7	31.9	51.1	71.0	95.3	117.2
FAST 1st -2.0% FAST	8.2	8.5	9.0	9.7	10.7	13.9	19.7	30.4	47.7
FAST 1st - 21.0% FAST	8.6	9.0	9.4	10.4	11.5	13.4	16.7	23.6	36.3

Table F2. GP Average Maximum Waits with 2009 FAST + Empty Arrival Rates

	Traffic Volume Level								
Border Configuration	-10%	2011/12	+10%	+20%	+30%	+40%	+50%	+60%	+70%
Baseline -2.0% FAST	16.8	22.7	41.0	68.5	97.2	120.8	141.9	160.1	177.1
Baseline - 21.0% FAST	10.9	11.5	12.9	17.5	26.3	42.1	57.9	76.9	94.8
FAST 1st -2.0% FAST	8.1	8.3	8.8	9.6	10.5	13.7	19.3	29.8	46.7
FAST 1st - 21.0% FAST	7.0	7.3	7.7	8.5	9.3	10.8	13.5	18.9	28.9

Table F3. Overall Average Maximum Waits with 2009 FAST + Empty Arrival Rates