Regional Freight Capacity Management:

Free and Secure Trade (FAST) Program Optimization at the Pacific Highway, Southbound Crossing

by

Mark Springer,
Professor,
Department of Decision Sciences
College of Business and Economics
Western Washington University

September 2011

***Project Funded by the Washington State Department of Transportation**

INTRODUCTION

In the spring of 2011, a pilot project at the southbound Pacific Highway Crossing (PHC) tested the impact of opening the previously restricted FAST lane at the PHC to all commercial freight traffic. The FAST, or Free and Secure Trade program (USCBP, 2005), was designed to increase the security of southbound commercial freight into the United States. To qualify for FAST, carriers, drivers, and shippers are required to follow certain security procedures which aim to enhance the safety and security of the border. Trucks enrolled in FAST are then allowed to use the dedicated lane and inspection booth at the southbound PHC which enables them to bypass the typically much longer queues in the general purpose (GP) lane. The objective of the pilot project was to determine if overall wait times could be reduced for GP trucks without a dramatic increase in the wait times for FAST-enrolled trucks. An earlier study (Springer, 2010) had found that opening the southbound FAST lane and booth to GP traffic would reduce the average waiting time across all trucks, although waiting times for the FAST trucks mixed in with the GP traffic would increase. The results of this experiment led to the pilot project as a means of testing the predictions of the simulation.

To conduct the test, data were collected over several days while two different lane configurations were in operation at the southbound PHC. The configuration at that time, involving one FAST lane and booth, and one GP lane and two GP booths, was termed the *baseline* configuration; the *pilot* configuration consisted of a single GP lane and three GP booths (Davidson, 2011). As expected, the results of the pilot project showed a sharp drop in system-wide average wait times when the FAST booth was opened to GP traffic (Springer, 2011a; BPRI & WCOG, 2011). Average waiting times for weekdays without unrelated system problems dropped from over fifty minutes to just under eleven minutes for GP trucks; FAST-enrolled

trucks increased their average waiting times from under four minutes to almost eleven minutes. These results were further validated by a follow-up simulation study where arrival rates and inspection times were calibrated to the observations of the 2011 experiment (Springer, 2011b). This study held external factors (e.g., the arrival rate patterns) steady across simulations of both the baseline and pilot phases. The results showed that the overall gains of switching from the baseline to the pilot system were slightly greater than observed during the pilot project: the estimated average waiting time per truck dropped from the observed eleven minutes to less than nine minutes.

While these results indicated dramatic time savings for GP trucks in switching from the baseline to the pilot configuration at the U.S. PHC, there was some concern about the increase in average waiting time for FAST-enrolled vehicles. Noting these concerns, and the fact that the earlier studies examined only two border approach configurations. follow-on discussions identified some alternative approach configurations that might yield a more satisfactory combination of waiting time costs and benefits for both FAST and GP trucks. Ideally, these different configurations would yield shorter waiting times for *both* FAST and GP trucks than exhibited by the pilot configuration. However, even if this is not possible, there may be a different configuration that, relative to the baseline configuration, obtains sharp reductions in GP waiting times for a smaller increase to FAST waiting times.

This study uses simulation to investigate three alternative border configurations in pursuit of this objective. Each of these different configurations is a "shared-booth" configuration, in that all booths are open to all types of vehicles. This approach allows greater utilization of the three booths, and offers the possibility of a "compromise" between the baseline and pilot configurations: waiting times for FAST trucks which are not much higher than the waiting times

of the baseline configuration; and waiting times for GP trucks which are only slightly higher than the waiting times of the pilot configuration under current traffic levels. In the following pages, the differences between the booth configurations will be outlined first; then the parameter settings used in the simulation experiment will be discussed; and finally an analysis of the results will be presented.

EXISTING AND ALTERNATIVE BORDER CONFIGURATIONS

In all configurations, trucks are served by three booths, each of which is immediately preceded by a radiation portal monitor (RPM) several meters in front of the booth. In each lane, trucks approaching the booth must stop in front of the RPM and wait for the inspection booth to become available. After the truck being inspected at the booth departs, the truck waiting at the RPM must move forward to the inspection booth before the inspection process can begin. The average time between the departure of a truck from the inspection booth and the arrival of the truck that had been waiting at the RPM is approximately thirty-six seconds; this time limits the utilization of the inspection booth under the baseline and pilot configurations. The distribution of this time did not vary throughout the day, or between different border configurations, and it was modeled as such in the simulation.

The Baseline Border Configuration

This configuration includes one approach lane and booth reserved for FAST vehicles, and one approach lane and two booths for general-purpose vehicles. Average inspection times for FAST vehicles were less than GP trucks, and were modeled accordingly. FAST-qualified trucks arriving at the border have their own approach lane; they queue up behind the RPM in this lane to wait for the availability of the dedicated FAST booth. GP trucks arriving at the border also have their own approach lane, but it turns off of Highway 15 at 2nd Avenue and is routed behind

the West Coast Tax and Duty Free (WCTDF) store. After passing south of the store, the single GP queue breaks into six different feeder queues, each of which holds on average three trucks, and is controlled by a traffic signal at the signal bar. The signal bar rotates through all six feeder queues, selecting trucks to join one of the two lanes feeding the dedicated GP RPMs and booths. Each lane between the signal bar and the RPM holds approximately five trucks.

The Pilot Border Configuration

In the pilot configuration, one approach lane and three booths are open for general-purpose truck traffic; any FAST-qualified trucks moving through the border crossing are mixed in with the GP trucks. All trucks turn off Highway 15 onto 2nd Avenue and rejoin the queue behind the WCTDF store, which feeds into six three-truck feeder queues controlled by the signal bar. From the signal bar, trucks are selected in rotation to join one of the three lanes feeding the three GP booths. Each of these three lanes holds five trucks between the signal bar and the RPM. The inspection time distribution for the pilot phase was modeled separately using data gathered from the pilot phase of the project.

The Three "Shared-booths" Configurations

In addition to the baseline and pilot configurations, there are many possible different border configurations that could be considered for future use. In this study, three additional primary different configurations will be considered, and for each of these three configurations, different lane placements will be considered. Each of the three configurations retains the same core element: rather than having a dedicated inspection booth for FAST-qualified trucks and two inspection booths open to GP trucks, as in the baseline configuration, all three booths are opened to FAST and GP trucks and access to the booths is controlled through signaling. FAST and GP trucks would therefore have separate arrival lanes, unlike the pilot configuration, but trucks

could be chosen from these two distinct queues based on whatever priority rule yielded the most desirable waiting time profiles for FAST and GP trucks. With this approach, FAST trucks could retain some of the advantage in terms of waiting time that they enjoyed under the baseline configuration, and GP trucks would keep some of the gains in waiting time reduction they achieved under the pilot configuration. Before reviewing the three "shared-booths" configurations in greater detail, the following section outlines the lane placement alternatives considered within each of the three shared-booths configurations.

FAST Lane Placement

In each of the three shared-booths configurations, there is a separate approach lane for FAST-qualified vehicles as well as a separate approach lane for general purpose (GP) vehicles. Two different locations of the FAST lane, however, are considered. In one option, the dedicated FAST approach lane remains on Highway 15: as in the baseline configuration, FAST vehicles share an approach lane with busses and Nexus participants from 8th Avenue to 2th Avenue, where busses and Nexus card holders split off into a separate lane. Unlike the baseline configuration, however, FAST vehicles in this option do not feed into a dedicated booth, but are stopped at a signal parallel to the existing signals that exist immediately to the west for GP traffic. When a green light is signaled, the FAST vehicle at the front of this queue passes through the signal point to fill an empty slot in one of the three lanes in front of the RPM. As in the baseline configuration, these lanes can generally hold five vehicles each between the RPM and the GP/FAST signals. At this point, as vehicles are processed, the FAST truck moves to the front of the RPM queue, and when the booth corresponding to that queue is available it is signaled to pass through the RPM and approach the booth.

In the second lane placement option, the dedicated FAST lane is re-located to the *west* side of the WCTDF store. While FAST vehicles still share an approach lane with busses and Nexus participants from 8th Avenue to 2nd Avenue, at 2nd Avenue the FAST traffic is routed with the GP traffic westward down 2nd Avenue until it reaches an extension of the dedicated FAST lane parallel to the GP approach lane and west of the WCTDF store. The FAST lane then continues alongside the GP lane until it feeds into the eastern-most of the six existing traffic signals. In the baseline configuration, all six traffic signals are used to regulate six feeder queues of GP traffic to the two existing GP booth lanes. In the FAST "west of duty free" lane placement option, the eastern feeder queue and signal are used to regulate FAST traffic, while the remaining five feeder queues and signals remain in use for GP traffic.

While there are significant signaling and lane striping differences between the FAST lane placement options, from a modeling consideration there are two primary differences. The first option (FAST lane on Highway 15) results in more GP trucks able to fit between the GP signals and 8th Avenue (sixty-eight versus sixty-five). This may result in a very slight performance difference for one of the shared-booths configurations under consideration. The Highway 15 option also results in six feeder queues for GP trucks, rather than the five GP feeder queues for the WCTDF option. This is likely to result in a more significant performance difference for another of the three shared-booths configurations.

The FAST 1st Border Configuration

One possible priority rule for a shared-booths configuration is a "FAST 1st" rule that always awards the next open slot beyond the signal bar to any waiting FAST truck; GP trucks are only allowed to progress beyond the signal bar when there are no FAST trucks waiting at the signal bar. In modeling the performance of this rule, it is not necessary to distinguish between

the Highway 15 and the WCTDF FAST lane placement options; while these options imply different physical infrastructure, the operation of the FAST 1st rule is not affected by this difference, and the waiting time performance for each lane placement option would be the same.

The FAST 1st + GP2 Configuration

To avoid the buildup of GP trucks to possibly prohibitive levels, one can modify the FAST 1st policy so that an alternative priority rule kicks in when the GP queue length exceeds some pre-specified level. We shall consider the following modification of the FAST 1st rule: when the queue of GP trucks backs up to 8th Avenue, two GP trucks are signaled to advance past the stop bar for every FAST truck. This secondary rule, which we shall call the GP2 rule, stays in force until the GP queue drops below 8th Avenue. The modified FAST 1st policy will therefore be denoted as the FAST 1st + GP2 rule.

Since the number of GP trucks that fill the queue from behind the stop bar to 8th Avenue varies slightly depending on the placement of the FAST lane, we need to consider lane placement separately in the analysis of this configuration. Based on analysis of aerial photos, there is a capacity for fifty GP trucks in a lane stretching from 8th Avenue down to the entry point to the six staging queues behind the signal bar. Each of the six staging queues can hold three trucks; if the FAST lane was also west of the Duty Free Store, the eastern most staging queue would be reserved for FAST, leaving a maximum possible fifteen GP trucks in the five remaining staging queues. The GP2 secondary rule would therefore take effect when a total of sixty-five GP trucks were waiting behind the signal bar. If the FAST lane was located on Highway 15, all six feeder queues in the WCTDF area would be used for GP traffic, resulting in a trigger queue length of sixty-eight rather than sixty-five GP trucks.

The FCFS Border Configuration

We also consider the "first-come-first-served" (FCFS) border configuration, in which FAST trucks have a dedicated approach lane, but must wait at the signal bar as all lanes are cycled through in rotation. As with the FAST 1st + GP2 configuration, there may be a difference in system operation depending upon the location of the FAST approach lane. If the FAST lane is located west of the WCTDF store, it will share one of the six existing queues in front of the feeder bar; in such a situation, one interpretation of FCFS would have, during busy times, every sixth selected truck be a FAST truck as the signals cycle through all six queues. If the FAST lane was located on Highway 15, on the other hand, all six existing signal bar lanes would remain as GP queue lanes, and a seventh signal would be added for the FAST signal queue. Under a strict FCFS interpretation, this could result in every seventh truck selected being a FAST truck. Of course, one could also modify the FCFS priority rule so that FAST trucks were selected more frequently; since twenty-three percent of all current trucks are FAST vehicles, if only every sixth or seventh truck chosen is a FAST truck this could result in unacceptably large FAST waiting times. Combining the FCFS rule with the GP2 rule discussed above, for example, we could permit every third truck to be a FAST truck.

PARAMETER SETTINGS AND REPORTED STATISTICS

For each of the border configurations discussed above, certain parameters were systematically varied across multiple simulated days, and other parameters were held constant. As with the earlier study comparing the baseline and pilot configurations, the traffic volumes were varied from ten percent below spring 2011 levels to seventy percent above those same levels. As noted in Springer (2011b), southbound border traffic levels remained relatively low in Spring 2011, and may therefore be expected to increase as the global economy improves. The

highest level observed over the course of four studies completed since 2002 was at a level of more than forty percent higher than spring 2011, so the upper bound of seventy percent for the simulation study appears to cover the likely values for the intermediate future.

The spring 2011 study also found the FAST usage rate[1] to be twenty-three percent, which is relatively unchanged from an earlier observation in 2009 (Springer, 2010). A 2006 study observed thirty-five percent of the southbound traffic using the FAST booth (Roelofs and Springer, 2007); an unknown portion of this traffic was not FAST-qualified, however, as during periods of heavy traffic GP trucks were also admitted to the FAST booth. To ensure that the simulation analysis covered all likely FAST usage levels, FAST ratios of 23% and 35% were both examined in this study.

The remaining parameters needed to define the system were held constant across all simulations. This includes the distributions for inspection time and the time needed for trucks to move from the RPM to the inspection booth. The same distributions fitted to the baseline data and used in the 2011 simulation of baseline conditions were used in this study to simulate service times for the shared-booths configurations (Springer, 2011b). Baseline conditions for the inspection times were used as a reference since each of the three proposed shared-booths configurations included separate FAST and GP arrival lanes, thus enabling separate tracking of FAST and GP trucks as they passed through the inspection booths. Unlike the baseline configuration, however, each booth is prepared to handle FAST and GP trucks in the three primary configurations. The time necessary for inspection at a booth therefore depends on whether the truck being inspected is FAST-qualified or not.

[1] "FAST usage" refers here to commercial trips in which all of the three required components are "FAST:" driver, carrier, and goods (the shipper). Thus, "FAST trips" (those that would be eligible for a dedicated lane) also include (in past and current observations) empty trucks belonging to FAST carriers which are driven by FAST drivers. High volumes of non-FAST cross-border trips are made by FAST-carriers hauling non-FAST goods.

For each combination of border configuration, traffic volume level, and FAST arrival ratio, twenty-five days of border operation were simulated. Random fluctuations from day to day result in different average and maximum waiting times for each of the twenty-five days, imitating 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. Finally, 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.

RESULTS FOR THE CURRENT FAST RATIO OF 23%

We first compare the border configurations when the proportion of FAST vehicles arriving at the southbound Pacific Highway Crossing is 23%, the same level observed in the spring 2011 study. The average waiting times for FAST and GP trucks under the different border configurations are shown in Figures 1 and 2; Figure 3 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[2]; the vertical axis is the same scale for each of the three charts, ranging from 0 to 120 minutes, to facilitate comparison.

The results of six different configurations are shown on each chart: the baseline and pilot configurations; the FAST 1st configuration; the FAST 1st configuration with the GP2 priority rule when the FAST approach lane is west of the WCTDF store (FAST 1st+GP2); the FCFS configuration when the FAST approach lane is west of the WCTDF store (FCFS); and the FCFS rule when every third truck selected is FAST (FCFS/GP2). The configurations where the FAST approach lane is on Highway 15 (FAST 1st+GP2/HW15, FCFS/HW15) are not presented in the charts since their results are very similar to, and/or worse than, the corresponding configurations where the approach lane is west of the WCTDF store. This similarity can be clearly seen in Appendix A, which shows the data for all eight configurations.[3]

Several important observations can be made when examining Figures 1 through 3. First, the FCFS configuration results in unacceptably high average waiting times. This is perhaps not surprising, since twenty-three percent of the arriving trucks are FAST trucks, but they are receiving only one-sixth (roughly seventeen percent) of the inspection capacity. Since these wait times are worse than those experienced by the GP trucks in the FCFS configuration, this configuration does not seem to warrant serious consideration.

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

[3] The average waiting times for FAST 1st+GP2 and FAST 1st+GP2/HW15 are virtually identical; having a trigger point of three additional GP vehicles when the FAST approach lane is on Highway 15 does not make a significant difference on the performance of the system. There are small but significant differences in the performance of the FCFS/HW15 and FCFS configurations; both of these configurations are likely to yield unacceptable FAST waiting times, so to de-clutter the graphs we only plot the results for the FCFS configuration, which gave slightly lower (but still extremely high) average waiting times for FAST vehicles. This convention will be adopted throughout the paper: results for the Highway 15 configurations will be found in the appendices, but not in the graphs.

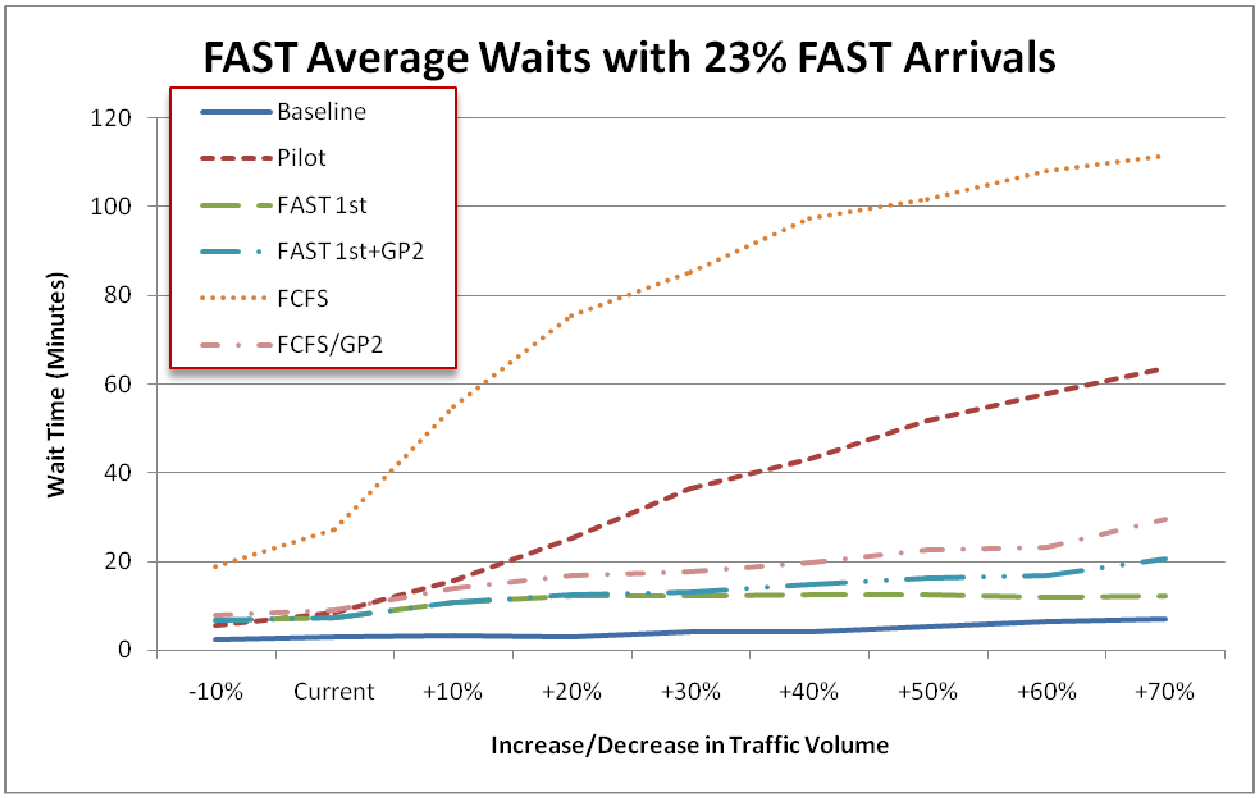

Figure 1. FAST average waiting times with arrival ratio = 23%.

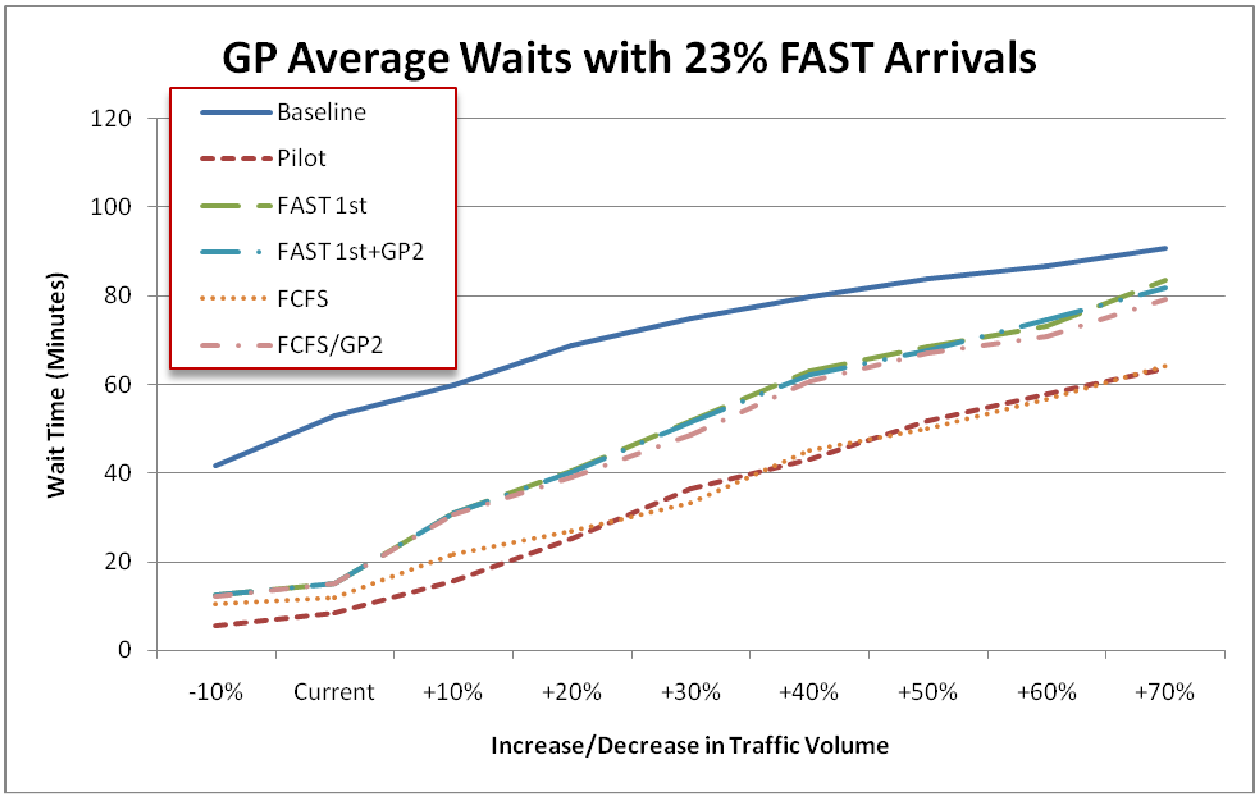

Figure 2. GP average waiting times with arrival ratio = 23%.

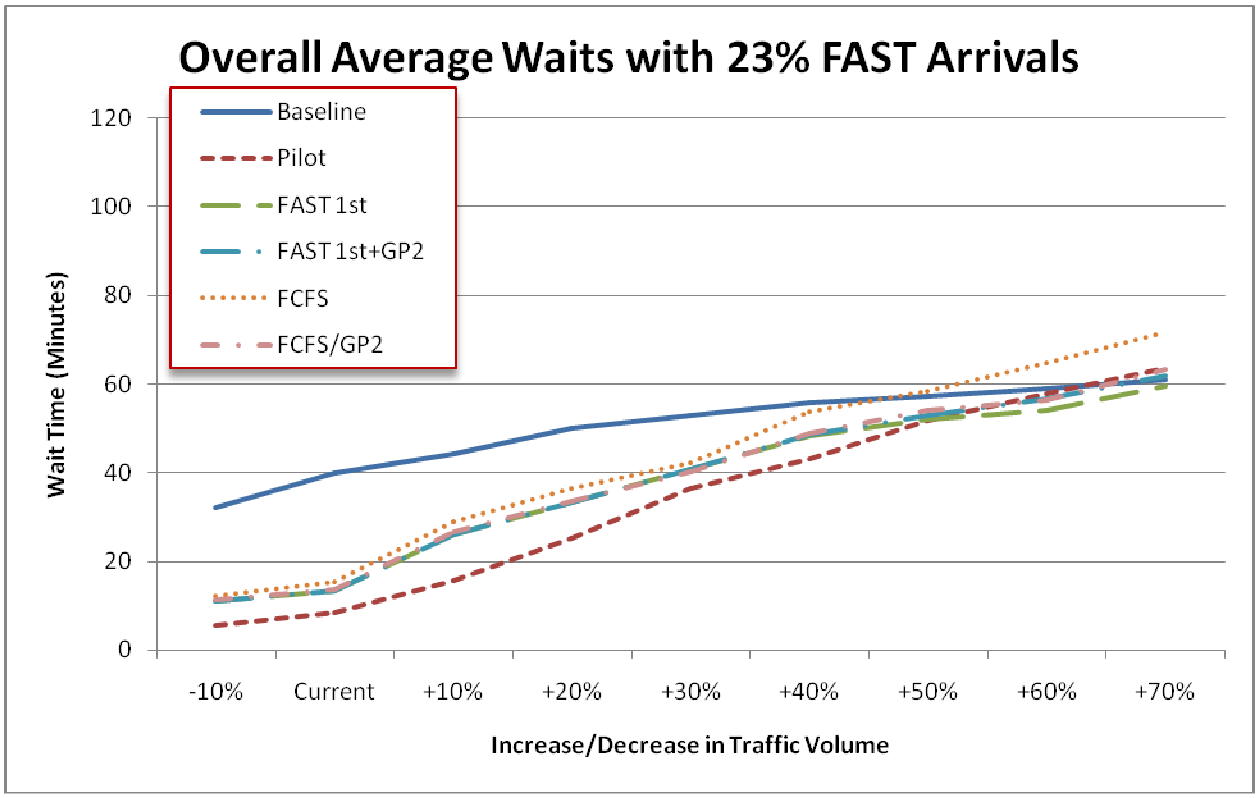

Figure 3. Overall average waiting times with arrival ratio = 23%.

Since these wait times are worse than those experienced by the GP trucks in the FCFS configuration, this configuration does not seem to warrant serious consideration.

Second, in terms of average waiting time, none of the proposed systems outperforms the baseline configuration in terms of FAST truck performance; even as traffic volume increases towards seventy percent, FAST average waiting times stay below ten minutes in the baseline system. Three configurations, however, perform better for FAST than does the pilot configuration: as traffic conditions worsen, the FAST 1st, FAST 1st+GP2, and FCFS/GP2 configurations yield waiting times less than half of the FAST waiting times of the pilot configuration. Furthermore, when considering GP waiting times, these three configurations perform nearly as well as the pilot configuration for traffic volumes near current levels. When traffic volume increases towards seventy percent, the performance of these three systems

deteriorates, but their performance remains mid-way between the best-for-GP pilot performance and the worst-for-GP baseline performance.

Finally, it is interesting to observe the overall average waiting time for all trucks in Figure 3. Ignoring the unusable FCFS configuration, the best configuration at low traffic levels is the pilot configuration, while the worst is the baseline configuration. These two configurations are separated by roughly thirty minutes of average wait time at current traffic levels. The FAST 1st, FAST 1st+GP2, and FCFS/GP2 configurations are not too inferior to the pilot configuration, adding roughly five minutes at current traffic levels. As the traffic level increases, however, the overall waiting time for all of these configurations converges at about an hour. The difference between the systems is shown in how the waiting time is split up between the FAST and GP vehicles: baseline is the best for FAST, the pilot configuration is the best for GP vehicles, and the three shared-booth configurations are in the middle. As can be seen in Figure 2, all three of these configurations are roughly equal in their treatment of GP trucks. With regards to FAST vehicles, however, the FAST 1st configuration appears to offer a small but significant advantage over the other two, especially as traffic levels increase.

A closer comparison of the baseline, pilot, and FAST 1st configurations clearly shows FAST 1st to be a compromise with large benefits for GP trucks at lower traffic levels and protection for FAST vehicles at higher traffic levels. At current traffic levels, moving from the baseline to the pilot configuration raises the FAST average wait time from 3.0 to 8.5 minutes, while the GP average wait time declines from 52.8 to 8.5 minutes. As traffic volume increases, however, the FAST average wait time increases dramatically: at traffic levels fifty percent above the current level, moving from the baseline to the pilot configuration raises the FAST average wait time from 5.2 minutes to 51.8 minutes, while the wait time for GP trucks drops from 83.8

minutes to 51.8 minutes. Using a FAST 1st configuration, however, the wait times for FAST and GP trucks at current traffic levels are 7.4 and 15.2 minutes, while raising the traffic volume by fifty percent yields FAST average waiting times of only 12.4 minutes and GP waiting times of 73 minutes. The FAST 1st policy therefore is able to dramatically improve average wait times for GP vehicles at a small additional waiting time cost for FAST vehicles at lower traffic volumes; at higher traffic levels, FAST retains a clear advantage, but GP waiting times are better than in the baseline configuration.

At first, it may seem strange that the FAST 1st rule results in benefits for the GP trucks at the expense of FAST trucks at lower traffic volumes. However, it is important to note that FAST trucks are given priority not to go immediately to an open inspection booth, but only to join a queue of trucks waiting to clear the RPM and then proceed to an inspection booth. During busy parts of the day, the FAST truck will be joining a queue with four trucks between it and the RPM; waiting for these trucks, as well as the truck being inspected ahead of the RPM, will lengthen the average wait times of FAST trucks even when they have priority. As for the benefits accruing to GP trucks, this is achieved by the better utilization of all inspection booths. At lower traffic volumes, there will be frequent stretches of time when there are no FAST trucks waiting in the FAST lane; during these times, the GP trucks may occupy all three inspection booths. In the baseline configuration, by contrast, while the two GP booths reach their maximum utilization, only a fraction of the FAST inspection booth is being utilized. By making all three booths open to GP traffic when FAST traffic is low, this spare capacity can be used to reduce the GP waiting times.

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 4 – 6 show the maximum average waiting times for the same configurations and a FAST arrival ratio of twenty-three percent; the numbers for all the configurations appear in Appendix B. Note that the vertical axis for Figures 4 – 6 is scaled from 0 to 150 minutes. Once again, the FCFS configuration appears unacceptable; the pilot configuration is best for GP trucks; and the FAST 1st+GP2 and FCFS/GP configurations occupy a "middle ground." Intriguingly, however, the FAST 1st policy appears to perform just as well as the baseline policy in terms of minimizing FAST maximum average waiting times. Even though, on average, FAST 1st does not perform as well as baseline, its performance on the worst day of the month will be roughly equal to the baseline's performance on its worst day of the month, even at higher traffic levels.

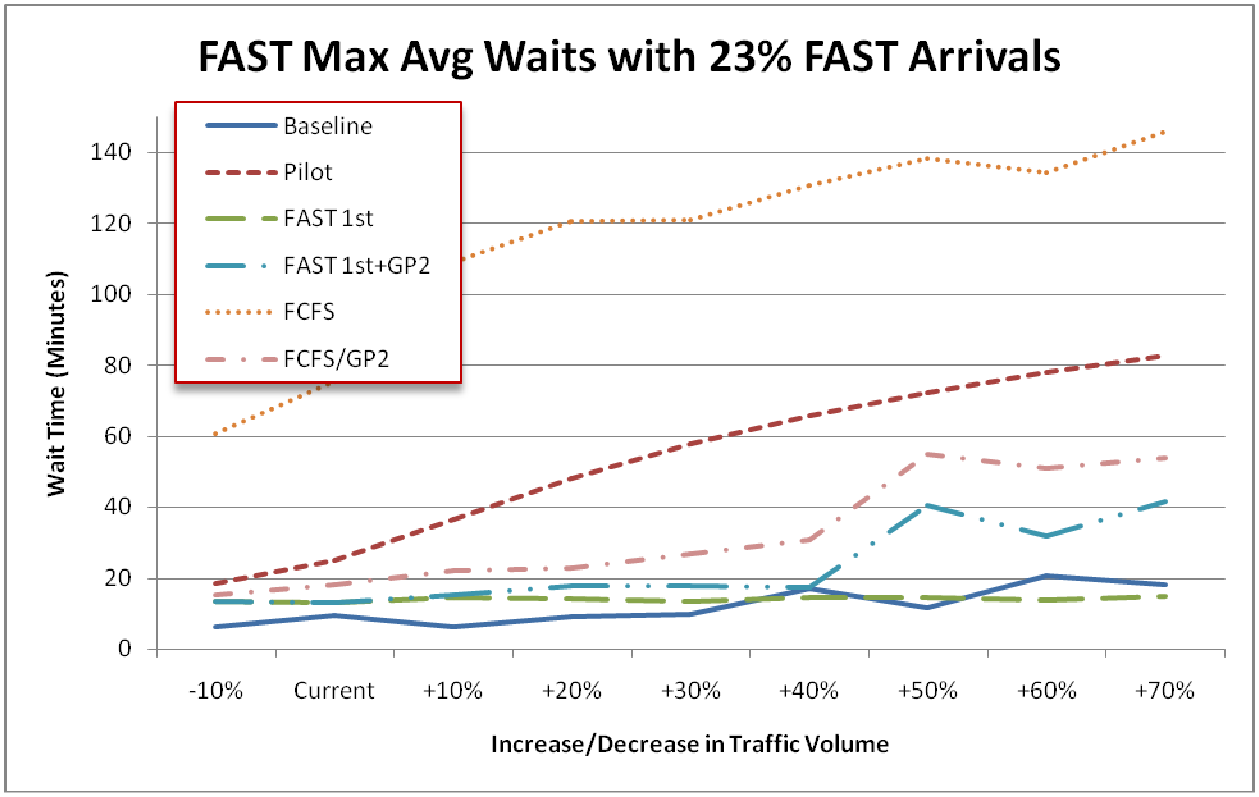

Figure 4. FAST maximum average waiting times with arrival ratio = 23%.

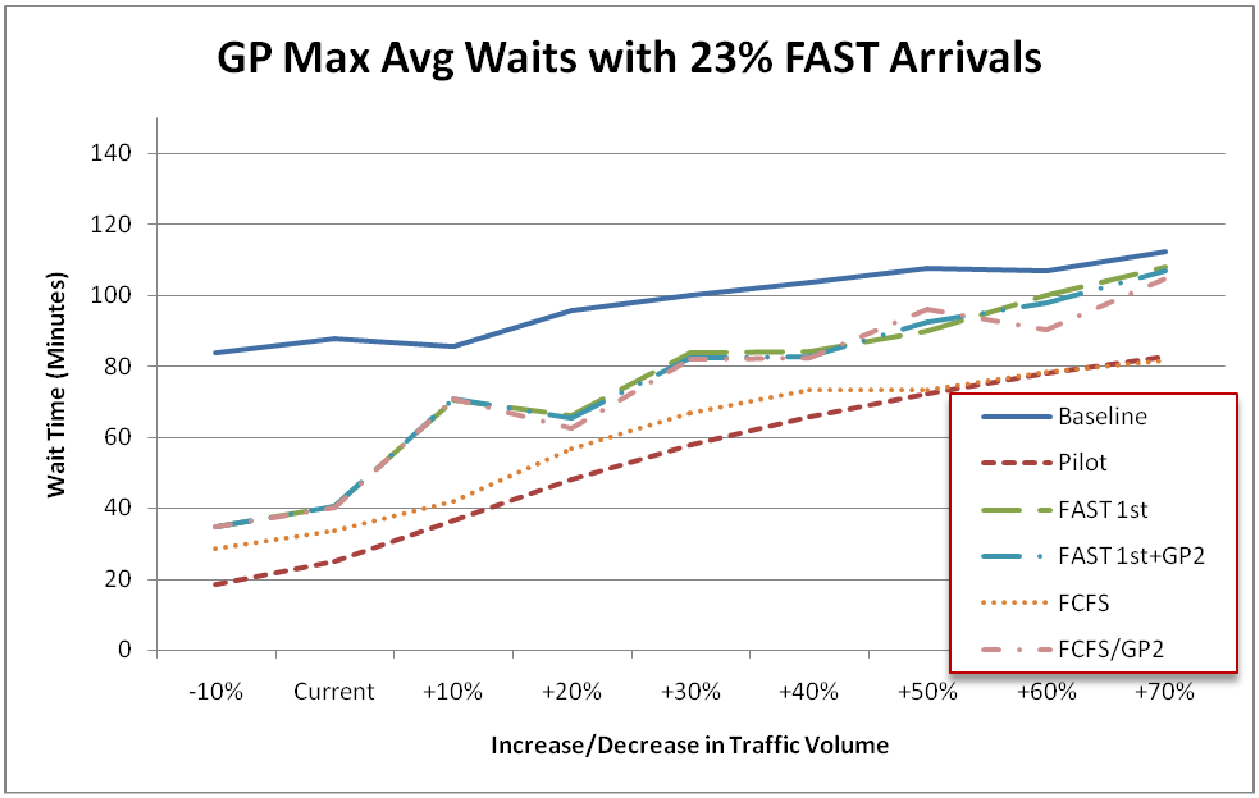

Figure 5. GP maximum average waiting times with arrival ratio = 23%.

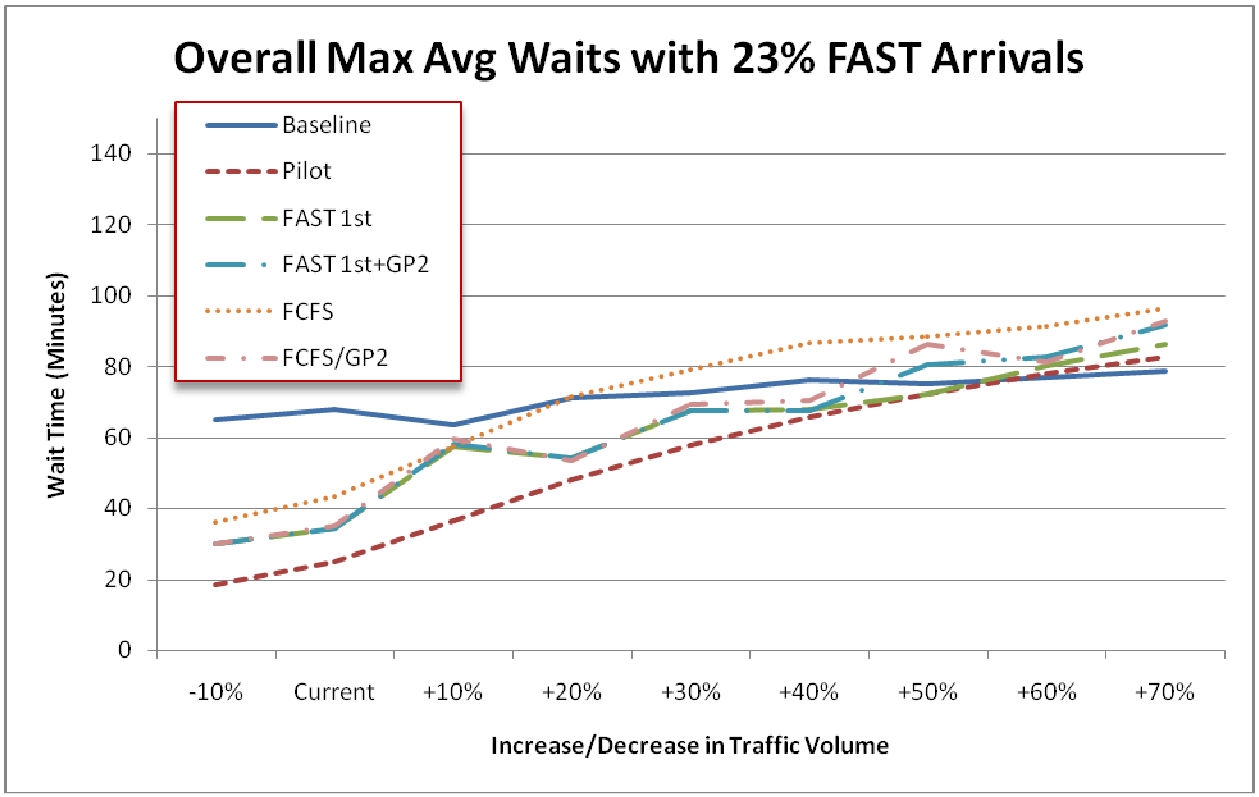

Figure 6. Overall maximum average waiting times with arrival ratio = 23%.

Figures 7 – 9, and Appendix C, show the average maximum waiting times for the different configurations. As discussed above, these are averages of the worst 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 180 minutes. The relative performance of the different configurations is similar to that evidenced by the charts of maximum average waiting times: the FCFS configuration yields large FAST wait times; the pilot configuration is best for GP trucks; the FAST 1st+GP2 and FCFS/GP configurations occupy a "middle ground"; and the FAST 1st and baseline policies perform equally well at minimizing FAST wait times.

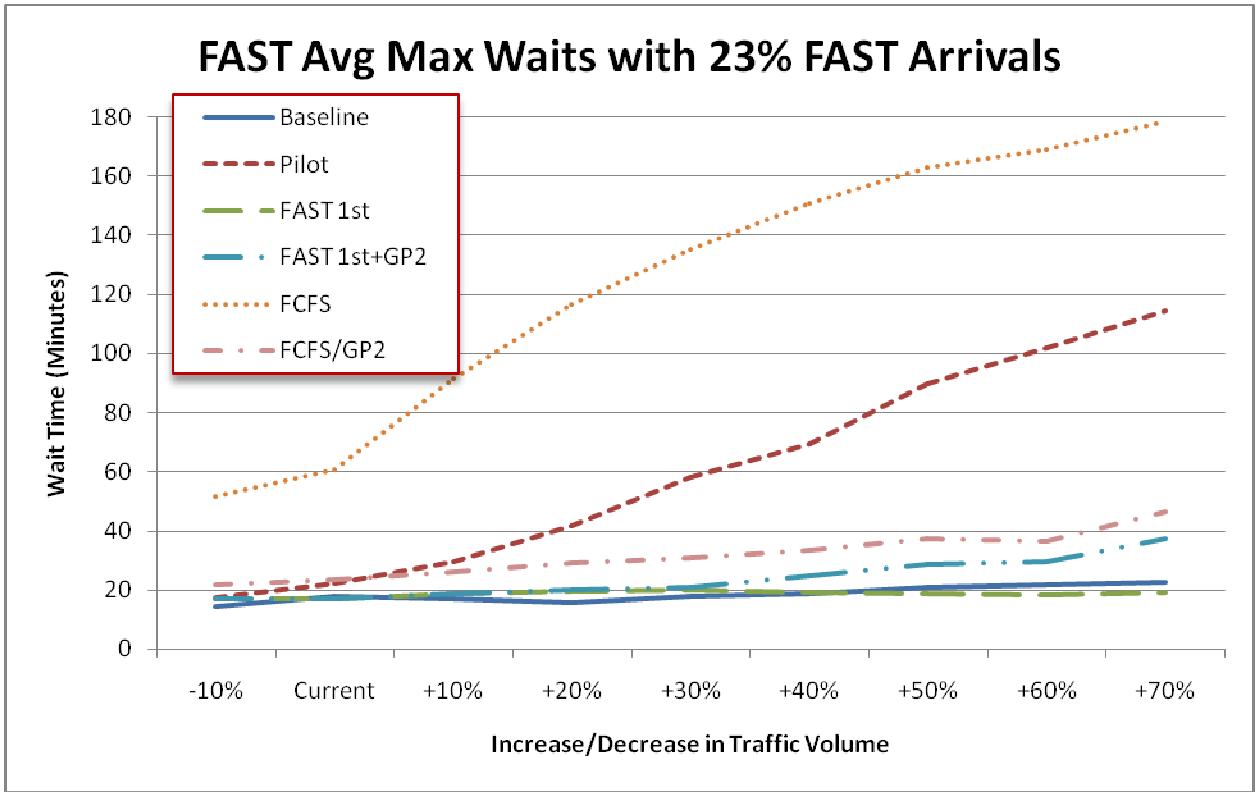

Figure 7. FAST average maximum waiting times with arrival ratio = 23%.

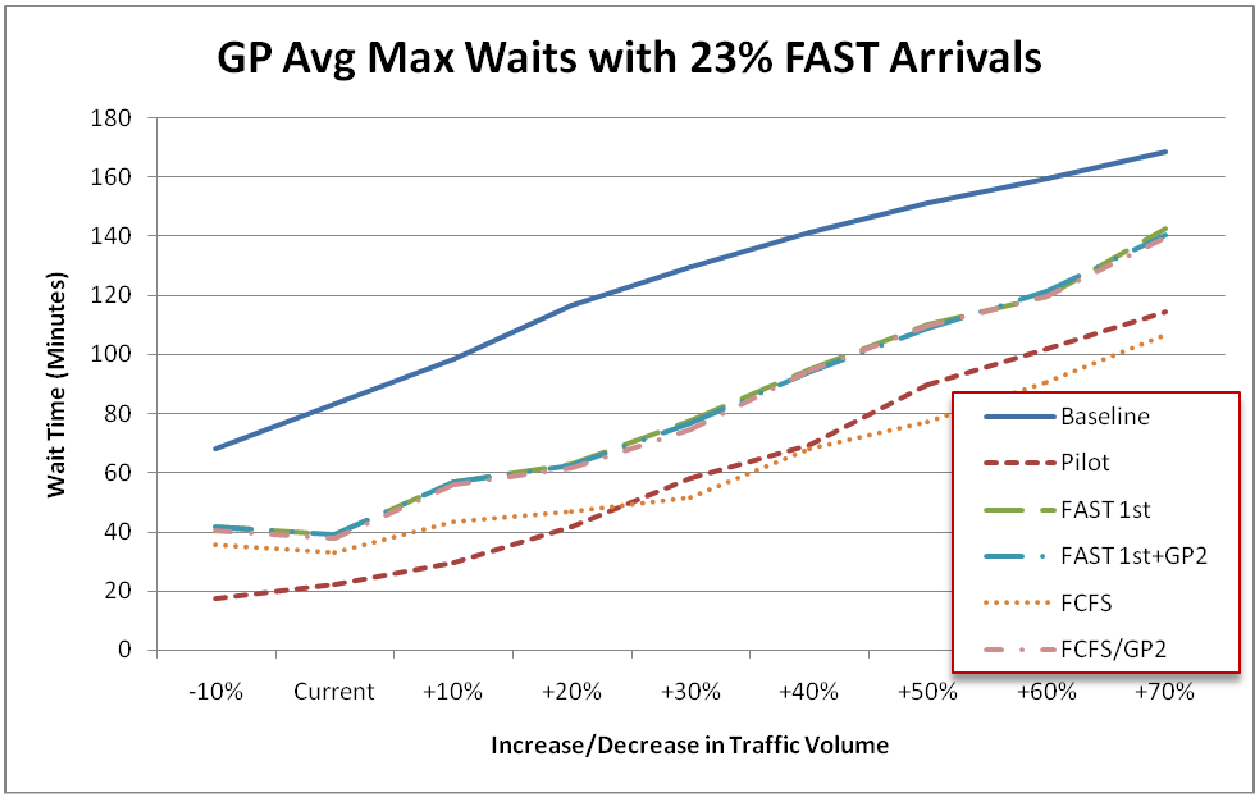

Figure 8. GP average maximum waiting times with arrival ratio = 23%.

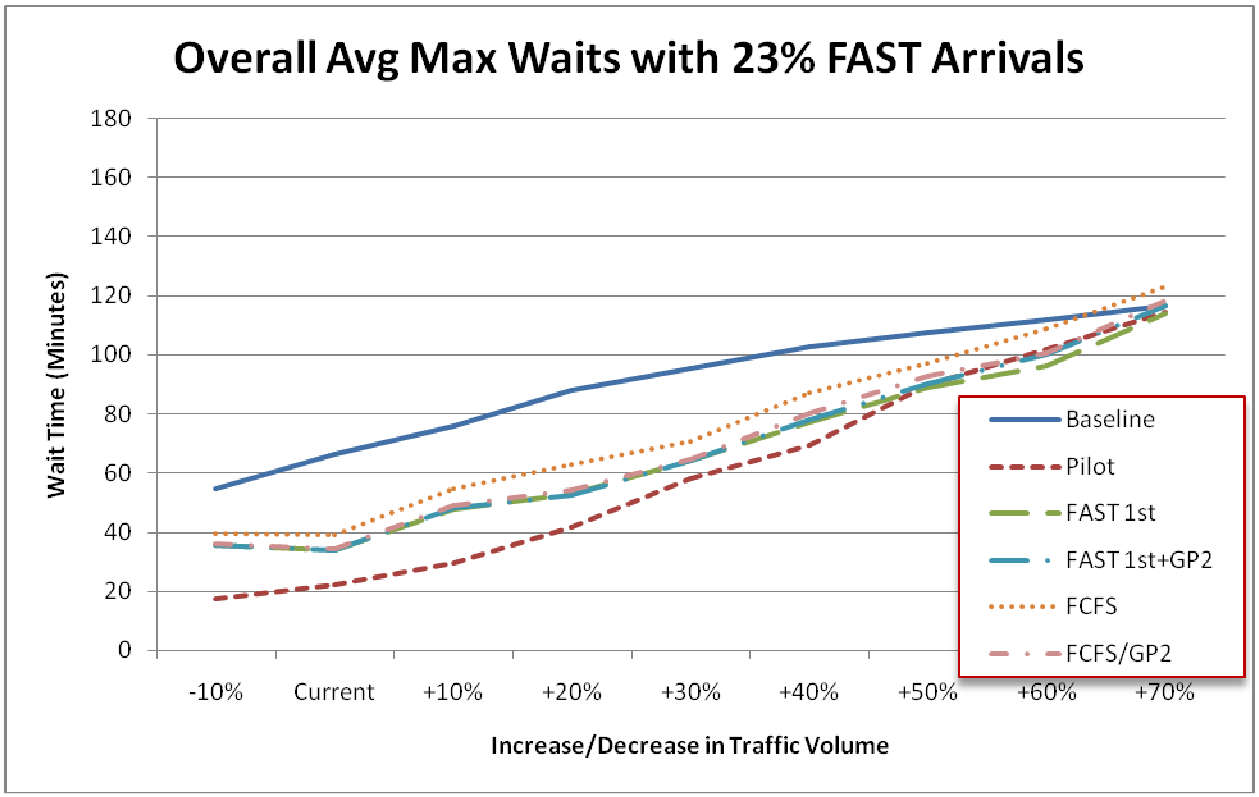

Figure 9. Overall average maximum waiting times with arrival ratio = 23%.

The chart of overall average maximum waiting times in Figure 9 appears quite similar to the chart of overall maximum average waiting times in Figure 6; the main difference is that as traffic volume rises, the average maximum waiting times in Figure 9 rise at a faster rate and end up twenty minutes above the maximum average wait times in Figure 6.

Finally, consider the overall utilization of the three inspection booths under the different configurations. Figure 10 shows that all of the configurations, with the exception of the baseline, exhibit the same pattern: utilization begins at around sixty percent at low traffic levels, and then tops out at around seventy-five percent. As discussed in the introduction, one hundred percent utilization is not possible because of the transition times between trucks; the time necessary for a truck to begin moving from the RPM to the booth, and the time it takes the truck to complete that distance, will result in slack time that puts an upper bound on booth utilization. The different performance of the baseline configuration, however, requires an additional explanation.

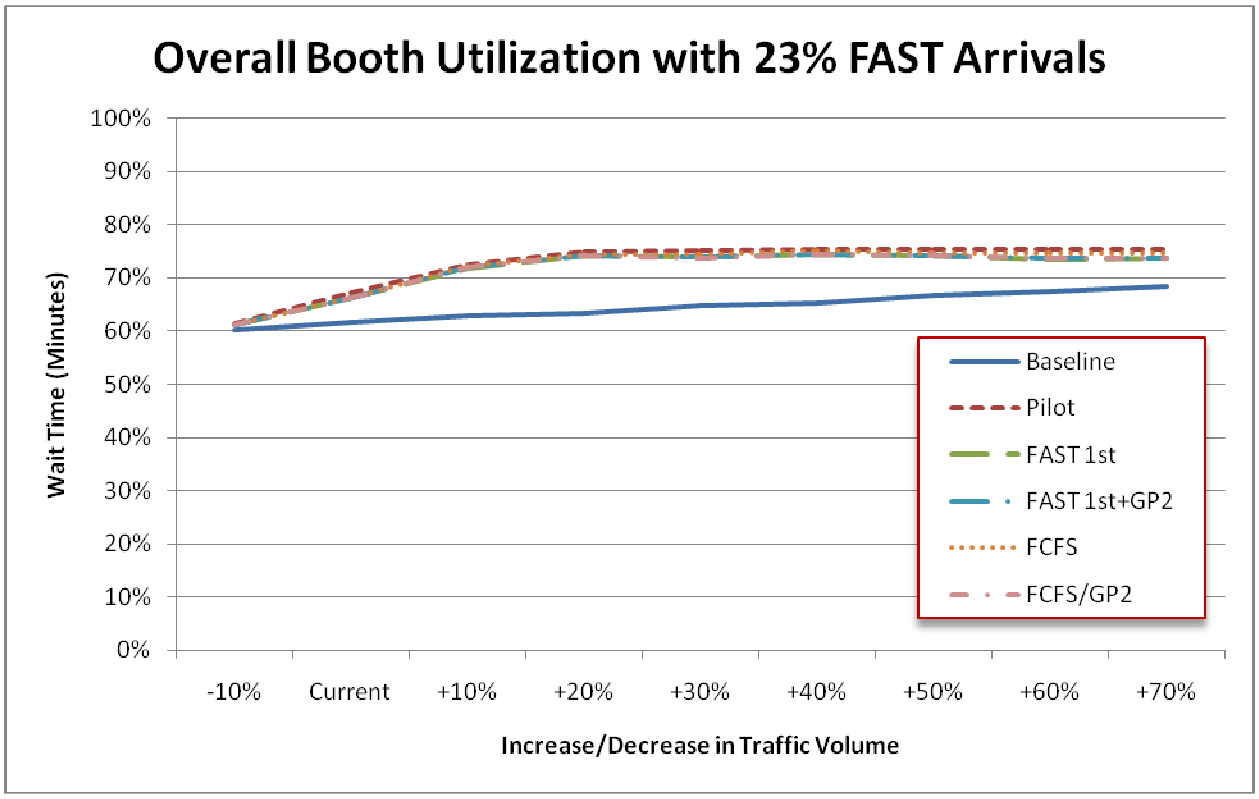

Figure 10. Overall booth utilization with arrival ratio = 23%.

In the baseline system, the booth dedicated to FAST vehicles is underutilized: only twenty-three 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 trucks waiting. The shared-booth configurations and the pilot configuration avoid this possibility, since even in the FAST 1st configuration the GP trucks can access all three booths when no FAST trucks are waiting. Making use of this extra capacity is what enables the "shared-booth" configurations – especially the FAST 1st configuration – to offer lower waiting times for GP trucks with a smaller penalty for FAST trucks.

Summing up, one can reach the following conclusions for border configurations when the FAST ratio is expected to be twenty-three percent. First, the baseline yields the best overall performance for the FAST vehicles and the worst performance for the GP trucks. Second, The pilot configuration offers the best overall performance for GP trucks and the second worst (after the FCFS configuration) performance for FAST trucks. Third, the other three shared-booth configurations offer a compromise which is especially appealing at current traffic levels: a small relative wait time penalty for FAST trucks in exchange for a dramatic drop in GP waits. Finally, the best-performing shared-booth configuration appears to be the FAST 1st configuration, which not only manages to keep average FAST wait times around twenty minutes even as traffic volumes soar, but also yields average maximum and maximum average waiting times for FAST trucks similar to those of the baseline configuration.

RESULTS FOR A FAST RATIO OF 35%

To examine the robustness of our conclusions in the previous section, we consider the performance of the configurations if the FAST ratio were to rise to thirty-five percent. On

average, overall system performance should be slightly better for a higher FAST ratio, since FAST trucks have a lower inspection time than GP trucks. Since the relative performance of the different border configurations and the split of the benefits between FAST and GP vehicles could change, however, 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 11-13 and Appendix D. Comparing Figures 3 and 13, we see that for most configurations, the overall average waiting time has declined very slightly for most traffic volumes. The notable exception is the FCFS/GP2 configuration, which rises slightly for higher traffic volumes. This makes sense, as with a FAST arrival rate of thirty-five percent, selecting every third truck to be a FAST truck results in a slow building of the FAST queue when traffic volumes rise, resulting in a higher overall waiting time. The increase in the FAST wait time for the FCFS/GP2 configuration can be seen clearly in Figure 11, where it performs worse than the pilot configuration for FAST vehicles.

The big surprise regarding average waiting times at this higher FAST ratio, however, is the relative performance of the baseline and FAST 1st configurations. With the higher level of traffic, the FAST 1st configuration has less than half of the average wait time as the baseline configuration. The reason for the slippage of the baseline configuration is similar to that given for the poorer performance of FCFS/GP2: FAST trucks are arriving in a greater proportion (35%) than the fraction of capacity they are being allocated (33%). The FAST 1st configuration, by contrast, is flexible: as the FAST ratio increases, it allocates a greater proportion of the booth capacity to FAST vehicles, resulting in an average waiting time that is almost identical to that experienced at lower levels of FAST arrivals.

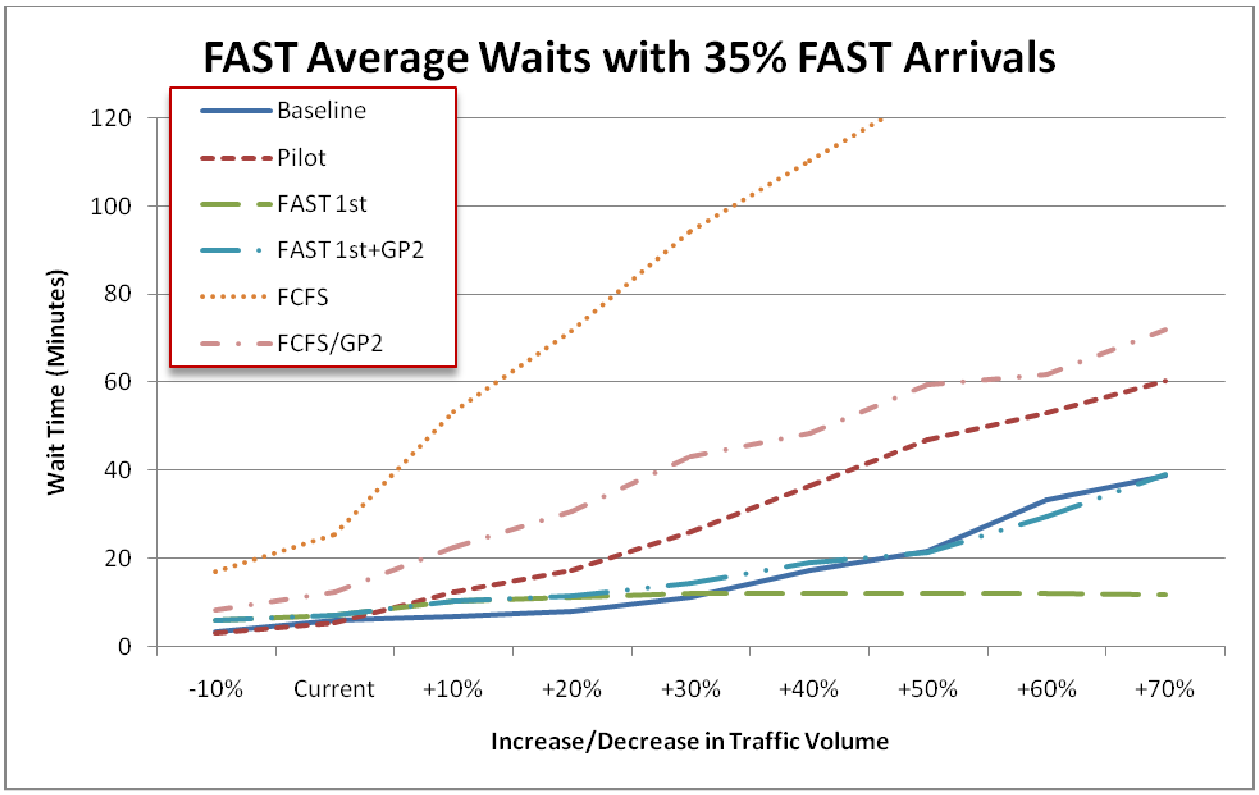

Figure 11. FAST average waiting times with arrival ratio = 35%.

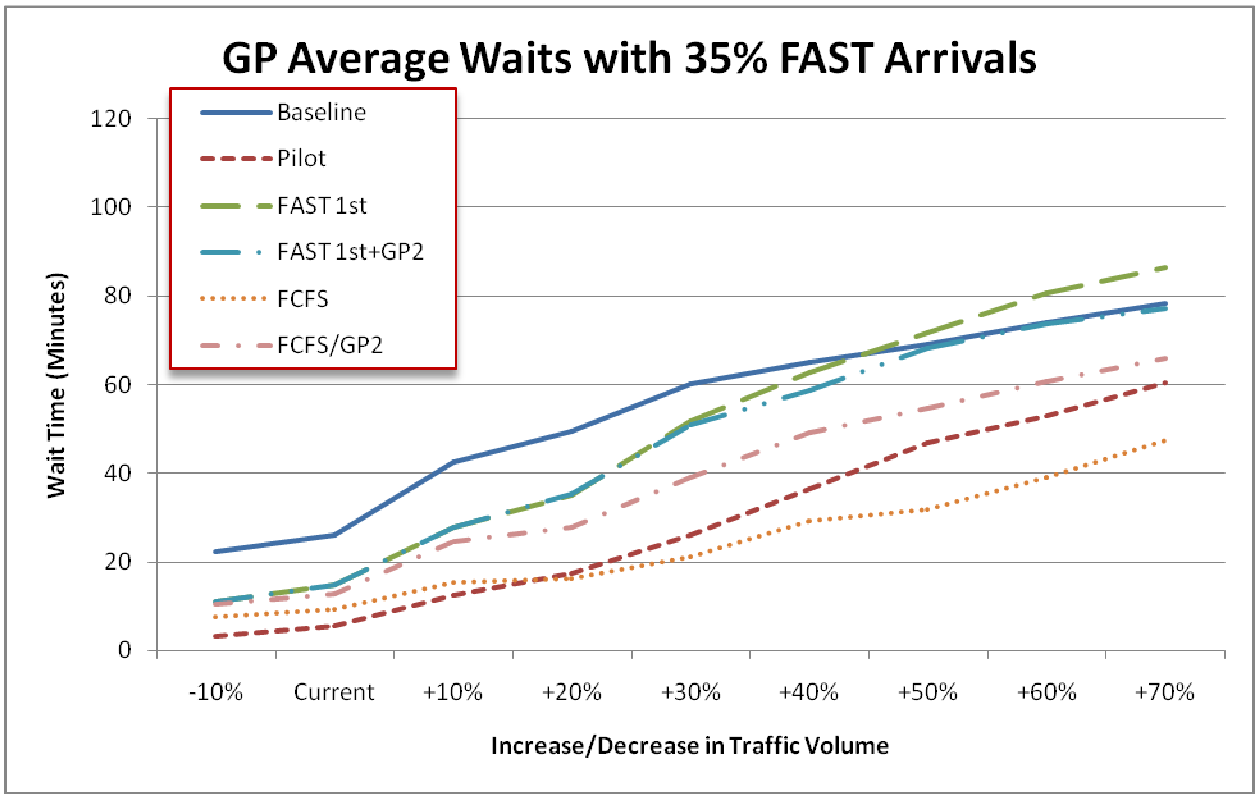

Figure 12. GP average waiting times with arrival ratio = 35%.

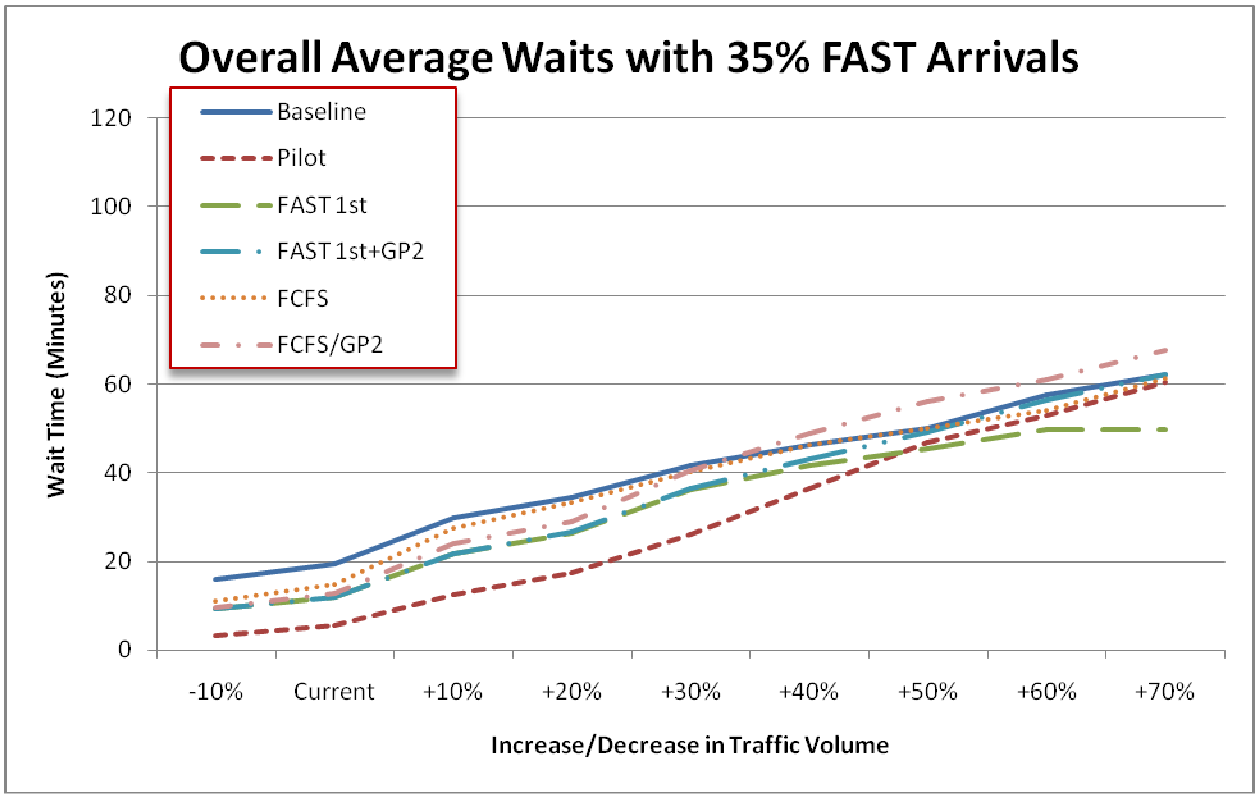

Figure 13. Overall average waiting times with arrival ratio = 35%.

The downside of this FAST 1st flexibility, of course, is that it results in slightly longer average waiting times for GP trucks: at higher levels of traffic, the FAST 1st configuration now results in longer waiting times for GP trucks than does the baseline configuration.

Examining the maximum average waiting times in Figures 14 – 16 and Appendix D, one sees a similar pattern as exhibited with the average wait times. The overall maximum average waiting times are similar, and on average perhaps slightly lower, than those experienced for the lower FAST arrival rate of twenty-three percent. The FCFS/GP2 configuration performs worse than the baseline configuration for FAST vehicles, while the FAST 1st configuration continues to deliver a maximum average wait time less than twenty minutes for FAST vehicles. This benefit comes at an additional cost to GP vehicles for higher levels of traffic.

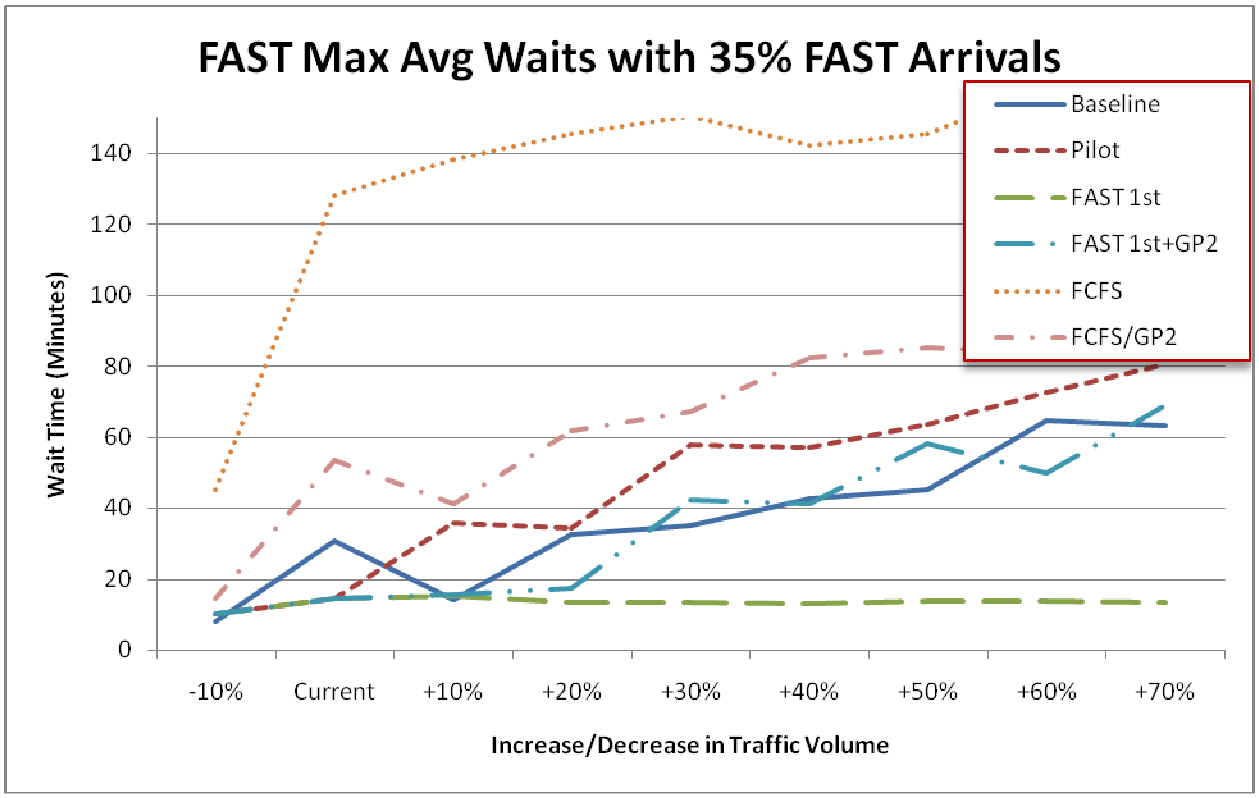

Figure 14. FAST maximum average waiting times with arrival ratio = 35%.

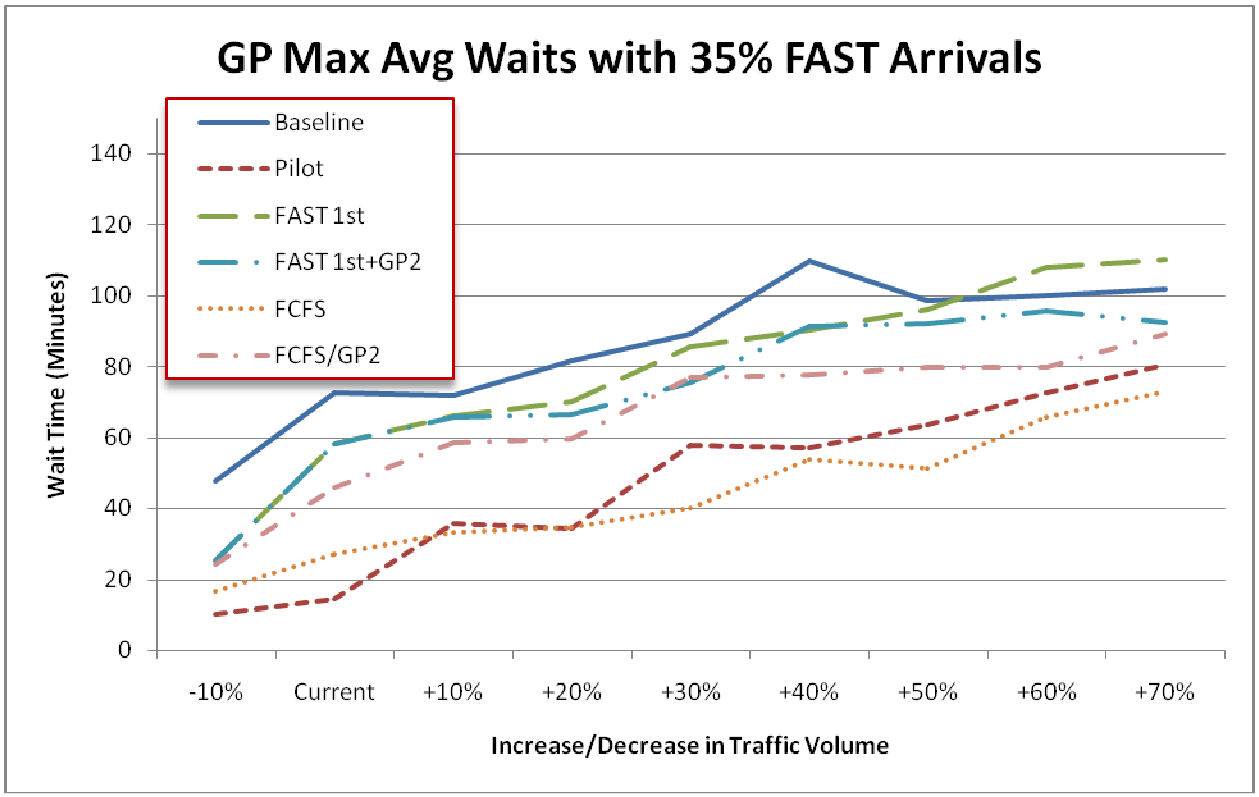

Figure 15. GP maximum average waiting times with arrival ratio = 35%.

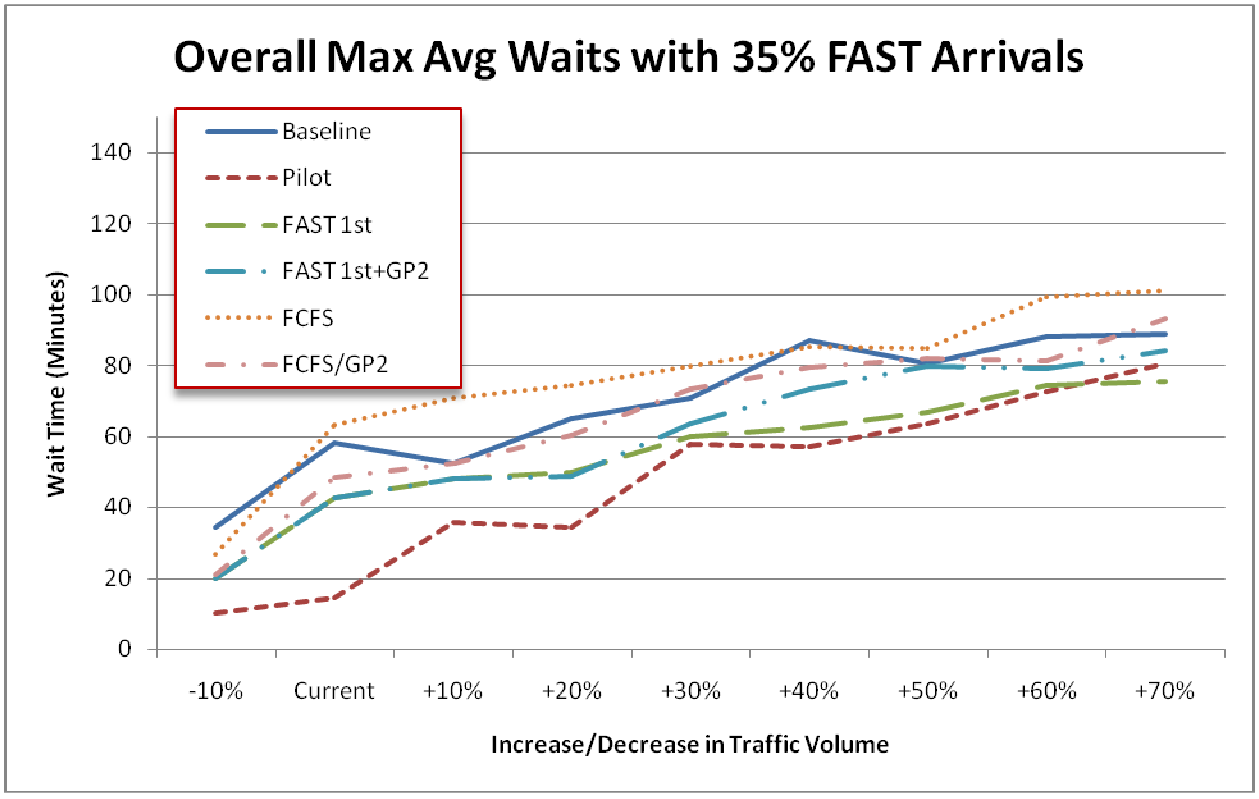

Figure 16. Overall maximum average waiting times with arrival ratio = 35%.

For the average maximum waiting times shown in Figures 17-19 and Appendix F, the narrative is mostly the same as for the average and maximum average waiting times at this higher FAST ratio. For most configurations, increasing the FAST arrival rate slightly lowers the overall maximum average waiting time; the decrease is particularly notable for the baseline configuration, at lower traffic volumes.

Finally, a quick examination of the overall utilization of the three inspection booths at the higher FAST ratio shows that the gap between the baseline configuration and the shared-booth configurations has narrowed. With thirty-five percent of the arrivals FAST-qualified and one third of the booth capacity dedicated to serving FAST trucks, the baseline configuration no longer has as much excess capacity as it did when the FAST arrival rate was lower.

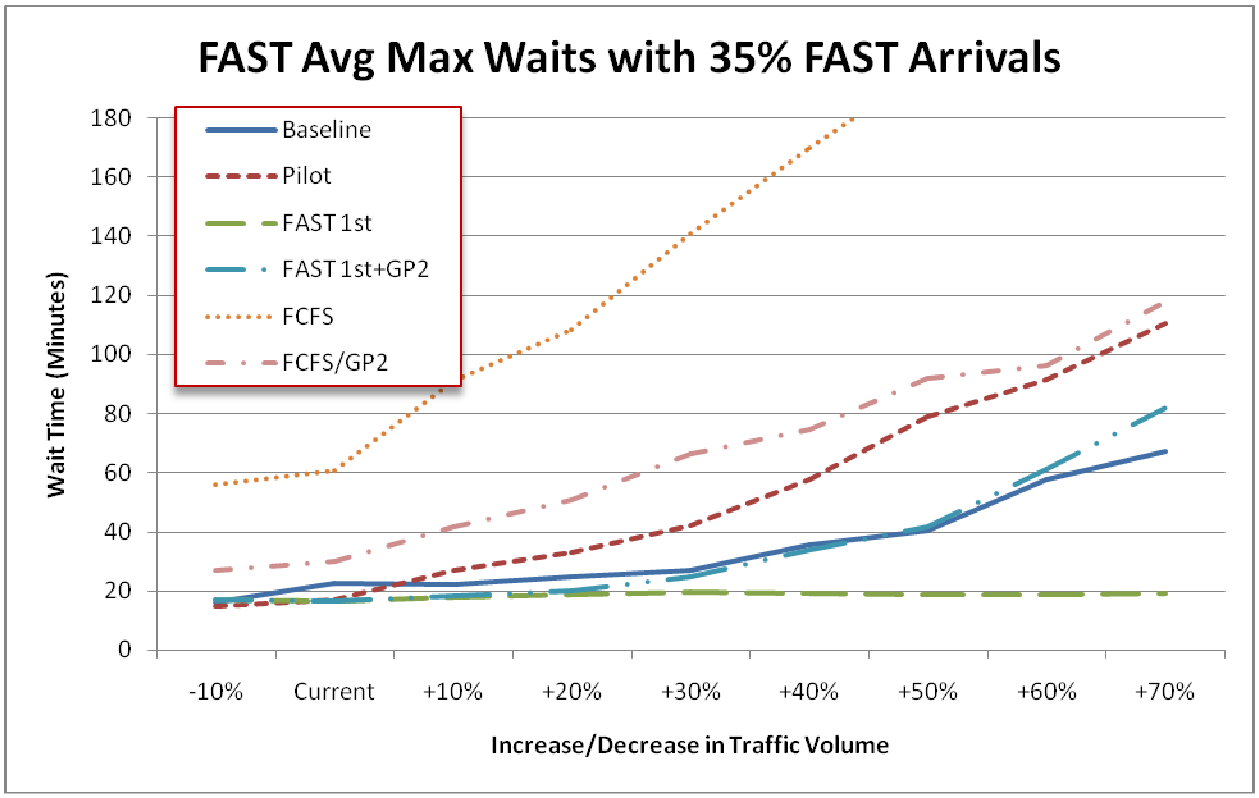

Figure 17. FAST average maximum waiting times with arrival ratio = 35%.

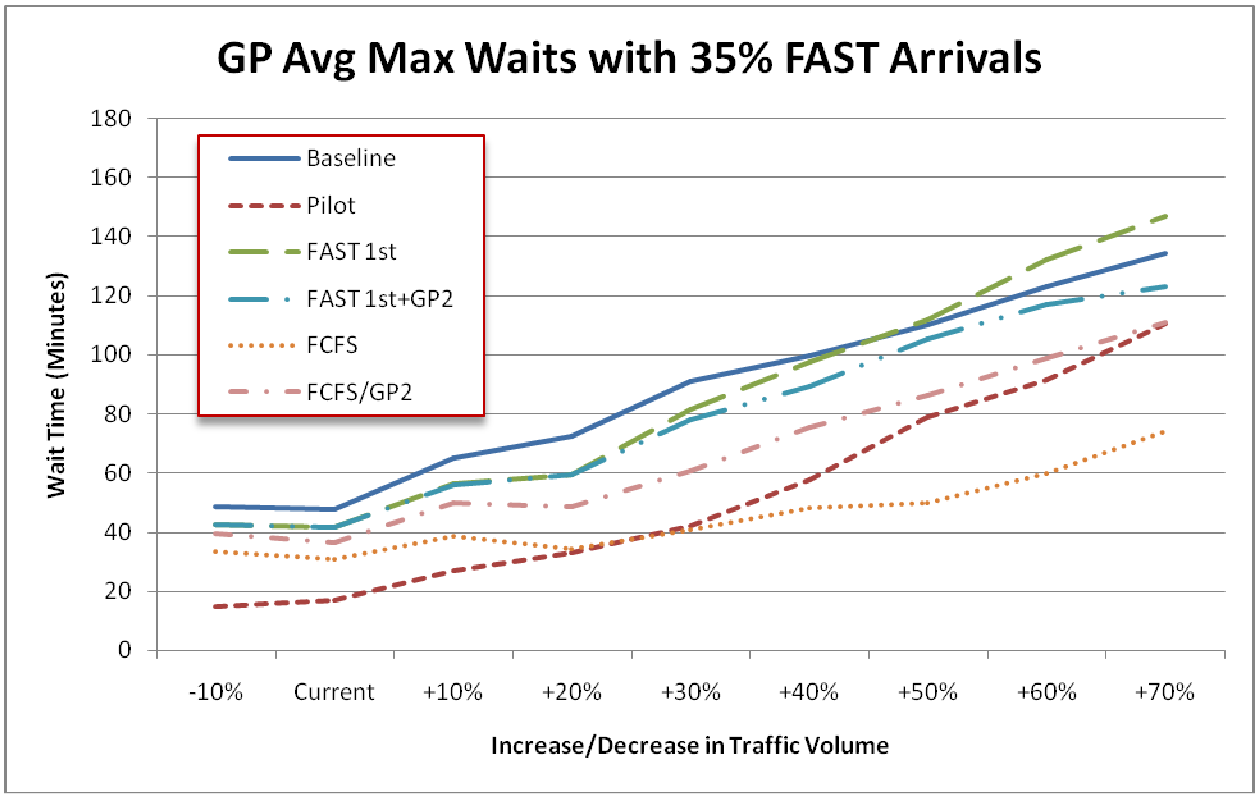

Figure 18. GP average maximum waiting times with arrival ratio = 35%.

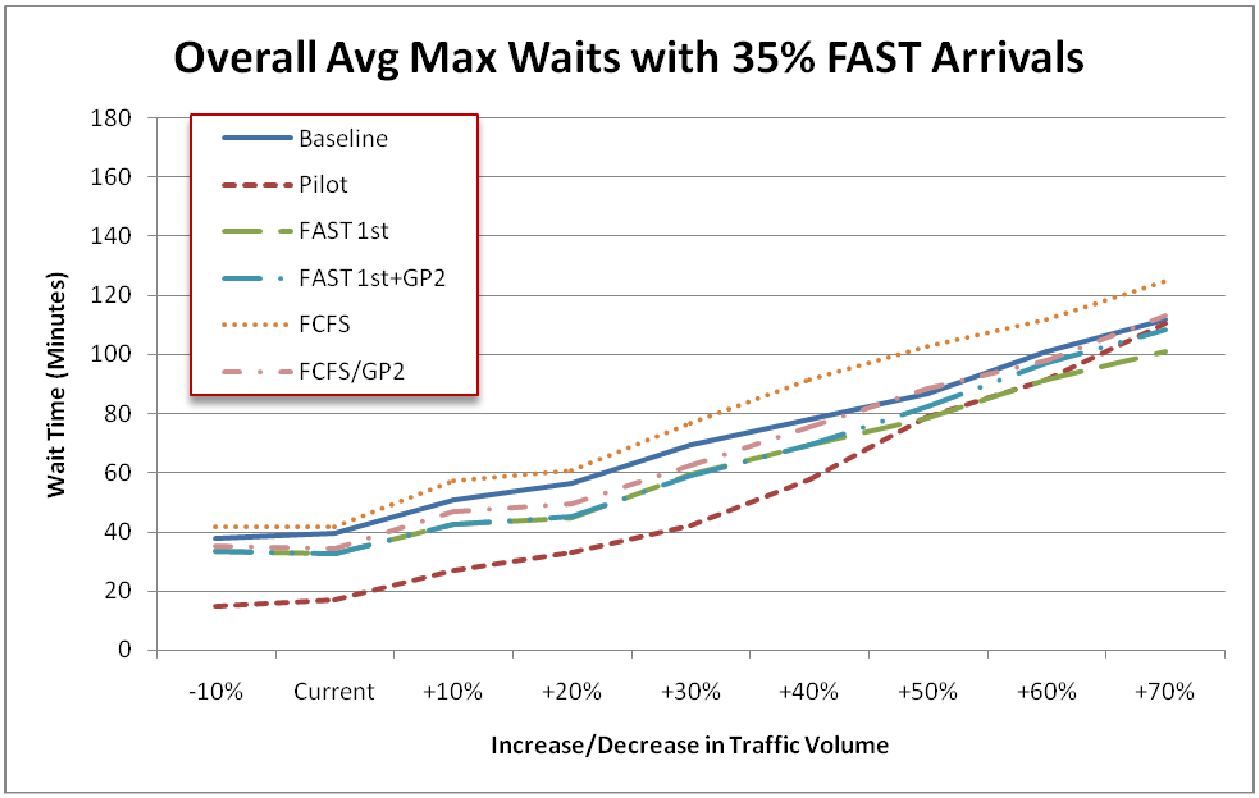

Figure 19. Overall average maximum waiting times with arrival ratio = 35%.

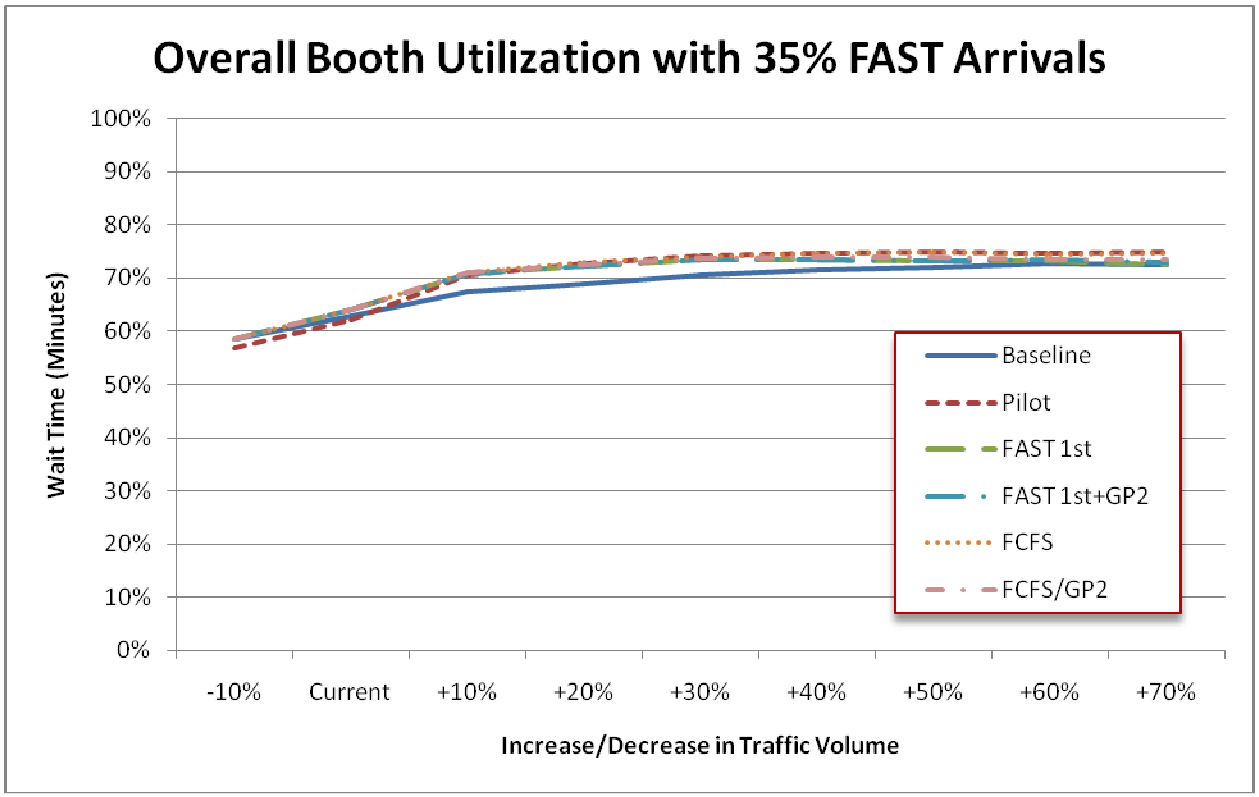

Figure 20. Overall booth utilization with arrival ratio = 35%.

Nonetheless, as we have seen in the preceding charts, there is still a benefit in the shared-booth configurations, particularly FAST 1st, as the flexibility offered by the shared-booth configuration can squeeze additional capacity out of the system.

CONCLUSION

Some of the shared-booth border crossing configurations considered in this paper offer advantages over both the baseline and pilot configurations examined in a previous study. Similar to the pilot configuration, the best of the shared-booth configurations utilize more booth capacity; unlike the pilot configuration, however, they still offer a distinct advantage to FAST-qualified trucks. This advantage over the pilot configuration is most evident at higher traffic volumes. Of course, the flip side of this benefit for FAST trucks is longer waiting times for GP trucks, relative to the pilot configuration, especially at higher traffic levels. At current traffic levels, however, average GP waits under the FAST 1st configuration are less than ten minutes higher than under the pilot system; while average FAST waiting times under FAST 1st are less than five minutes greater than under the baseline configuration.

Of the shared-booth configurations examined, one pair – the FCFS configuration, with lane placement either on Highway 15 or west of the duty free store – results in FAST waiting times that are worse than GP waiting times; this configuration can clearly be dropped from further consideration. In general, lane placement was not an important variable in system performance: both lane placements performed poorly for the FCFS configuration, while for the FAST 1st+GP2 configurations the lane placements had no discernable impact on results.

Of the three distinct viable shared-booth configurations – FAST 1st, FAST 1st+GP2, and FCFS/GP2 – the first two had the advantage of being flexible in the face of a shifting FAST arrival ratio. If the arrival ratio were to increase to thirty-five percent, using the FCFS/GP2

configuration would result in a deterioration of FAST waiting times to values greater than under the pilot configuration. In choosing between FAST 1st and FAST 1st+GP2, the key question is the relative treatment of FAST and GP vehicles when traffic levels rise past forty percent. Under the FAST 1st rule, in such a situation the FAST waiting times remain low and the GP trucks bear the brunt of the traffic increase; adding the GP2 secondary rule when GP traffic backs up to 8th Avenue, waiting times for both FAST and GP trucks begin to rise as traffic volume reaches this level.

BIBLIOGRAPHY

Border Policy Research Institute and Whatcom Council of Governments (2011). *2011 Pacific Highway Southbound FAST Lane Study: Final Report, June 2011.*

David Davidson, (2011). "Testing a Reconfiguration of FAST at the Blaine POE," *Border Policy Brief*, vol. 6., no. 2, Spring 2011. Bellingham, WA: Border Policy Research Institute, Western Washington University.

Roelofs, Mattthew., and Springer, Mark C. (2007). *An Investigation of Congestion Pricing Options for Southbound Freight at the Pacific Highway Crossing*. Bellingham, WA: Border Policy Research Institute, Western Washington University.

Springer, Mark C., (2010). "An Update on Congestion Pricing Options for Southbound Freight at the Pacific Highway Crossing," *BPRI Research Report, no. 11*. Bellingham, WA: Border Policy Research Institute, Western Washington University.

Springer, Mark C. (2011a). *Eliminating the FAST Lane at the Pacific Highway Border Crossing: Results of a Pilot Project.* Bellingham, WA: Border Policy Research Institute, Western Washington University.

Springer, Mark C. (2011b). *Eliminating the FAST Lane at the Pacific Highway Border Crossing: A Simulation Analysis.* Bellingham, WA: Border Policy Research Institute, Western Washington University.

US Department of Transportation (2003). *Washington State-British Columbia IMTC ITS-CVO Border Crossing Deployment Evaluation Final Report*.

US Customs and Border Protection (2005). *FAST Reference Guide: Enhancing the Security and Safety of Cross-Border Shipments*. CBP Publication 0000-0700.

Whatcom Council of Governments (2007). *International Mobility & Trade Corridor Project Pacific Highway Port-of-Entry Commercial Vehicle Operations Survey*.

Whatcom Council of Governments (2010). *2009 International Mobility & Trade Corridor Project (IMTC) Commercial Vehicle Operations Survey: Final Report*.

APPENDIX A: AVERAGE WAITING TIMES, FAST RATIO = 23%

	Traffic Volume Level								
Border Configuration	-10%	Current	+10%	+20%	+30%	+40%	+50%	+60%	+70%
Baseline	2.5	3.0	3.1	3.1	3.9	4.0	5.1	6.4	6.9
Pilot	5.5	8.5	15.6	25.2	36.4	43.0	51.8	57.7	63.7
FAST 1st	6.6	7.4	10.7	12.1	12.1	12.4	12.4	12.0	12.2
FAST 1st+GP2*	6.6	7.4	10.8	12.3	13.0	14.6	16.1	16.8	20.7
FAST 1st+GP2/HW15**	6.6	7.4	10.7	12.3	12.9	14.4	15.9	16.3	20.2
FCFS*	18.8	27.2	55.0	75.6	85.2	97.4	101.8	107.9	111.6
FCFS/HW15**	21.5	30.8	64.4	79.0	100.8	108.1	114.9	122.4	124.7
FCFS/GP2	7.9	9.1	13.8	16.7	17.6	19.6	22.5	23.2	29.5

Table A1. FAST Average Waits with 23% FAST Arrival Rates

	Traffic Volume Level								
Border Configuration	-10%	Current	+10%	+20%	+30%	+40%	+50%	+60%	+70%
Baseline	41.8	52.8	60.0	68.8	74.9	79.9	83.8	86.8	90.8
Pilot	5.5	8.5	15.6	25.2	36.4	43.0	51.8	57.7	63.7
FAST 1st	12.4	15.2	30.9	40.3	51.7	62.9	68.5	73.0	83.5
FAST 1st+GP2*	12.4	15.2	31.0	40.1	51.3	62.1	67.7	74.5	81.6
FAST 1st+GP2/HW15**	12.4	15.2	30.8	40.2	51.3	62.1	67.9	74.3	81.6
FCFS*	10.3	11.8	21.8	27.0	33.1	45.2	50.0	56.6	64.1
FCFS/HW15**	9.9	11.1	19.6	25.1	30.8	41.6	46.6	54.4	61.2
FCFS/GP2	12.2	15.0	30.7	39.2	48.4	60.6	67.0	70.8	79.0

Table A2. GP Average Waits with 23% FAST Arrival Rates

	Traffic Volume Level								
Border Configuration	-10%	Current	+10%	+20%	+30%	+40%	+50%	+60%	+70%
Baseline	32.0	39.9	44.1	50.0	53.0	55.9	57.2	58.9	60.9
Pilot	5.5	8.5	15.6	25.2	36.4	43.0	51.8	57.7	63.7
FAST 1st	11.1	13.4	25.9	33.3	40.8	48.4	51.9	53.9	59.6
FAST 1st+GP2*	11.1	13.4	26.0	33.2	40.8	48.5	52.8	56.7	61.9
FAST 1st+GP2/HW15**	11.1	13.4	25.9	33.2	40.8	48.5	52.8	56.3	61.7
FCFS*	12.3	15.4	28.8	36.5	42.2	53.8	58.3	64.6	71.5
FCFS/HW15**	12.5	15.6	28.7	34.7	41.4	51.4	55.8	63.3	69.6
FCFS/GP2	11.3	13.6	26.6	33.6	40.1	48.9	54.2	56.5	63.2

Table A3. Overall Average Waits with 23% FAST Arrival Rates

* FAST lane west of the WCTDF Store

** FAST lane on Highway 15

APPENDIX B: MAXIMUM AVERAGE WAITING TIMES, FAST RATIO = 23%

	Traffic Volume Level								
Border Configuration	-10%	Current	+10%	+20%	+30%	+40%	+50%	+60%	+70%
Baseline	6.2	9.5	6.4	9.1	10.0	16.9	11.7	20.7	18.3
Pilot	18.6	25.1	36.6	48.2	57.7	65.6	72.3	77.9	82.8
FAST 1st	13.4	13.1	14.4	14.3	13.6	14.5	14.5	13.8	14.8
FAST 1st+GP2*	13.4	13.1	15.3	17.7	17.8	17.5	40.3	32.0	41.6
FAST 1st+GP2/HW15**	13.4	13.1	15.0	16.5	18.1	18.9	40.2	29.5	38.7
FCFS*	60.9	75.4	109.1	120.6	120.9	130.8	138.4	134.4	145.9
FCFS/HW15**	76.6	81.3	123.6	139.0	147.4	150.6	149.5	151.1	150.5
FCFS/GP2	15.2	18.2	22.0	22.7	26.7	30.8	55.0	50.9	53.7

Table B1. FAST Maximum Average Waits with 23% FAST Arrival Rates

	Traffic Volume Level								
Border Configuration	-10%	Current	+10%	+20%	+30%	+40%	+50%	+60%	+70%
Baseline	83.8	87.6	85.6	95.8	100.1	103.5	107.5	107.0	112.2
Pilot	18.6	25.1	36.6	48.2	57.7	65.6	72.3	77.9	82.8
FAST 1st	34.8	40.6	70.4	66.1	83.7	84.2	89.8	100.2	107.8
FAST 1st+GP2*	34.8	40.6	71.0	65.4	82.4	82.5	92.5	98.0	106.8
FAST 1st+GP2/HW15**	34.8	40.6	70.1	66.0	82.2	82.0	93.0	98.9	107.4
FCFS*	28.5	33.6	41.8	56.8	66.8	73.5	73.4	78.3	81.6
FCFS/HW15**	26.5	30.7	39.2	51.1	56.4	59.9	74.6	69.6	81.4
FCFS/GP2	34.6	40.1	70.8	62.6	82.1	82.5	96.0	90.4	104.6

Table B2. GP Maximum Average Waits with 23% FAST Arrival Rates

	Traffic Volume Level								
Border Configuration	-10%	Current	+10%	+20%	+30%	+40%	+50%	+60%	+70%
Baseline	65.0	67.8	63.8	71.2	72.7	76.3	75.3	77.1	78.7
Pilot	18.6	25.1	36.6	48.2	57.7	65.6	72.3	77.9	82.8
FAST 1st	29.9	34.2	57.5	54.1	67.5	68.1	72.4	80.2	86.3
FAST 1st+GP2*	29.9	34.2	58.1	54.4	67.5	67.5	80.4	82.8	91.8
FAST 1st+GP2/HW15**	29.9	34.2	57.4	54.5	67.4	67.4	80.8	82.9	91.5
FCFS*	36.0	43.2	57.3	71.5	79.3	86.7	88.5	91.2	96.4
FCFS/HW15**	38.1	42.4	58.7	71.4	77.4	80.9	91.9	88.4	97.4
FCFS/GP2	30.2	35.0	59.5	53.4	69.3	70.5	86.5	81.3	92.8

Table B3. Overall Maximum Average Waits with 23% FAST Arrival Rates

* FAST lane west of the WCTDF Store

** FAST lane on Highway 15

APPENDIX C: AVERAGE MAXIMUM WAITING TIMES, FAST RATIO = 23%

	Traffic Volume Level								
Border Configuration	-10%	Current	+10%	+20%	+30%	+40%	+50%	+60%	+70%
Baseline	14.2	17.9	17.1	15.9	17.9	18.5	21.0	21.8	22.7
Pilot	17.5	22.2	29.5	41.5	58.3	69.6	89.5	102.0	114.4
FAST 1st	16.9	16.8	18.7	19.4	19.9	19.2	18.8	18.1	19.2
FAST 1st+GP2*	16.9	16.8	18.8	19.8	21.0	24.8	28.6	29.3	37.2
FAST 1st+GP2/HW15**	16.9	16.8	19.0	19.8	21.1	24.6	28.3	28.6	36.4
FCFS*	51.6	60.7	91.4	116.7	135.2	150.9	162.8	169.0	178.5
FCFS/HW15**	59.1	66.9	105.5	124.7	160.4	170.6	183.4	191.7	195.9
FCFS/GP2	21.9	23.4	25.9	28.9	30.8	33.4	37.3	36.7	46.4

Table C1. FAST Average Maximum Waits with 23% FAST Arrival Rates

	Traffic Volume Level								
Border Configuration	-10%	Current	+10%	+20%	+30%	+40%	+50%	+60%	+70%
Baseline	67.9	83.1	98.3	116.6	129.6	141.1	151.1	159.4	168.6
Pilot	17.5	22.2	29.5	41.5	58.3	69.6	89.5	102.0	114.4
FAST 1st	41.5	39.0	56.6	62.8	77.4	94.8	109.9	119.8	142.6
FAST 1st+GP2*	41.5	39.0	56.9	62.5	76.9	94.2	108.8	121.6	140.4
FAST 1st+GP2/HW15**	41.5	39.0	56.6	62.7	76.9	94.0	109.1	121.2	140.5
FCFS*	35.7	32.8	43.5	46.8	51.6	68.0	77.2	90.5	106.7
FCFS/HW15**	35.0	31.8	41.1	43.8	48.7	63.6	71.9	88.7	101.7
FCFS/GP2	40.2	37.8	56.0	61.6	74.8	94.4	109.7	119.8	139.8

Table C2. GP Average Maximum Waits with 23% FAST Arrival Rates

	Traffic Volume Level								
Border Configuration	-10%	Current	+10%	+20%	+30%	+40%	+50%	+60%	+70%
Baseline	54.9	66.5	75.9	88.1	95.5	102.6	107.3	111.8	116.6
Pilot	17.5	22.2	29.5	41.5	58.3	69.6	89.5	102.0	114.4
FAST 1st	35.8	33.9	47.9	52.8	64.1	77.3	88.9	96.3	114.1
FAST 1st+GP2*	35.8	33.9	48.1	52.6	64.0	78.2	90.3	100.3	116.6
FAST 1st+GP2/HW15**	35.8	33.9	47.9	52.8	64.0	78.0	90.4	99.8	116.5
FCFS*	39.4	39.2	54.6	62.9	70.9	87.2	97.0	108.6	123.3
FCFS/HW15**	40.5	39.9	56.0	62.5	74.5	88.3	97.7	112.5	123.5
FCFS/GP2	35.9	34.5	49.0	54.1	64.6	80.3	93.0	100.6	118.2

Table C3. Overall Average Maximum Waits with 23% FAST Arrival Rates

* FAST lane west of the WCTDF Store

** FAST lane on Highway 15

APPENDIX D: AVERAGE WAITING TIMES, FAST RATIO = 35%

	Traffic Volume Level								
Border Configuration	-10%	Current	+10%	+20%	+30%	+40%	+50%	+60%	+70%
Baseline	3.5	5.9	6.8	7.9	11.2	17.3	21.8	33.4	38.8
Pilot	3.2	5.4	12.5	17.4	26.0	36.6	46.9	53.0	60.4
FAST 1st	5.9	7.1	10.3	11.3	12.2	12.1	12.0	12.1	11.8
FAST 1st+GP2*	5.9	7.1	10.4	11.6	14.5	19.1	21.3	29.5	39.2
FAST 1st+GP2/HW15**	5.9	7.1	10.4	11.5	14.2	18.2	21.1	28.0	38.0
FCFS*	16.9	25.5	53.5	71.8	94.2	110.3	125.8	128.9	132.3
FCFS/HW15**	17.6	26.4	55.8	77.1	98.9	122.5	139.0	138.4	141.3
FCFS/GP2	8.4	12.5	22.6	30.7	43.1	48.3	59.4	61.7	71.9

Table D1. FAST Average Waits with 35% FAST Arrival Rates

	Traffic Volume Level								
Border Configuration	-10%	Current	+10%	+20%	+30%	+40%	+50%	+60%	+70%
Baseline	22.2	26.2	42.5	49.4	60.2	65.0	69.1	74.1	78.4
Pilot	3.2	5.4	12.5	17.4	26.0	36.6	46.9	53.0	60.4
FAST 1st	11.0	14.7	27.7	35.0	51.8	62.6	71.6	80.8	86.4
FAST 1st+GP2*	11.0	14.7	27.7	35.2	50.9	58.6	68.2	73.8	77.1
FAST 1st+GP2/HW15**	11.0	14.7	27.7	35.2	51.0	59.7	68.5	73.5	79.2
FCFS*	7.7	9.2	15.2	16.3	21.0	29.2	31.8	38.9	47.4
FCFS/HW15**	7.4	8.8	14.5	15.4	19.8	27.3	30.4	35.4	43.8
FCFS/GP2	10.3	12.7	24.6	27.8	39.1	49.3	54.6	60.6	65.8

Table D2. GP Average Waits with 35% FAST Arrival Rates

	Traffic Volume Level								
Border Configuration	-10%	Current	+10%	+20%	+30%	+40%	+50%	+60%	+70%
Baseline	16.0	19.3	29.9	34.5	41.6	46.4	50.1	57.6	62.2
Pilot	3.2	5.4	12.5	17.4	26.0	36.6	46.9	53.0	60.4
FAST 1st	9.2	12.0	21.7	26.2	36.0	41.7	45.5	49.6	49.8
FAST 1st+GP2*	9.2	12.0	21.7	26.5	36.5	43.1	49.1	56.3	62.1
FAST 1st+GP2/HW15**	9.2	12.0	21.7	26.5	36.5	43.3	49.1	55.4	62.7
FCFS*	10.9	14.6	27.5	33.2	40.3	46.3	50.0	54.0	61.2
FCFS/HW15**	11.0	14.7	27.7	34.2	40.3	46.0	49.9	50.7	57.0
FCFS/GP2	9.7	12.7	24.0	28.8	40.5	48.8	56.1	60.9	67.7

Table D3. Overall Average Waits with 35% FAST Arrival Rates

* FAST lane west of the WCTDF Store

** FAST lane on Highway 15

APPENDIX E: MAXIMUM AVERAGE WAITING TIMES, FAST RATIO = 35%

	Traffic Volume Level								
Border Configuration	-10%	Current	+10%	+20%	+30%	+40%	+50%	+60%	+70%
Baseline	8.2	30.6	14.0	32.7	35.2	42.7	45.0	64.6	63.1
Pilot	10.3	14.5	35.6	34.2	58.0	57.1	63.6	72.5	80.5
FAST 1st	10.3	14.6	15.2	13.4	13.5	13.1	13.9	13.9	13.4
FAST 1st+GP2*	10.3	14.6	15.7	17.4	42.4	41.2	58.0	49.8	69.2
FAST 1st+GP2/HW15**	10.3	14.6	15.3	16.6	40.8	39.1	56.0	44.9	55.4
FCFS*	45.1	128.2	138.5	145.5	150.5	142.2	145.5	159.2	152.3
FCFS/HW15**	47.3	134.9	146.2	158.1	161.8	156.6	155.2	160.8	164.4
FCFS/GP2	14.6	53.3	41.3	61.8	67.4	82.5	85.4	83.9	100.3

Table E1. FAST Maximum Average Waits with 35% FAST Arrival Rates

	Traffic Volume Level								
Border Configuration	-10%	Current	+10%	+20%	+30%	+40%	+50%	+60%	+70%
Baseline	47.8	72.4	71.8	81.6	89.1	109.7	98.8	99.9	101.8
Pilot	10.3	14.5	35.6	34.2	58.0	57.1	63.6	72.5	80.5
FAST 1st	25.3	58.3	66.2	70.1	85.7	90.2	96.1	108.1	110.3
FAST 1st+GP2*	25.3	58.3	65.9	66.5	75.5	91.5	92.0	95.7	92.5
FAST 1st+GP2/HW15**	25.3	58.3	66.0	66.8	76.1	90.1	88.3	87.5	94.0
FCFS*	16.5	27.1	33.1	34.7	40.2	53.7	51.3	65.7	72.9
FCFS/HW15**	15.9	25.7	30.8	31.8	35.8	50.9	52.5	61.6	67.2
FCFS/GP2	24.4	45.9	58.7	59.7	76.9	77.6	80.0	79.8	89.1

Table E2. GP Maximum Average Waits with 35% FAST Arrival Rates

	Traffic Volume Level								
Border Configuration	-10%	Current	+10%	+20%	+30%	+40%	+50%	+60%	+70%
Baseline	34.4	58.4	52.3	65.1	70.9	87.1	80.7	88.0	88.7
Pilot	10.3	14.5	35.6	34.2	58.0	57.1	63.6	72.5	80.5
FAST 1st	19.9	42.6	48.0	49.8	59.9	62.6	66.7	74.4	75.6
FAST 1st+GP2*	19.9	42.6	47.9	48.9	63.6	73.5	79.8	79.3	84.1
FAST 1st+GP2/HW15**	19.9	42.6	47.9	48.8	63.4	71.9	76.7	72.2	80.2
FCFS*	26.8	63.3	70.8	74.4	79.7	85.4	85.0	99.2	101.3
FCFS/HW15**	27.1	64.8	72.2	77.0	80.9	88.8	89.3	97.1	102.0
FCFS/GP2	20.8	48.6	52.5	60.4	73.5	79.4	81.9	81.3	93.1

Table E3. Overall Maximum Average Waits with 35% FAST Arrival Rates

* FAST lane west of the WCTDF Store

** FAST lane on Highway 15

APPENDIX F: AVERAGE MAXIMUM WAITING TIMES, FAST RATIO = 35%

	Traffic Volume Level								
Border Configuration	-10%	Current	+10%	+20%	+30%	+40%	+50%	+60%	+70%
Baseline	16.2	22.6	22.3	24.7	26.9	35.8	40.2	57.5	67.3
Pilot	14.8	16.8	26.9	33.1	42.0	57.5	78.9	91.6	110.6
FAST 1st	16.8	16.7	18.0	18.8	19.5	19.3	18.7	18.5	19.0
FAST 1st+GP2*	16.8	16.7	18.0	20.0	24.6	33.7	41.7	61.1	82.1
FAST 1st+GP2/HW15**	16.8	16.7	18.0	19.9	24.0	32.3	39.3	57.8	78.0
FCFS*	56.1	60.9	91.1	108.5	140.9	169.7	196.9	205.1	215.5
FCFS/HW15**	58.9	63.4	95.0	113.4	142.2	181.0	204.8	215.6	228.4
FCFS/GP2	27.0	29.8	41.5	50.5	66.4	74.8	92.1	96.3	117.7

Table F1. FAST Average Maximum Waits with 35% FAST Arrival Rates

	Traffic Volume Level								
Border Configuration	-10%	Current	+10%	+20%	+30%	+40%	+50%	+60%	+70%
Baseline	48.7	47.8	65.1	72.6	91.2	99.7	110.3	123.2	134.2
Pilot	14.8	16.8	26.9	33.1	42.0	57.5	78.9	91.6	110.6
FAST 1st	42.4	41.7	56.2	59.2	81.5	97.5	111.9	132.0	146.7
FAST 1st+GP2*	42.4	41.7	56.1	59.4	78.2	89.4	105.2	116.9	122.9
FAST 1st+GP2/HW15**	42.4	41.7	56.2	59.4	78.6	90.7	105.5	117.4	124.6
FCFS*	33.4	30.7	38.6	34.3	40.7	48.1	49.9	60.1	74.3
FCFS/HW15**	32.8	29.9	37.7	33.2	39.0	46.5	48.4	55.3	66.8
FCFS/GP2	39.5	36.5	50.0	48.8	60.6	75.7	86.5	99.0	110.8

Table F2. GP Average Maximum Waits with 35% FAST Arrival Rates

	Traffic Volume Level								
Border Configuration	-10%	Current	+10%	+20%	+30%	+40%	+50%	+60%	+70%
Baseline	37.8	39.3	50.7	56.4	69.5	78.2	86.7	101.1	111.7
Pilot	14.8	16.8	26.9	33.1	42.0	57.5	78.9	91.6	110.6
FAST 1st	33.2	32.7	42.5	44.7	59.3	69.5	78.5	91.4	101.0
FAST 1st+GP2*	33.2	32.7	42.5	45.3	59.0	69.5	82.5	96.9	108.3
FAST 1st+GP2/HW15**	33.2	32.7	42.5	45.3	59.0	69.8	81.8	96.0	107.9
FCFS*	41.5	41.5	57.4	60.9	76.6	91.6	102.6	112.0	124.8
FCFS/HW15**	42.1	41.9	58.2	61.9	75.9	94.7	104.4	112.7	124.7
FCFS/GP2	35.0	34.1	47.0	49.4	62.7	75.3	88.5	98.0	113.3

Table F3. Overall Average Maximum Waits with 35% FAST Arrival Rates

* FAST lane west of the WCTDF Store

** FAST lane on Highway 15