Evaluation of the Effects of Changing to Continuous Access HOT Lanes on SR 167

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SR 167 Access Study

Evaluation of the Effects of Changing to Continuous Access HOT Lanes on SR 167

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15. SUPPLEMENTARY NOTES

This study was conducted in cooperation with the U.S. Department of Transportation, Federal Highway Administration.

16. ABSTRACT

In August 2014, The Washington State Department of Transportation (WSDOT) changed the access controls for the HOT (High Occupancy Toll) lanes on State Route (SR) 167. The lanes were initially designed and implemented to allow access at only six points northbound and four points southbound. Since August 23, 2014, free access has been allowed into and out of the HOT lanes. This study was performed to determine the effects of allowing continuous access to the SR 167 HOT lanes. It examined customer attitudes toward the new access rules, the performance of the corridor, including both the HOT lanes and the parallel general purpose (GP) lanes, and the volumes of use and travel times experienced. It also examined the amount of revenue collected, the amount of toll evasion occurring, collision frequency and severity, and the impacts on transit operations.

The changes in the corridor since the change in access rules have been complex. This report describes that complexity. In general, traffic volumes are increasing in the corridor. Travel times have degraded slightly in both the GP and HOT lanes in the corridor. Prices and total revenue are up in the HOT lane. Prices increased substantially during the first five months of operation of the new rules, declined somewhat after that, but remain higher than under access control rules. No statistically significant change in safety is apparent. A large fraction of the travelers in the corridor are in favor of the access rule changes, and that includes the transit agencies operating in the corridor.

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EXECUTIVE SUMMARY

In August 2014, WSDOT changed the access controls for the HOT lanes on State Route (SR) 167. The lanes were initially designed and implemented to allow access at only six points northbound and four points southbound, as illustrated in Figure Ex-1. This controlled access design was selected for many reasons. Among those reasons was that limited access was expected to reduce the occurrence of merge disruptions to just a few locations in the corridor, and to provide better payment control (decreasing toll avoidance and the number of gantries needed). However, since August 23, 2014, free access has been allowed into and out of the HOT lanes at any location.

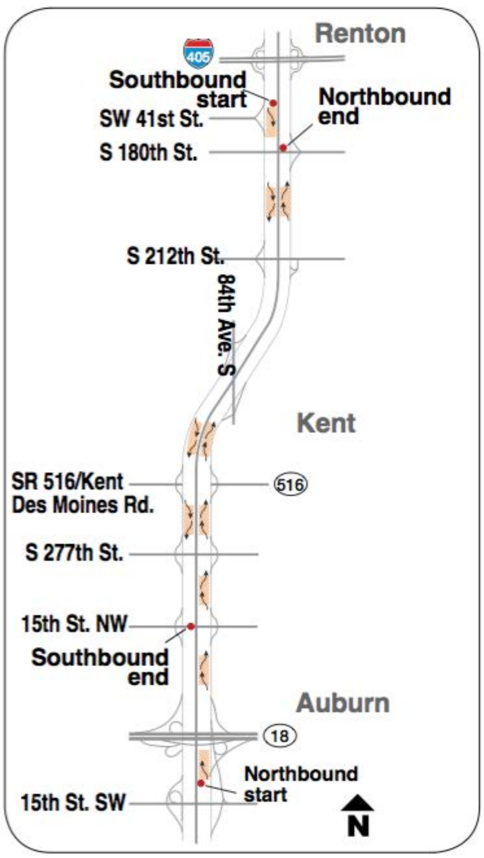


Figure Ex-1: Map of SR 167 HOT Lanes and Merge/Diverge Points before August 2014

The change was made because the original controlled access design created some operational limitations. Primarily, the restricted number of entry/exit points could make it difficult for vehicles to efficiently access the HOT lane from their freeway on-ramps and efficiently exit to their desired off-ramps. This access problem was particularly an issue for transit vehicles, which had difficulty weaving across congested freeway lanes in the space allowed between their on-ramps and the designated entry points. When they were unable to make the required movement safely, buses would spend considerable time stuck in traffic congestion along with the general purpose traffic. WSDOT also learned from an ongoing survey of corridor users that 40 percent of survey respondents were dissatisfied with the initial access restrictions. The WSDOT changed the access to test continuous access and determine whether that would help the corridor perform better for its users. This study was performed to determine the effects of allowing continuous access to HOT lanes.

CUSTOMER ATTITUDES

WSDOT conducted an electronic survey at the beginning of December 2014 to obtain customer feedback on the change in HOT operating rules. The overall response from the public toward the changes was positive. The researchers sent out 44,276 e-mail invitations to take the survey to Good To Go! customers who had paid to use the SR 167 HOT lanes at least once during the previous eight months. The study received 3,932 responses (9 percent). Roughly one tenth of those respondents answered only one question: whether the respondent was aware of the change in access. The remainder of the respondents completed most of the survey. Just under 70 percent of respondents were aware of the change from limited access to open access.

Of the respondents who were aware of the change, 65 percent said they preferred the open access rules. Another 18 percent preferred the old rules, and the remaining 17 percent had no opinion or did not answer the question. Importantly, 78 percent said they believed that the new rules made the HOT lane more useful to them. Public opinion can therefore be said to be strongly in favor of the change.

Regarding the value obtained from the HOT lanes, 36 percent stated that the HOT lane was more expensive after the change than before it. Yet 46 percent of the respondents aware of the access rule change also felt that the HOT lane was now a better value. Only 22 percent of that group disagreed with the statement that the HOT lane was a better value. This set of responses indicates that a substantial portion of the public was aware of the price increases that occurred during the first six months of the new access rules, but a significant majority of the public still valued the ability to pay for a fast, reliable trip, even at those higher prices.

Regarding safety, 54 percent felt the new access rules allowed the corridor to operate more safely. 43 percent agreed that SR 167 was safer because of the increase in freedom to enter and exit the HOT lane, and 23 percent disagreed with that statement. The remaining 34 percent did not express an opinion. However, while respondents were indicating that they felt that the corridor operated more safely, they also indicated that weaving into and out of the HOT lane had increased as a result of the access rule changes. Comments written by survey respondents indicated that increased weaving was viewed both as a positive and a negative. These somewhat mixed responses suggest that the access changes did not have a significant impact on perceived safety in the corridor.

Survey responses were mixed to questions about whether toll avoidance and evasion had increased. Of the respondents aware of the rule change, 34 percent disagreed that more toll evasion was occurring. Another 24 percent agreed that more toll evasion was taking place, and 42 percent had no opinion about changes in toll avoidance.

Survey respondents' attitudes toward HOT lane performance mirrored their attitudes toward toll avoidance. 22 percent thought that the HOT lane had slowed as a result of the new access rules; 37 percent disagreed with the statement that the HOT lane had slowed, and over 34 percent had no opinion or were unsure.

Survey respondents reported a modest increase in use of the HOT lane, with 20 percent stating that they used the HOT lane more often, specifically because of the improved access changes. However, 62 percent stated that they had <u>not</u> changed their usage patterns, and 5 percent stated that they used the HOT lane less as a result of the access rule changes.

PERFORMANCE OF THE FACILITY

Seasonally adjusted comparisons were made of roadway performance for both the general purpose and HOT lanes on SR 167. The analysis compared traffic conditions observed from September 2013 to March 2014, before the change, with conditions observed from September 2014 to March 2015, immediately after the change. Because questions remained about whether performance had stabilized after the initial seven months, an additional five months—April through August 2015—of volume, travel time, and price data were collected and analyzed.

Traffic Volume Changes

The before and after analysis showed that for nearly every location of the HOT lane, the average weekday peak period volumes were higher in the After time period. Traffic volumes rose between 1 to 22 percent in the peak period during the first six-month period, and remained at those levels during the second six months after the access rule change. Twenty-four-hour HOT lane volumes were always higher, by a similar range. For the GP lanes, results were more mixed. In the peak period, 18 locations had volumes that were lower by 1 to 7 percent, and 16 locations experienced volume increases of 0 to 4 percent. Average weekday GP lane volumes were always higher, by up to 5 percent. These same patterns also remained during the second six months of operation.

Total volume (the combination of both HOT and GP volumes) increased at almost all locations throughout the corridor. The exceptions were found at the very southern end of the corridor, where total northbound AM peak period and total southbound PM peak volumes decreased slightly.

Traffic volumes during the second six months of operation after the access rule change were very similar to those observed during the first six months after the change. No significant differences in volume patterns were observed from March to August of 2015 in comparison to the patterns observed immediately after the implementation of the new access rules.

Figure Ex-2 illustrates the changes in the morning peak period, northbound HOT and GP traffic volumes. Figure Ex-3 illustrates the changes in the evening, peak period, southbound HOT and GP traffic volumes.

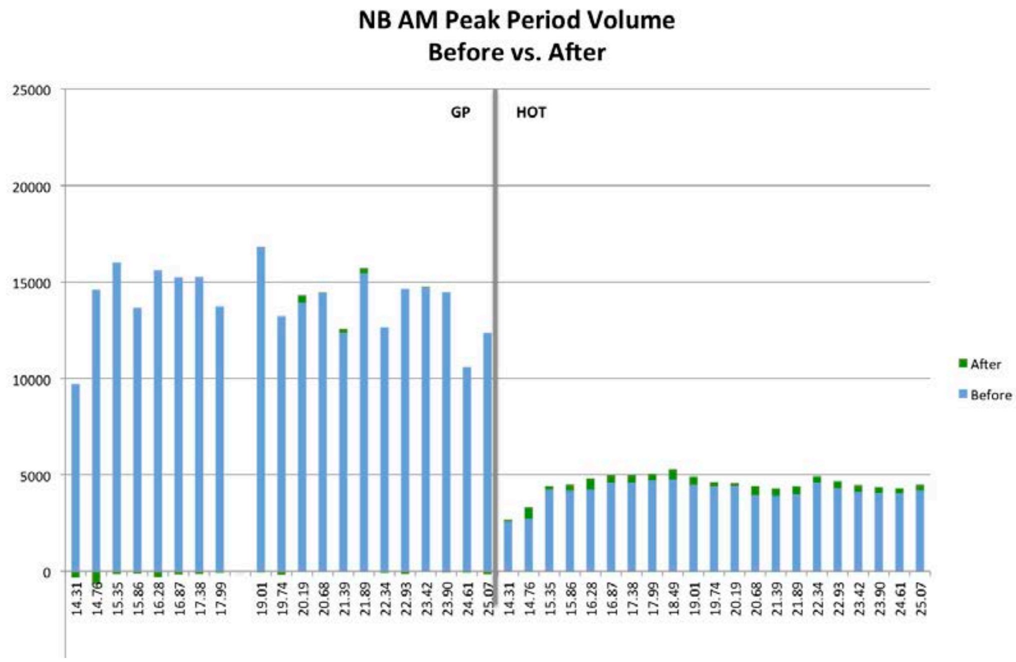


Figure Ex-2: Northbound AM Peak Period Volumes Before and After Access Rule Changes

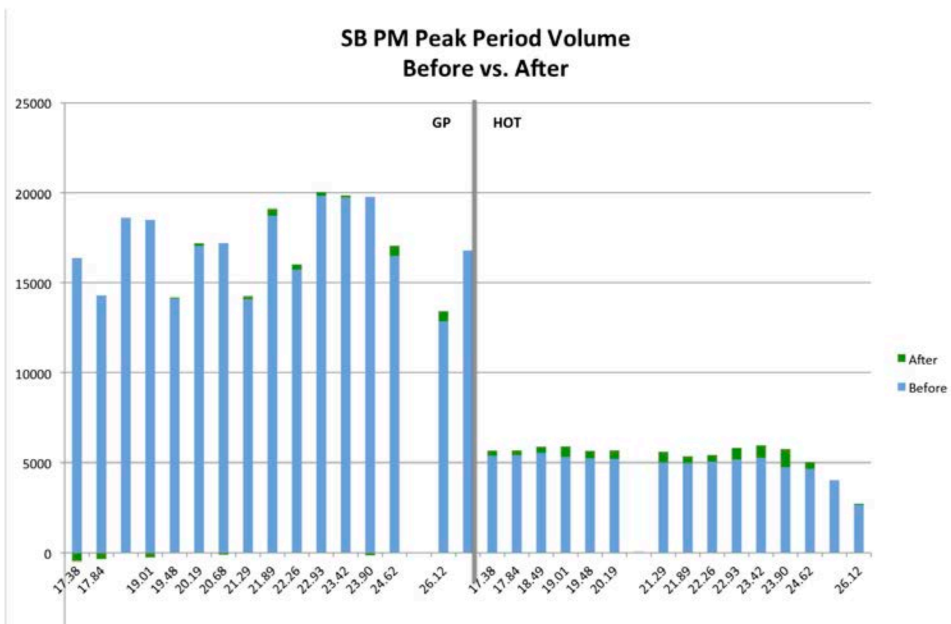


Figure Ex-3: Southbound PM Peak Period HOT and GP Volumes Before and After Access Rule Changes

Travel Time and Reliability

Travel times were compared for the same initial seven-month Before and After periods as traffic volumes. In addition, travel times were compared for two control periods before the start of the new access rules to examine background trends in the corridor. Finally, an additional five months of travel time data were analyzed for April through August 2015 and then compared with April through August 2014. For the initial seven-month Before/After period studied, travel time and reliability in the SR 167 corridor generally worsened in the peak directions in the peak periods, the time periods when the HOT lane is meant to provide the most substantial travel benefits. However, because a background trend of growing congestion in the corridor already existed, the project team is not certain whether the growth in congestion can be attributed to the change in access rules.

Table Ex-1 shows the mean travel times for the northbound (Auburn to Renton) trip for the AM peak period for both the GP and HOT lanes for both of the Before and After periods, and for the control period. Mean travel times increased in the After period for both the HOT and GP lanes. During the first seven months of operation, the peak mean 5-minute travel time grew in the dominant northbound AM direction for both GP (+2.1 minutes) and HOT lane travelers (+1.3 minutes), corresponding to a 2-mph drop in average GP trip speed and a 4-mph drop in average HOT lane trip speed. However, Table Ex-1 also shows that travel times were also degrading in the control period before the change in access rules. In the additional five-month analysis period, both HOT and GP lane performance improved marginally over times observed in the first seven months under the new rules. Travel times were still slower than those observed before the introduction of the open access rules. However, the year-over-year growth observed was consistent with that observed in the control period before implementation of the new access rules. This suggests that at least a portion of the growth was due to traffic growth in the corridor.

Table Ex-1: Auburn to Renton Mean Travel Times in the AM Peak Period (minutes)

		Control	Sept - March	April - August
After HOT Access	HOT	12.3	15.5	15.4
Rule Change	GP	17.9	25.9	24.8
Before HOT Access	HOT	11.7	14.2	15.1
Rule Change	GP	17.1	23.8	23.6
Change	HOT	0.6	1.3	0.3
(After – Before)	GP	0.8	2.1	1.2

The degradation of the HOT lane travel times are important because the northbound HOT lane no longer meets the adopted performance standard.[1] Before the start of the open access policy, the northbound HOT lane was able to meet or exceed the 45 mph state standard 91 percent of the time in the AM peak period. After the continuous access rules were implemented, the HOT lane met the standard only 76 percent of the time. This change was mostly caused by an increase in delays at the northern end of the corridor, much of which stemmed from queues backing up from the SR 167/I-405 interchange and added delays between mileposts 16.5 and 18.5 (near Emerald Downs).

Table Ex-2 shows the mean travel times for the southbound (Renton to Auburn) trip for the PM peak period for both the GP and HOT lanes. As with the AM peak period in the northbound direction, mean travel times increased in both the After period and the control period for both the HOT and GP lanes, but the increases after the change in HOT lane access rules were smaller in this direction than in the northbound direction. The increases in travel times after implementation of the access rule changes were also smaller than the increases observed in the first six months of 2014 (compared to 2013) before the change in the HOT lane access rules. This suggests that the changes in southbound congestion were as much due to growth in the region as they were to changes in the HOT lane access rules. Unlike the northbound direction, the southbound direction of travel showed a larger increase in travel time during the April-August period of operation under the new access rules in comparison to the first seven

[1] Note that this computation includes the northern end of the corridor which includes the queue which forms at the SR 167 / I-405 interchange ramps. If these queues are removed, the HOT facility corridor likely meets the 45 mph standard, 90 percent of the time.

months. However, this increase in travel time was still consistent with expectations based on the pre-implementation growth rate.

Table Ex-2: Renton to Auburn Mean Travel Times in the PM Peak Period (minutes)

		Control	Sept - March	April - August
After HOT Access	**HOT**	**12.4**	**10.0**	**10.7**
Rule Change	**GP**	**19.3**	**15.9**	**18.4**
Before HOT Access	**HOT**	**12.1**	**9.8**	**10.3**
Rule Change	**GP**	**15.7**	**15.2**	**16.4**
Change	**HOT**	**0.3**	**0.2**	**0.4**
	GP	**3.6**	**0.7**	**2.0**

Unlike the northbound direction, the southbound HOT lane was able to meet or exceed the 45 mph standard over 97 percent of the time both before and after the start of continuous access.

<u>Friction Between HOT and GP Lanes</u>

One specific performance concern with the change in HOT lane access rules was that the unfettered ability for vehicles to enter and exit the HOT lane would cause the HOT lane to slow down relative to the GP lanes. The term "friction" is used to describe the fact that a lane (in this example, an HOV or HOT lane) generally slows down "in sympathy" with the neighboring (GP) lane, when that neighboring lane slows. This effect was examined by comparing HOT lane speeds with GP lane speeds when the GP lane slowed below 50 mph.

Figure Ex-4 shows the comparison. With the HOT lane speed on the Y-axis and the GP-lane speed on the X-axis, the steeper the slope of the line, the more the HOT lane speed is affected by the GP lane speed. Of the 30 locations evaluated in the corridor, 25 showed a steeper slope after the start of continuous HOT lane access (i.e., a higher positive correlation between HOT lane speeds and adjacent GP lane speeds) in comparison to the relationship before the start of continuous access. This pattern continued in the analysis of April-August, as 27 of the 30 locations showed a greater impact of GP lane performance on HOT lane speeds. This suggests that with the opening of continuous HOT lane access, the friction effect became somewhat stronger.

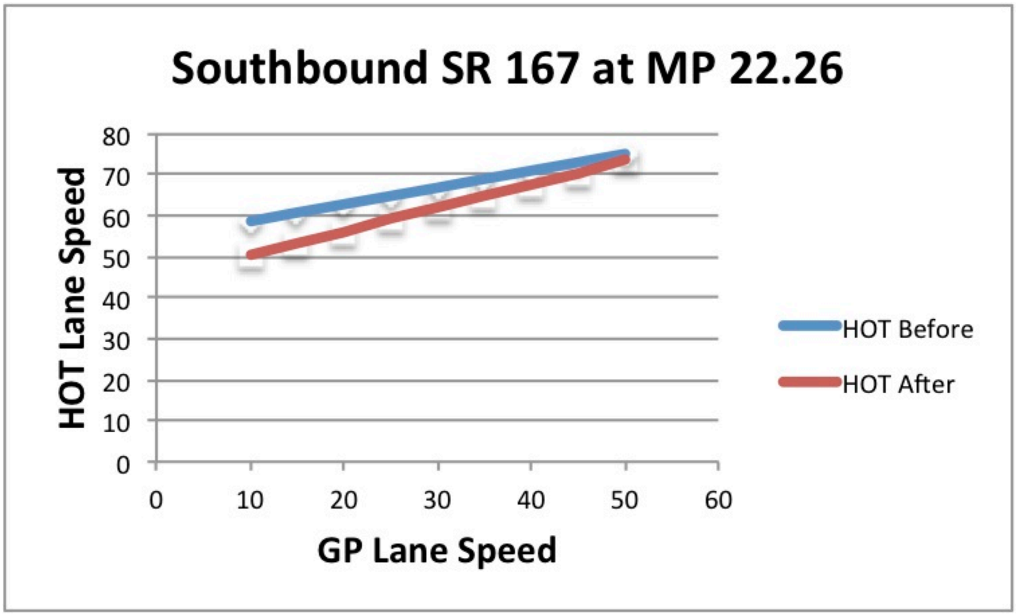


Figure Ex-4: Changing Relationship of GP and HOT Lane Speeds, Southbound at Milepost 22.26

The implications of the increase in friction are that as the GP lane slows, the HOT lane also slows, which in turn causes prices to rise in the HOT lane, as the toll pricing algorithm attempts to maintain free flow speed in the HOT lane. The result is an increase in the price paid per vehicle for travel conditions similar to those in the GP lane. This partly explains the rise in prices in the HOT lane observed during the first five months of the new access rules.

Changes in Origin/Destination Patterns in the HOT Lane

An area of interest to WSDOT was whether the change in HOT lane access rules would change when and where customers used the HOT lane. That is, now that motorists could legally enter and exit the HOT lane when and where they wished, would that new freedom change when and where they actually entered and exited the HOT lane?

The analysis of where travelers chose to enter and exit the HOT lane (i.e., at which gantry they first entered the HOT lane, and which gantry they last passed before exiting the HOT lane) showed that while small changes in the origin/destination patterns of HOT lane users were observed, the overall changes observed were overshadowed by the month-to-month variation in those patterns. The same basic use pattern remained constant in the corridor, but specific events appeared to temporarily change when and where travelers chose to enter and/or leave the HOT lane. These temporary patterns were far larger than any long-term change caused by the HOT lane access rule change, and the presence of several of these temporary changes strongly suggests that no major, permanent change in the patterns of HOT lane entry and exit have occurred.

REVENUE COLLECTION

Toll revenues used in this report were generated directly from the toll tag data collected in the field and the toll rates reported by WSDOT. The before/after evaluation of revenue collection in the corridor was complicated by the fact that WSDOT changed the pricing algorithm on December 4, 2014. WSDOT took this step because of significant price increases occurring in the HOT lane during the Fall of 2014 (see Figure Ex-5). WSDOT determined that the pricing algorithm was keeping the price for entering the HOT lane too high after congestion in the HOT lane had started to ease. High prices had not previously been commonly observed before the access rule change, and their presence during the first three months of open access rules pointed out the fact that the algorithm needed to be revised to more quickly lower the prices when they became high. In response, WSDOT changed the algorithm so that prices fell more quickly as congestion eased.

Price per HOT Lane Customer

The term "customer" used in this section refers to a GoodToGo toll tag-equipped vehicle that passes under a toll gantry in the HOT lane. It does NOT include carpools using the HOT lane without a toll tag. However, note that not all "customers" pay a toll. When the HOT lane's performance falls below the adopted standard, the operating rules are changed to "HOV Only"—and no paying customers should enter the lane. However, it is clear from the data that many tag-equipped vehicles continue to use the HOT lane even when the signs say "HOV Only." These vehicles are not charged a toll (i.e., the toll value is set to zero[2]). While, vehicles are allowed to stay in the lane if they had already

[2] It is unclear whether these vehicles are carpools that have forgotten to remove or shield from their toll tags, or whether they are single occupant vehicles that are ignoring the HOV Only sign. A limited number

entered when a price was displayed, in this specific analysis, these vehicles are considered to have entered the lane AFTER the HOV Only sign has been lit.

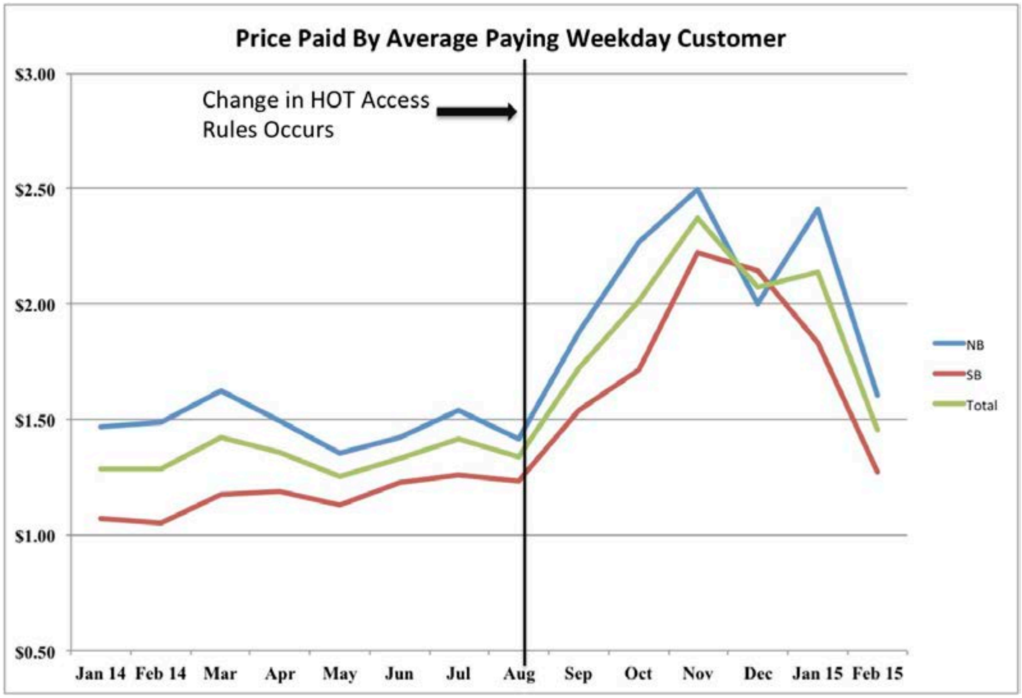


Figure Ex-5: Changing Price Paid per HOT Lane SOV Customer

Figure Ex-5 clearly shows that after the access rules were changed to allow free entry and exit, the prices charged were routinely higher than prices charged before the rule change. Only in February 2015 did prices return to near the levels that were common before the change in access rules. After February, prices remained higher than before the open access rules were adopted, but lower than experienced during the first few months of operation. The significant drop apparent in the price per paying customer traveling northbound in December 2014 was in part due to the fact that December 2014 was by far the least congested month for northbound traffic (using average travel times as the measure) of the seven months initially examined since the change in access rules. This was in large part due to the effect on morning commute traffic of the large number of people taking winter vacations. December's northbound prices were also significantly

of these vehicles are daily users of the HOT lane, regardless of the cost posted. This suggests that at least some "HOV Only" tagged vehicles are SOV drivers that simply do not read the VMS signs.

affected by a large number of non-paying tagged vehicles traveling during the congested morning commute. December 2014 experienced an average of 285 non-paying tagged vehicles per non-holiday weekday, more than twice the number of the next highest month. There were two days (Dec 9th and 18th) when the HOT lane appears to have been opened to general traffic; however, eight additional days had HOT lane performance issues significant enough to warrant the imposition of "HOV Only" conditions, despite the lower overall peak period congestion. Southbound in December 2014, neither the traffic congestion, the price per vehicle, nor the number of non-paying "customers" was significantly different than that experienced in the early months after the access rule change.

Figure Ex-6 shows the average price per customer northbound, by time of day, between 5:00 AM and 2:30 PM, for each month between January 2014 and August 2015. The first seven months after the change in HOT lane access rules are shown in dark lines, the second five months are shown in dashed lines. Figure Ex-6 illustrates the fact that after the access rule change, prices increased faster and earlier in the day, and stayed higher longer in the peak period than in the months before the change (January 2014 – July 2014, with August 2014 having mixed operations). Even though WSDOT changed the tolling algorithm in early December, January 2015 still had the highest average price ($4.50 per paying customer at 6:30 AM) and one of the longest durations of average prices above $3.00. In addition, the figure shows that since February, prices have dropped back closer to pre-rule change conditions.

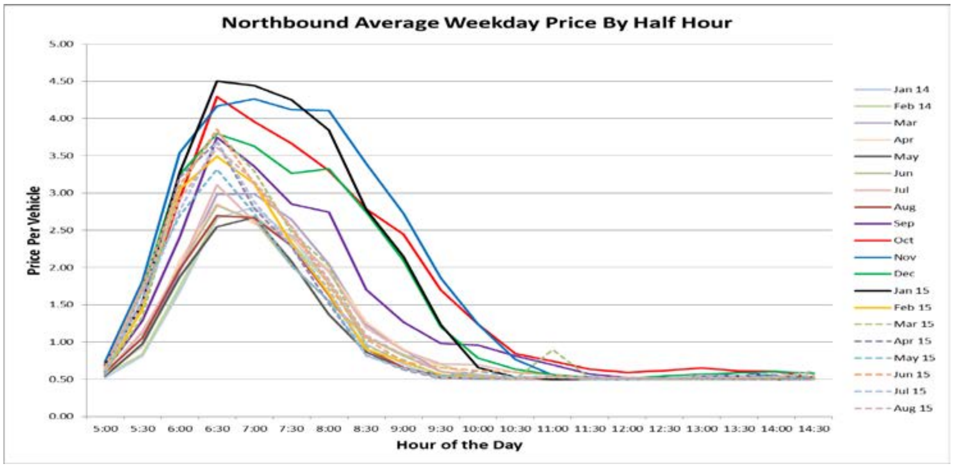


Figure Ex-6: Average Weekday Price Paid per Paying Customer by Half Hour by Month, Northbound SR 167 HOT Lane

A review of the prices paid in December 2014 illustrates the high level of price variability in the corridor. Figure Ex-7 shows the average price per half hour for each day in December, but based on only those tagged vehicles that actually paid a HOT lane toll. In Figure Ex-7, the maximum price paid in a half-hour increment on December 3rd was over $8, which occurred at 6:00 AM. The price actually peaked at $9 at about 6:15 in the morning, before the HOT lane converted to HOV Only operations. HOV Only operations lasted until just after 6:50 AM. This did the following:

1) dramatically reduced the mean price paid per customer reported for that day
2) significantly reduced the average price paid for each of the half hours that contained partial HOV Only prices
3) dramatically reduced the total revenue collected for that day, since it converted a period when maximum revenue was being collected into a period when no revenue was collected
3) significantly reduced the number of paying customers of the HOT lane, even if a large number of tagged vehicles continued to use the lane (thus limiting how much of the intended operational benefit WSDOT was getting from the HOV Only signs).

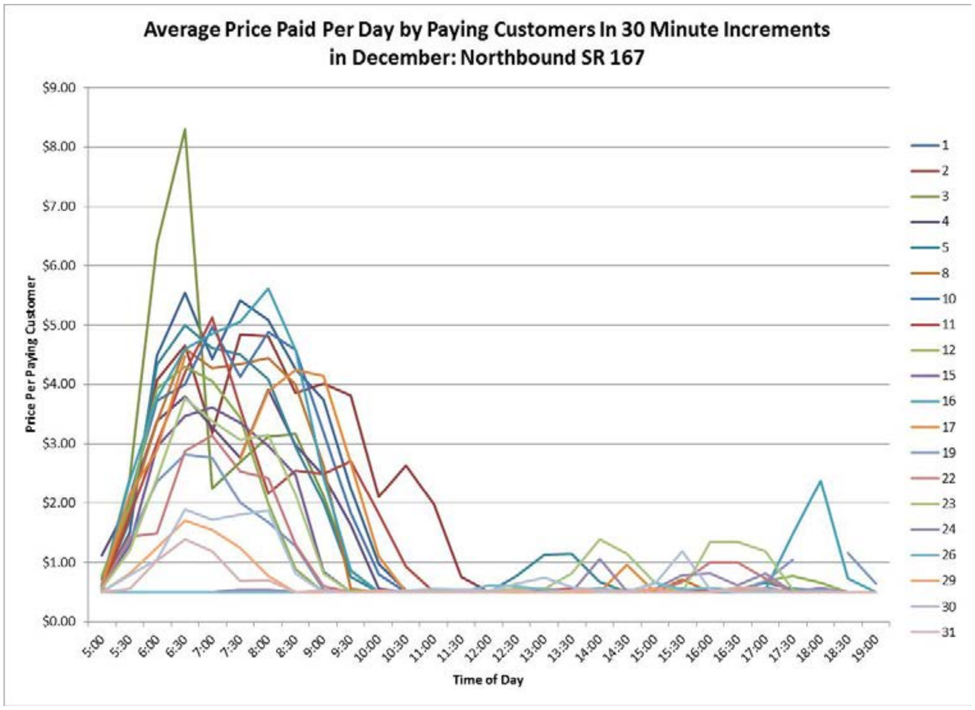


Figure Ex-7: Average Price Paid per Paying Customer by Half Hour by Day Northbound SR 167 HOT Lane

Also seen in Figure Ex-7 are the very low prices charged on the 29th, 30th, and 31st of December. These days are not officially holidays, but many workers take them as vacation (e.g., the Boeing 737 manufacturing plant in Renton is closed to allow all Boeing employees to take that week off), and therefore traffic volumes and congestion were down significantly, greatly reducing the demand—and thus price—for HOT lanes.

The public's reactions to the high prices experienced in the first few months of operation and illustrated in Figures Ex-5 and Ex-6 were reflected in the public attitude survey described in Chapter 2 of this report. At no time during the seven months before the access rule change did prices northbound exceed $6.25. After the rule change, prices hit the maximum value of $9.00 multiple times in four consecutive months. February 2015 was the first month since September 2014 that the northbound corridor did not reach the maximum allowed $9 toll at least once during the month.

Some of these extreme prices can be explained by roadway performance. For example, as shown in Figure Ex-8, in September and October, the HOT lane experienced significant congestion above normal conditions that would have resulted in increased HOT lane prices. In November, significant congestion occurred early in the peak period, and while it returned to more normal conditions by 7:30 AM, prices did not drop quickly under the original algorithm.

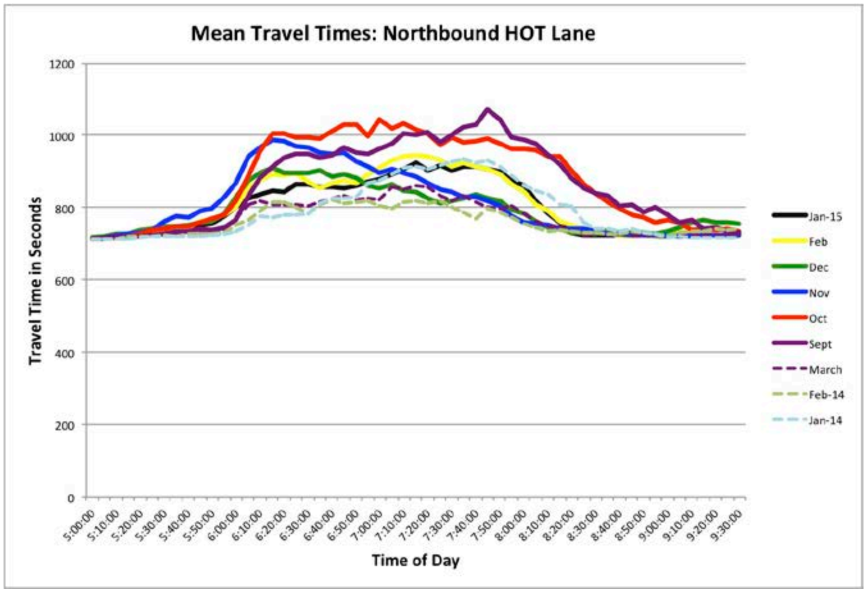


Figure Ex-8: Mean Travel Times by Time of Day, Morning Commute Northbound SR 167 HOT Lane

Figure Ex-9 shows that general purpose lane congestion was also routinely high during the initial months of operation under the new HOT lane access rules. This would have also increased demand for the HOT lane, further driving up prices.

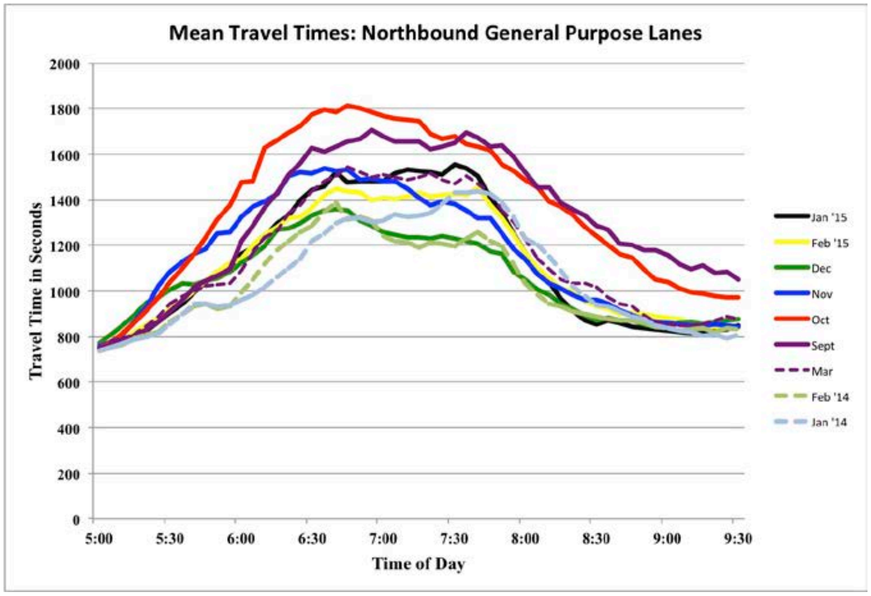


Figure Ex-9: Mean Travel Times by Time of Day, Morning Commute Northbound SR 167 General Purpose Lanes

In the southbound direction, prices also rose considerably after the access rules were changed. Figure Ex-10 illustrates the average price paid per paying customer southbound. The steep increase in prices that caused negative public reaction and resulted in the change in the HOT lane pricing algorithm are also obvious in this direction of travel, with all of the months between September 2014 and January 2015 showing prices well above those experienced before the HOT lane access change. Unlike northbound, prices for the southbound direction continued to rise, even in December after the pricing algorithm change. But southbound prices started dropping in January, dropped substantially in February, and now remain at levels that are well below the initial highs seen in the early months of the open access rules but slightly above the prices charged before the change to open access.

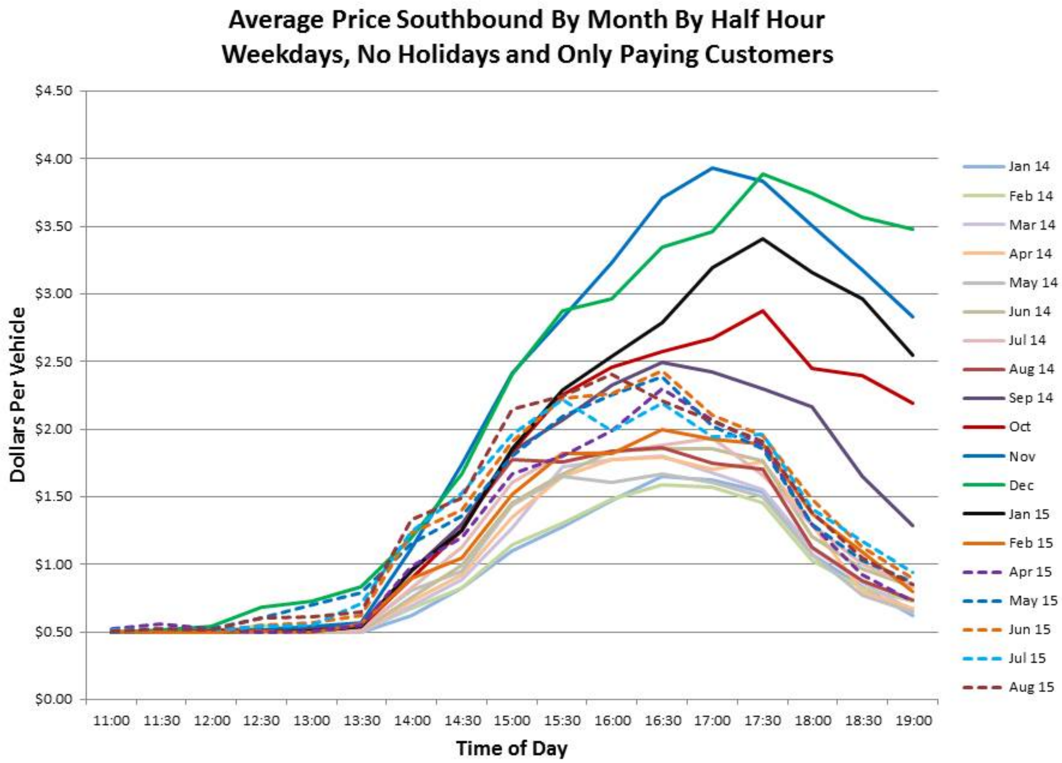


Figure Ex-10: Average Weekday Price Paid per Paying Customer by Half Hour by Month – Southbound SR 167

As with northbound travel, at least part of the increase in HOT lane prices can be associated with increasing congestion in the corridor. Southbound travel times were consistently slower than they were in early 2014. December 2014 travel times were similar to those seen during the first five months after the access rule changes (including during December afternoons, which explains why southbound prices did not drop like they did northbound). Southbound travel times only returned to pre-access rule conditions in February 2015, when coincidentally, HOT lane prices returned to near pre-access rule change levels.

Total Revenue

Figure Ex-11 shows the total revenue collected by month from January 2014 through February 2015. Total revenue was up substantially for the first five months after the change in HOT lane access rules, but in February, revenue dropped back to a value typically found before the change in access rules. However, the revenue increases before February were not steady. The maximum revenue month was October, with revenue decreasing from that high point in both directions in November. This drop was likely due to the fewer number of work days in the month. In December, northbound revenue continued to drop, in part because of the Christmas holiday commute traffic reduction, and in part because of the two full days of HOV Only operation. However, southbound, December revenue collection increased. For the additional months of April through August 2015, total revenue per month continued to be somewhat volatile. It typically exceeded the revenue obtained before the access rule change but stayed below the amounts experienced after the open access rules were first implemented.

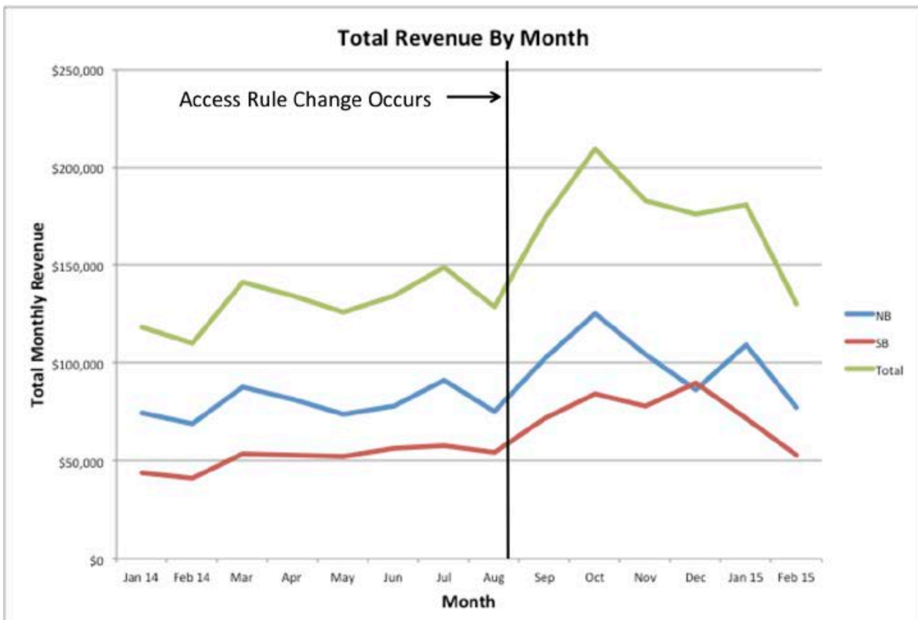


Figure Ex-11: Total HOT Lane Revenue, SR 167 Corridor

Figure Ex-12 normalizes these revenue figures for the number of workdays in each month. In this figure, the effects of both the algorithm change and the December holidays become clear. Total workday (non-holiday weekdays) revenue grew from the change in access rules to the end of November. It then declined both in December before rebounding partially in January 2015, only to drop again in February 2015 as congestion eased. From April through August 2015 the total revenue collected per workday has remained higher than before the change to open access but lower than that taken in during the first few months of the new access rules.

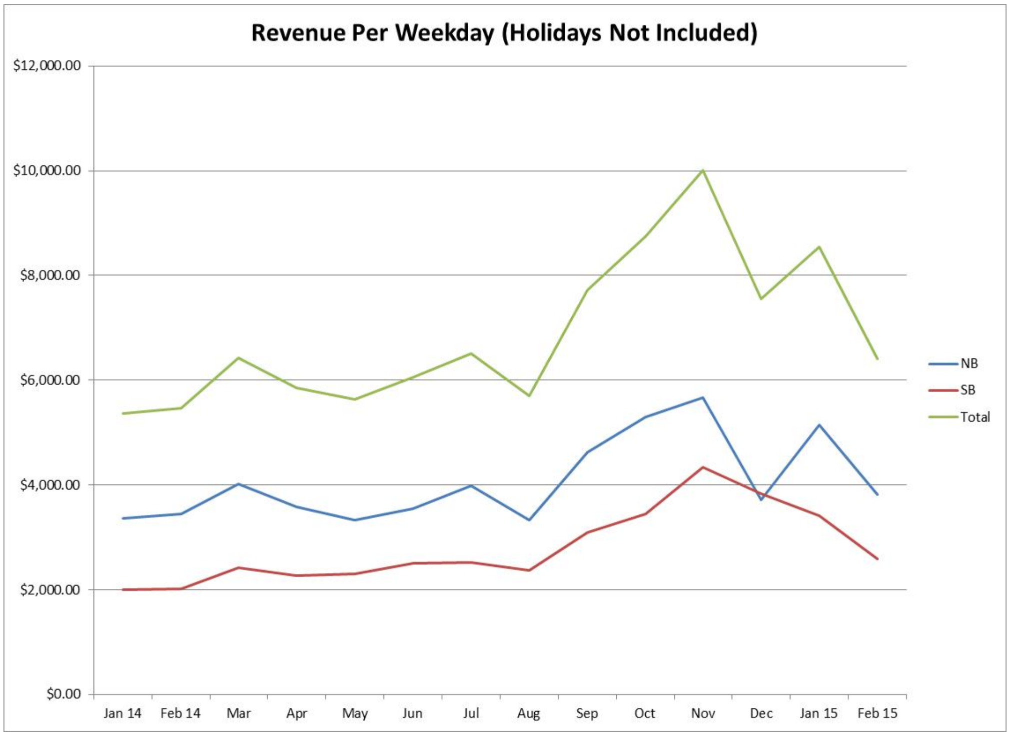


Figure Ex-12: Total HOT Lane Revenue per Day, Both Directions, for Non-Holiday Weekdays in the SR 167 Corridor

Number of Paying Customers

The final metric examined in the revenue category was the number of paying customers. The NW Region loop data clearly showed that traffic volumes in the HOT lane increased. The big question is whether those additional vehicles were paying customers, new carpools, or violators. Figure Ex-13 shows the total monthly volume of tagged vehicles between 5:00 AM and 7:00 PM (when SOVs pay to use the HOT lane). The total volume of vehicles remained flat until November and then dropped, in part because of the smaller number of workdays in November and in part because of rising prices.

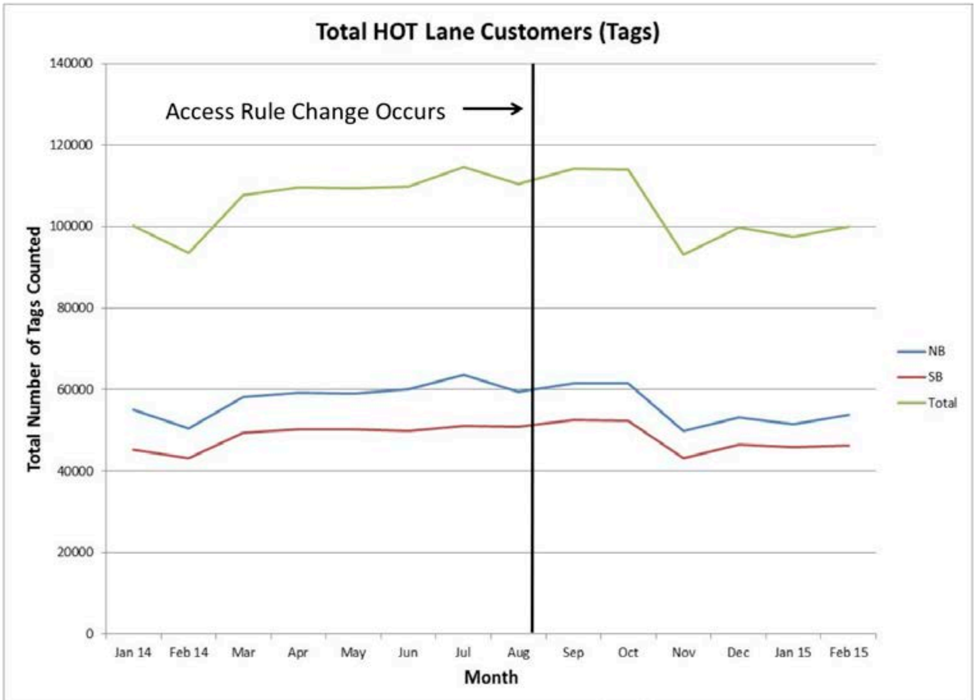


Figure Ex-13: Total Tagged Vehicle Customers Using the SR 167 HOT Lane between 5:00 AM and 7:00 PM

Figure Ex-14 illustrates the number of paying weekday customers per non-holiday weekday for each month. In this graphic, a pronounced drop can be seen in December, caused by the loss of two complete weekdays when the HOT lane was open to all traffic without charge. But the initial overall trend is still clear: the total number of paying customers each weekday decreased when the access rules were changed, despite the overall increase in HOT lane traffic volume. This downward trend in the number of paying customers reversed itself in the additional study period. As prices in the corridor came back down, the average number of paying customers grew. The majority of that growth was northbound. The change in southbound use was less consistent from a month to month basis, with an increase is paying customers in May and June 2015 (versus 2014), but a modest decline in July and August.

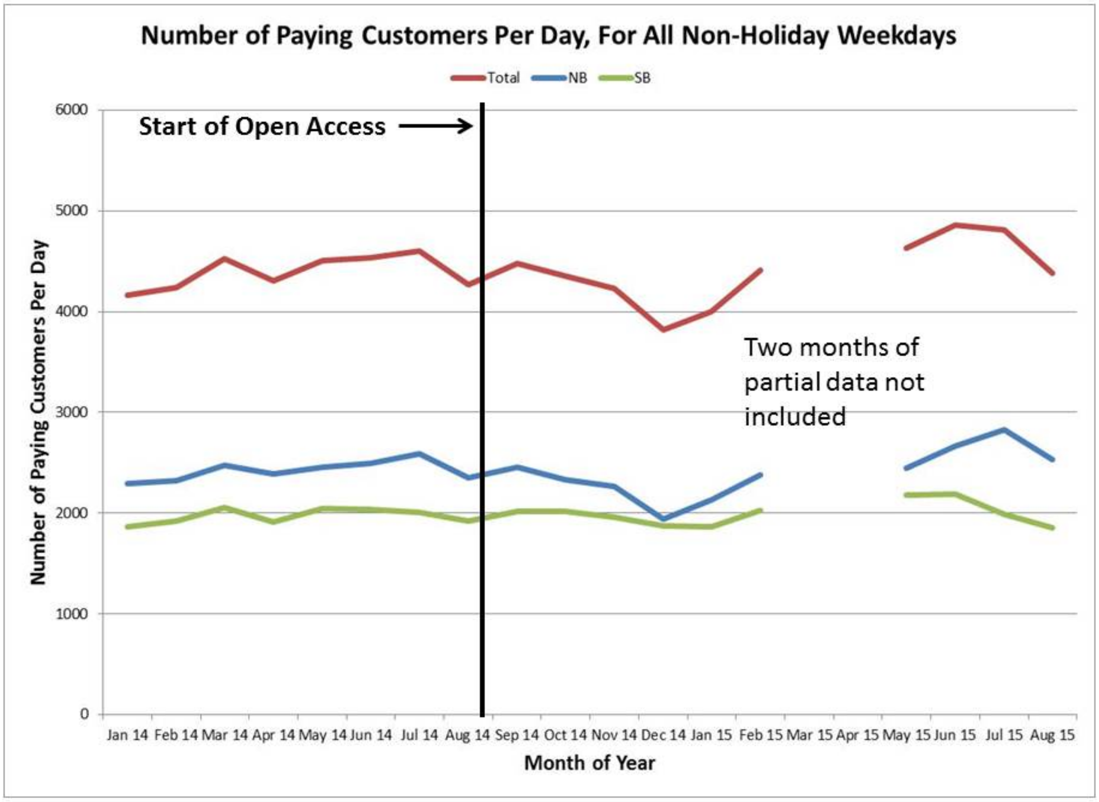


Figure Ex-14: Total Paying SR 167 HOT Lane Customers per Weekday

The evidence shows that a number of vehicles that carry electronic toll tags routinely use the HOT lane, regardless of whether signs governing the lane's operation state that the lane is reserved for HOVs only. The fact that many of these vehicles continue to use the lane even when the HOV Only sign is present suggests that many of them also pay (and sometimes pay quite a lot) to use the HOT lane without regard to the price posted. If we assume that these vehicles are not carpools, since many of them routinely pay tolls, then if they are observed when the HOV Only sign is lit, they are likely violating the HOT lane rules, and enforcement of the facility has not hindered their use of the facility. This suggests that other violations may also be growing in the corridor, as total volume in the HOT facility is up more than the number of paying HOT lane customers.

In contrast, just under 4 percent of the survey responders that were aware of the rule change indicated that they carpool more often as a result of the new access rules, and only 1 percent said they carpool less. This suggests that at least some additional carpooling is occurring in the corridor. Without more concrete evidence, it is only possible to speculate whether violations of the HOT lane are up, or whether additional carpools are using the HOT lane as a result of the new access rules.

TOLL EVASION

Two different approaches were used to determine whether toll evasion increased in the corridor as a result of the change in HOT lane access rules. Both approaches examined traffic volume patterns near the toll gantries to determine whether vehicles were exiting the HOT lane before the gantry and then re-entering the lane after the gantry. Neither analytical approach was able to detect significant toll gantry avoidance movements.

This does not mean that toll avoidance is not taking place. But if it is, it is not occurring such that drivers are changing lanes near the toll gantries to avoid paying tolls at those gantries.

One interesting “toll avoidance” mechanism that was noticed in the data was the significant numbers of toll tag-equipped vehicles that are still entering the toll lanes when the tolling signs state “HOV Only.” In these instances, no toll is charged to those toll tag-equipped vehicles. It is unclear whether those vehicles are in fact carpools—and the drivers have not removed their toll tags – or whether the vehicles are SOVs that are intentionally or unintentionally violating the “HOV Only” sign posting. Given that many of these vehicles are frequent users—and paying customers—of the facility, the project team suspects that these vehicles tend to be SOVs that would be willing to pay to use the HOT lane and are simply not paying attention to the posted signs. It is clear that WSDOT is losing revenue that would otherwise be obtained from these vehicles if it continued to charge tagged vehicles using the HOT lane when the “HOV Only” sign is posted.

COLLISION FREQUENCY AND SEVERITY

SR 167 showed a modest increase in the number of vehicle crashes occurring in the corridor since the change in HOT lane access rules. However, insufficient evidence was present to indicate that the increase in crashes was a direct result of the access rule change. The number of crashes occurring in the corridor—like congestion levels—was already growing in the beginning of 2014, before the change in access rules occurred (see Figure Ex-15). Thus the increase in crashes could simply be a continuation of that trend. In addition, the growth in crashes was too small and too variable from month to month to be statistically significant, given the variability in the number of crashes occurring over time.

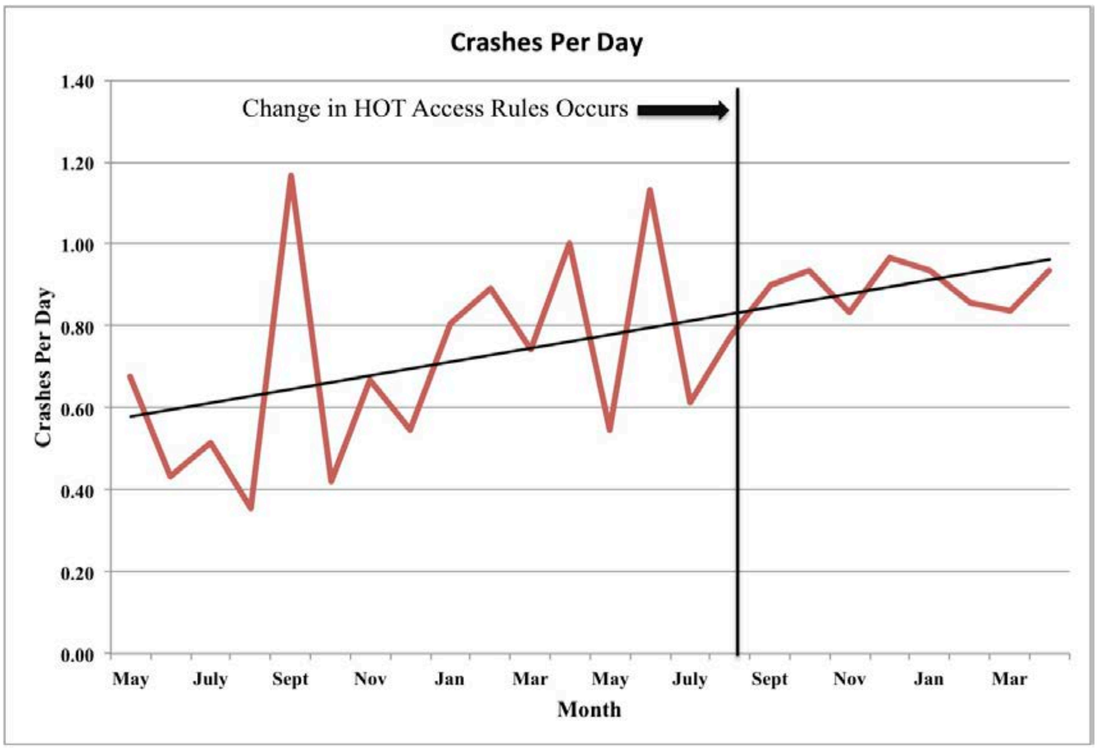


Figure Ex-15: Comparison of Crashes Each Month with Average Monthly Weekday Volume

There was no significant change in the severity of collisions that occurred during the Before and After periods. While the After time period had slightly more crashes than the Before period, those crashes were not significantly different than in the Before period. The fraction of crashes that involved injuries was remarkably consistent between the Before and After periods. Although in the northbound direction of travel crashes in the After period increased from 103 to 115, the fraction of crashes that involved injuries was unchanged at 33.0 percent. In the southbound direction, the number of crashes increased in the After period from 86 to 119. The fraction of crashes that involved injuries grew very slightly from 41.9 percent to 42.9 percent. This change was not statistically significant. Therefore, it can be concluded that the change in HOT lane access rules did not increase the severity of crashes occurring in the corridor. Neither the northbound or southbound direction of travel experienced a fatal collision within the boundaries of the HOT facility during either the Before or After time period.

TRANSIT IMPACTS

Sound Transit is the only agency that operates buses within the SR 167 HOT lane, and Pierce Transit physically operates those buses under contract to Sound Transit. According to ST staff, no direct changes in service reliability were associated with the change in access rules, but the two ST routes that use SR 167 both also use I-405 to Bellevue, which can experience very congested HOV lanes, and thus any improvements occurring on SR 167 could easily have been lost on I-405. Vehicle operators did comment that the improved ability to access the HOT lane helped keep them on schedule.

A request was made to Pierce Transit and Sound Transit staff to gather information on whether the change in access rules was a positive or negative event. Responses were obtained from operators, supervisors and safety and training office staff. All of those responses were positive. The two most descriptive responses received were as follows:

> "*It is great. Every driver I speak to really likes having these HOT lanes. We are looking forward to them expanding*."
>
> "*I like the ability for the coaches to enter and exit the HOT lanes on SR 167. We were getting complaints from the passengers if a driver could not make it over to the HOT lanes in time. And they would complain if the driver crossed the lanes. And they would complain if they didn't. So, I think the ability to get in and out is much better and it's faster. You might think that it is more dangerous with this ability but it is the same as I-5. Operators just need to be diligent and pay attention to what others are doing*."

CHAPTER 1: INTRODUCTION

In August 2014, WSDOT changed the access controls for the HOT lane on State Route (SR) 167. The lanes were initially designed and implemented to allow access at only six points northbound and four points southbound, as illustrated in Figure 1-1. Limiting HOT lanes access is the most common HOT lane design in the United States. Among other attributes, this design is intended to reduce the occurrence of merge disruptions to just a few locations in the corridor and to provide better payment control (lowering toll avoidance and the number of gantries needed), as well as to decrease friction between the HOT lane and neighboring GP lanes. However, since August 23, 2014, free access has been allowed into and out of the HOT lane.

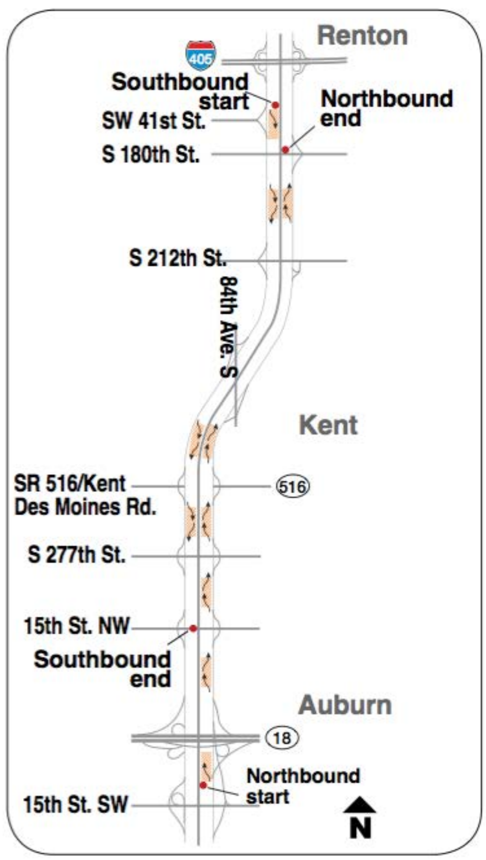


Figure 1-1: Map of SR 167 HOT Lanes and Merge/Diverge Points before August 2014

The change was made because the original controlled access design created some operational limitations. The most significant limitation was that the restricted number of entry/exit points could make it difficult for vehicles to efficiently access the HOT lane from their freeway on-ramps and efficiently exit to their desired off-ramps. This access problem was particularly an issue for transit vehicles, which had difficulty weaving across congested freeway lanes in the space allowed between their on-ramps and the designated entry points. Transit agencies expressed concerns to WSDOT that the reliability of their trips were affected because buses were unable to consistently use their desired HOT lane access points. When this occurred, it meant the buses spent considerable time stuck in traffic congestion along with the general purpose traffic until the next access point was reached. WSDOT also learned from an ongoing survey of corridor users that 40 percent of survey respondents were dissatisfied with the initial access restrictions.

WSDOT changed the SR 167 HOT lane access policy from “designated access” to “continuous access” partly to respond to these concerns, and partly to examine whether fully accessible HOT lanes function effectively enough to be considered a design option on other corridors.

This study was then performed to determine the effects of allowing continuous access to HOT lanes. The remainder of this report presents the findings of the analysis of whether any changes occurred in the following areas:

- Customer attitudes
- Performance of the corridor, including both the HOT lanes and the parallel general purpose (GP) lanes, and encompassing
    - the volume of use,
    - the mean travel times and
    - the reliability of that travel time.
- Revenue collection
- Toll evasion
- Collision frequency and severity
- Transit operations.

Each of these topics is covered in a separate chapter of this report.

CHAPTER 2: CUSTOMER ATTITUDES

WSDOT conducted an electronic survey at the beginning of December 2014 to obtain customer feedback on the change in HOT operating rules. The survey was sent to all Good To Go! customers who had paid to use the SR 167 HOT lanes at least once during the previous eight months. The study sent 44,276 e-mail requests. Of the individuals who received the e-mail, 46 percent opened it, and of those individuals, 9 percent clicked on the survey link. The vast majority of those individuals filled out at least a portion of the survey, which had 3,932 responses. Roughly one tenth of those respondents answered only one question: whether the respondent was aware of the change in access. The remainder of the respondents completed most of the survey.

A summary of the survey responses is shown in Table 2-1. This table shows the responses for just the survey respondents—69 percent—who reported being aware of the change from limited access to open access, as these individuals were more likely to be able to describe the *change* in performance due to the new operating rules. However, these same statistics were computed for all survey respondents. A comparison showed that in general, respondents who were either not aware or unsure of the change in access rules were far more likely to answer "no opinion" or to leave a question blank. However, when they did answer a question, they almost always answered positively (agree or strongly agree) or negatively (disagree or strongly disagree) in the same basic proportions as respondents who were aware of the change. This means that no significant change in survey conclusions would occur if the all survey responses were reported or if only responses from those who were aware of the change were reported.

Table 2-1: Summary of Public Attitude Survey Results

	Agree	Agree strongly	Disagree	Disagree strongly	I'm not sure/I don't know	No opinion
Were you aware of this change in the way travelers can access the SR 167 HOT lanes?	33%	52%	15%			
The change in access makes it more convenient for me to use the HOT lane.	29%	49%	5%	5%	1%	11%
SR 167 is not as safe now, because vehicles enter or leave the HOT lane unexpectedly, instead of only at designated locations.	14%	14%	30%	24%	2%	16%
The HOT lane is a better value for me because of the change in HOT lane access.	22%	25%	12%	10%	3%	28%
The HOT lane is more expensive to use now than it used to be.	14%	22%	13%	5%	13%	33%
It is easier to use the HOT lane because of the change in access.	36%	42%	5%	4%	1%	12%
The HOT lane has slowed down because of the change in access.	13%	8%	27%	10%	10%	31%
Traffic in the HOT lane moves more smoothly because of the change in access.	21%	12%	16%	8%	8%	34%
Because of the change in access, I observe vehicles weaving back and forth between the HOT lane and the adjacent general-purpose lane more often, for example to pass slower cars.	26%	18%	22%	7%	7%	21%
The change in access makes the HOT lane more useful to me, because now I can enter and exit the HOT lane when and where it makes the most sense for me.	32%	41%	7%	5%	1%	14%
Since the change in access, I observe HOT lane users temporarily leaving the HOT lane more often, to avoid paying the toll.	12%	10%	23%	10%	14%	31%
SR 167 is safer now, because drivers have more freedom to get in and out of the HOT lane when it is safe to do so.	24%	19%	13%	10%	5%	29%

<u>OVERALL PERSPECTIVE OF THE ACCESS CHANGE</u>

Perhaps the most important question related to drivers' perspective was whether the respondent wanted WSDOT to keep the new access rules or revert to the old rules. **Of the respondents who were aware of the change, 65 percent said they preferred the open access rules. 18 percent preferred the old rules, and the remaining 17 percent had no opinion or did not answer the question.** Among all survey responses, support for the new rules was to 60 percent, opposition to the new rules was 16 percent, and "no preference" and "no answer" were 23 percent. No significant change in attitude was found for men versus women, or for respondents who reported being less than 45 versus older than 45.

Another response that was also very clear was that many respondents noticed the increase in toll prices that occurred after access was opened. The reason that prices rose so much is not clear, but WSDOT was aware of the issue and eventually changed the toll rate algorithm to allow the price to drop more quickly once congestion on the HOT lane had eased. But at the time the survey was conducted, HOT prices were still frequently quite high in comparison to before the HOT lane access rules were eased. **Of respondents aware of the change, 36 percent stated that the HOT lane was more expensive after the change than before it**. Just as importantly, of people who thought the cost had increased, twice the number felt strongly about that (strongly agree) than felt less strongly (agree). Only 22 percent <u>disagreed</u> with the statement that the HOT lane was more expensive.

Interestingly, despite considering the HOT lane more expensive, **46 percent of the respondents aware of the access rule change felt that the HOT lane was now a better value.** Only 22 percent of that group disagreed with the statement that the HOT lane was a better value. However, if the respondents answered that the HOT lane was more expensive, their opinion about the value of the HOT lane became less enthusiastic. Respondents who thought the lane had become more expensive split very evenly concerning whether the HOT lanes had improved in value (39 percent agreed and 38 percent disagreed). In addition, both the "agree" and "disagree" responses split very evenly between the moderate "agree/disagree" statement and the stronger "strongly agree/strongly disagree" statement. (23 percent expressed no opinion on the value question.) No significant differences were found between men and women and between older and younger respondents.

Of the “aware” respondents, 78 percent said they believed that the new rules made the HOT lane more useful to them. Only 10 percent disagreed with that statement. 74 percent of all respondents felt the HOT lane was more useful. As before, many of the “not aware” respondents had no opinion to express on this question, so the percentage of both favorable and unfavorable opinions dropped while the fraction of “no opinion” responses increased if all responses were included.

The HOT lane was likely perceived as being more “useful” to users in part because they now considered the HOT lane to be easier to use. **Over 78 percent of the “aware” respondents said that the HOT lane was easier to use because of the change in access rules.** Only 9 percent disagreed that the lanes were easier to use. No real difference in these attitudes was found by either age or gender. Similarly, 78 percent of “aware” respondents (and 74 percent of all respondents) felt that the HOT lanes were more convenient as a result of the access changes.

PERCEPTION OF SAFETY

When asked whether they felt that the corridor was more dangerous, 54 percent of those who were aware of the change in operating rules disagreed that the roadway was more dangerous. That is, the majority of respondents felt the roadway was safer. Only 27 percent said the corridor was less safe. (The remaining 19 percent had no opinion.) Respondents who were unaware of the rules change were slightly more in favor of the safety of the new operational rules. Thus **54 percent felt the new access rules allowed the corridor to operate in a safer manner.** No significant difference was noted between men and women. If age was used (over 45 versus under 45), the percentage of people who looked favorably on the safety of the access changes increased slightly in both groups. This was due primarily to the fact that people who did not answer the age question (and therefore were dropped from the computations) often did not express an opinion about changes in safety. Thus, the percentage of “the road is safer” answers increased mostly because the percentage of “no opinion” responses decreased.

A second safety question was whether the HOT lane was safer because of the increased freedom to exit the lane. Of the “aware” respondents, 43 percent agreed that SR 167 was safer because of the increase in freedom, and 23 percent disagreed with that statement. The remaining 34 percent did not express an opinion. Reporting by age group slightly increased the fraction of both positive and negative responses at the expense of "no opinion" responses but did not alter the roughly 2 to 1 ratio in favor of the new operating rules.

At the same time that respondents were indicating that they felt that the corridor operated more safely, they also indicated that weaving into and out of the HOT lane had increased as a result of the access rule changes. In numerous comments, the ability to pass slower moving vehicles was mentioned. These comments were both positive (e.g., "I can use the GP lanes to pass slow moving vehicles in the HOT lane" and "I can move out of the HOT lane to let a speeding vehicle pass me, and then move back into the HOT lane") and negative (e.g., "Many cars use the HOT lane as a passing lane" and "Slow moving cars jump unexpectedly into the fast HOT lane. This is a hazard!"). Of the "aware" respondents, 44 percent agreed that they had observed an increase in weaving between the HOT lane and the general purpose lanes; 29 percent disagreed with this statement. Among all responses, 39 percent observed more weaving, 26 percent did not, and 36 percent had no opinion.

TOLL AVOIDANCE

One concern with the new access rules is that single occupant vehicles will avoid paying the toll by simply changing lanes to go around the toll gantry, and then re-enter the HOT lane once they have passed the gantry. When asked about whether this was occurring more frequently as a result of the new access rules, **34 percent of the "aware" respondents disagreed that more toll evasion was occurring**. 24 percent agreed that more toll evasion was taking place, and 42 percent had no opinion about changes in toll avoidance. Among all responses, 27 percent disagreed and 20 percent agreed with the statement that more toll evasion was occurring as a result of the new access rules.

FACILITY PERFORMANCE

Survey respondents' attitudes toward HOT lane performance mirrored their attitudes toward toll avoidance. Of "aware" respondents, 22 percent thought that the HOT lane had slowed as a result of the new access rules; 37 percent disagreed with the statement that the HOT lane had slowed, and over 34 percent had no opinion or were unsure. Among all responses, 31 percent thought the HOT lane had not slowed, 19 percent agreed that it had slowed, and 50 percent did not express an opinion.

The respondents also had mixed opinions about whether the HOT lane moved more smoothly as a result of vehicles having the ability to move into and out of it at will. Of the people familiar with the change, 34 percent agreed that the HOT lane operated more smoothly, but 24 percent disagreed.

USE OF THE HOT FACILITY

Of the "aware" respondents, 37 percent used the facility more than twice a week. Slightly less than half of those (19 percent) used the HOT facility more than four times a week, and another 19 percent used it less than once per month. Among all survey responses, 28 percent used the facility more than twice a week, 14 percent used it more than four times per week, and 26 percent used it less than once per month.

84 percent of the survey respondents who were aware of the access rule change reported having used the HOT facility at least once between the time the access rules changed and when they took the survey in early December. Another 5 percent of respondents had not used the facility since the access rules changed. Among all respondents, 72 percent reported having used the HOT lane both before and after the rule change, and only 8 percent had not used the facility since the rule change.

Of HOT lane users who were aware of the changes, 62 percent had not changed their usage patterns. 20 percent stated that they used the HOT lane more often, specifically because of the improved access changes, and 5 percent stated that they used the HOT lane less as a result of the access rule changes.

Over 60 percent of the survey respondents stated that they typically used the HOT lane as single occupancy, paying customers. Another 31 percent stated that they typically used the HOT lane as a carpool or vanpool, 1 percent typically rode a motorcycle, and less than 0.1 percent took the bus. (These percentages were greatly influenced by the way the survey was conducted. Because the survey was sent to electronic tag owners, carpool customers who did not have a tag—because a tag is not needed on SR 167 if the vehicle is a carpool—did not receive a survey. Therefore carpool users were under-represented in the survey responses.)

Not surprisingly, as a result of the under-representation of carpooling activity, the survey responses to the question about how the new access rules had changed carpool use showed relatively little impact. Only 4 percent of "aware" respondents had increased carpool use on the

HOT lane. Another 1 percent had decreased their carpooling activities in the HOT lane, and 49 percent did not carpool in the facility at all. 35 percent reported that the change did not affect their carpool activity in the corridor.

MISCELLANEOUS DEMOGRAPHICS

Not surprisingly, the age distribution of the survey respondents skewed toward the working demographic. That is, it contained relatively few younger drivers. The largest ten-year cohorts fell between 45 and 64 years (see Table 2-2).

Table 2-2: Survey Age Demographics

Age of Respondent	Percentage of Responses
15 – 17 years	0.0%
18 – 24 years	1.1%
25 – 34 years	10.8%
35 - 44 years	16.6%
45 - 54 years	22.1%
55 - 64 years	22.3%
65+ years	12.5%
left blank	14.8%

The genders of the survey respondents are shown in Table 2-3

Table 2-3: Number of Survey Responses by Gender

Gender	Percentage of Responses
Female	32.7%
Male	52.1%
left blank	15.1%

CHAPTER 3: PERFORMANCE OF THE FACILITY

This section discusses the overall performance of the SR 167 corridor. It compares performance of both the HOT lane and the parallel GP lanes before and after the change in HOT lane access rules. It examines the volumes of use and the travel times that road users experienced. Aggregate statistics are used to describe overall corridor performance, but the distribution of the corridor's performance is also examined to help explain the observed trends.

GENERAL ANALYTICAL APPROACH

Volume and roadway speed data were obtained from two data sources. The primary data source for roadway performance was the WSDOT's NW Region traffic surveillance, control, and monitoring system. This system uses fixed point, magnetic inductance loop detectors to collect volume and vehicle speed information. These detectors are located roughly every half-mile along the corridor. In addition, the project team used electronic transaction records for the corridor to examine travel patterns (when and where paying customers entered the HOT lane) to determine changes in HOT lane use. Using these data sources, the project team computed aggregate statistics for "Before" and "After" time periods. For roadway performance analyses, only weekday performance was examined.

Initially, the Before time period was defined as September 2013 through March 2014, and the After period was defined to include September 2014 through March 2015. The After period represented the first seven full months that continuous HOT lane access was in effect, while the Before period consisted of the same seven months in the 12-month period preceding the start of continuous access, when the HOT lane could be legally entered only via a limited number of access points. This year-over-year comparison approach was used to minimize the influence of any seasonal performance variations on the comparison. The results observed using these initial Before and After periods suggested that performance in the corridor was continuing to change. Therefore, as a small supplement to the initial project, an additional five months of Before and After performance data were examined. This secondary analysis compared data for April through August 2014 against data from April to August 2015.

Peak periods were typically defined as 6:00-9:00 AM and 3:00-7:00 PM. For some analyses a one-hour "shoulder" was added on each side of those peak periods to capture shifting peak period travel, with the result that some analyses had overall peak periods of 5:00-10:00 AM and 2:00-8:00 PM.

The primary roadway performance evaluation metrics used were

- the volume of vehicles using the corridor in both HOT and general purpose lanes
- the travel times and travel time reliability of both the HOT and general purpose lanes
- the friction relationship between the HOT and GP lanes.

Where appropriate, additional measures, such as the frequency and duration of congestion formation in the corridor, are also presented.

TRAFFIC VOLUMES

Using data from the NW Region's loop system, the project team computed traffic volume metrics for every 5 minutes of each weekday for every instrumented location along the SR 167 HOT lane corridor for both the HOT lane and the GP lanes. This included 21 northbound and 17 southbound sensor locations. Summaries of those data were made for both the Before and After time periods. The 5-minute data were then used to estimate average peak period volumes for each location. The data were also evaluated for time of day variations for the average weekday, for each location.

Summary Traffic Volume Findings

The before and after analysis showed that for nearly every location of the HOT lane, the average weekday peak period volumes were higher in the After period. Traffic volumes rose between 1 to 22 percent in the peak period. 24-hour HOT lane volumes were always higher, by a similar range.

For the GP lanes, results were more mixed. In the peak period, 18 locations had volumes that were lower by 1 to 7 percent, and 16 locations experienced volume increases of 0 to 4 percent. Average weekday GP lane volumes were always higher, by up to 5 percent.

Total volumes (the combination of both HOT and GP volumes) increased at almost all locations throughout the corridor. The exceptions to the increased volume outcome were found at the very southern end of the corridor, where total northbound AM peak period and total southbound PM peak volumes decreased slightly.

Traffic volume changes from April to August 2015, when compared to the same months in 2014, were very similar to those observed during the first seven months after the access rule change in comparison to the year before.

Figures 3-1 through 3-8 illustrate the volume changes by milepost in the corridor during the first seven months of changed access rules for both for peak period, peak direction travel and for the average weekday (Monday-Friday). Additional figures have been placed in an appendix so that volume changes from April to August can be examined.

In the HOT lane, the largest peak period percentage increases in volume were at mileposts 14.76 NB (near SR 18) and mileposts 23.42 SB and 23.90 SB (increases of 21, 14, and 22 percent, respectively), while the largest percentage drops in peak period volume occurred in the northbound GP lanes at mileposts 14.76, 24.61, and 25.07 (decreases of 6, 6, and 7 percent, respectively).

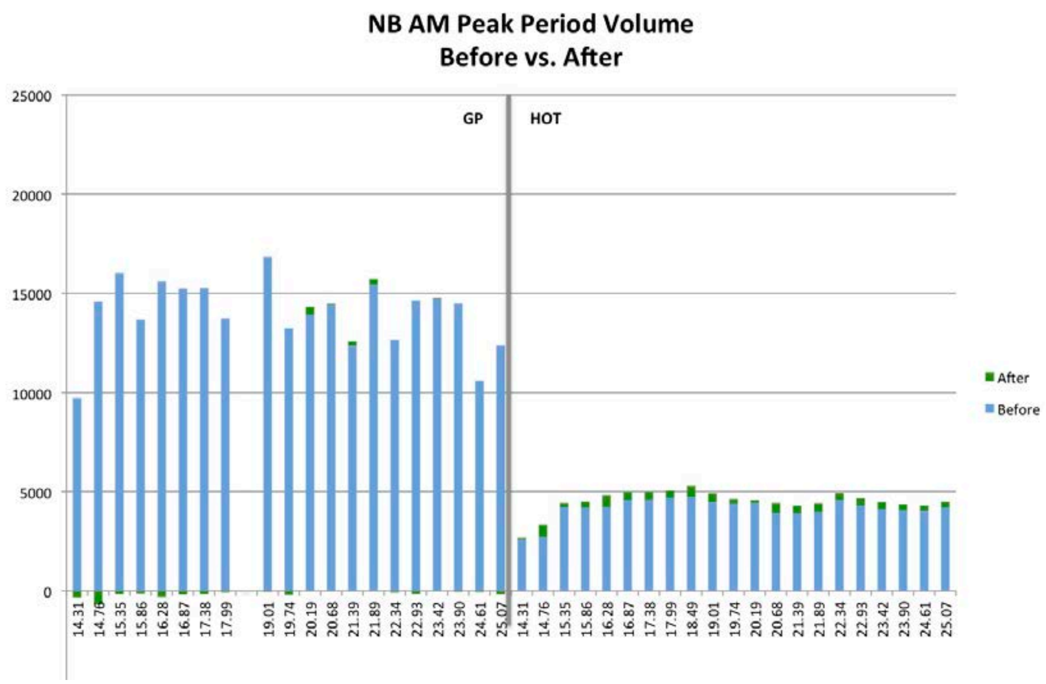


Figure 3-1: Northbound AM Peak Period Volumes Before and After Access Rule Changes

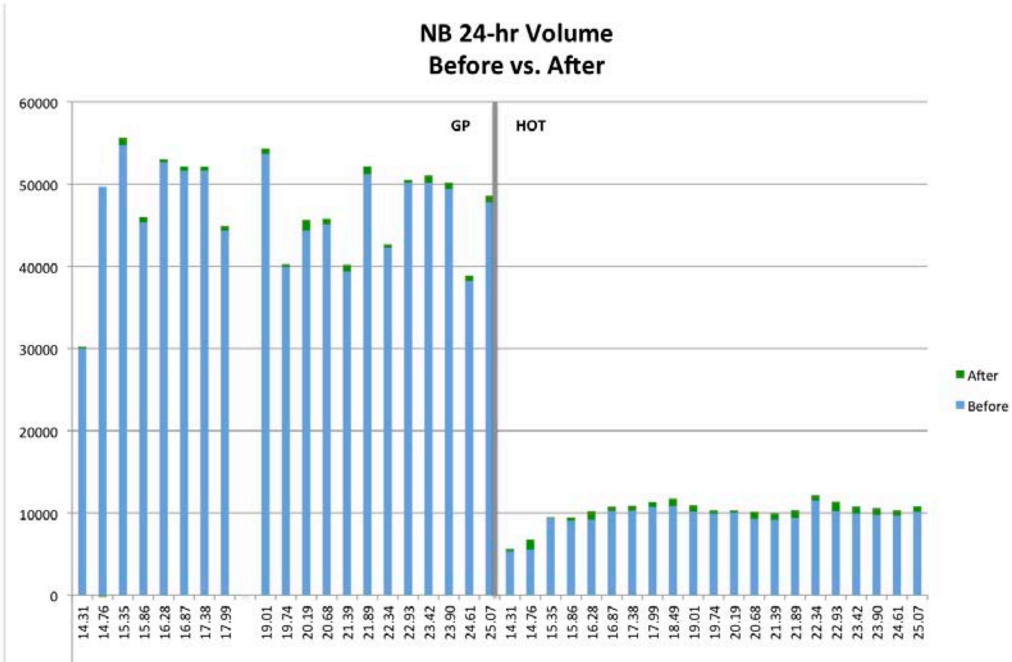


Figure 3-2: Northbound Daily Volumes Before and After Access Rule Changes

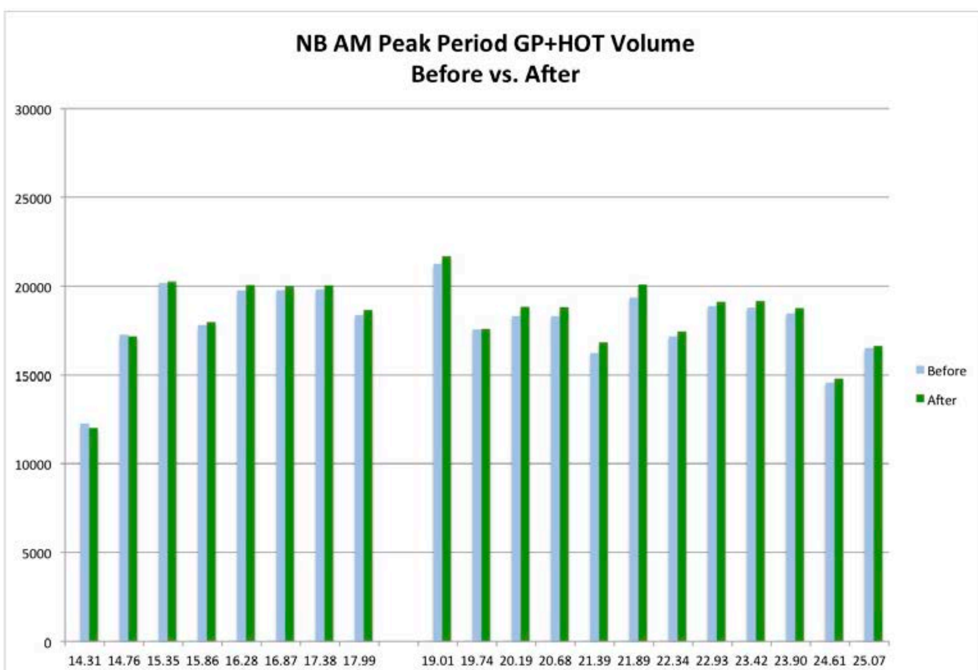


Figure 3-3: Combined Northbound AM Peak Period HOT and GP Traffic Volumes Before and After Access Rule Changes

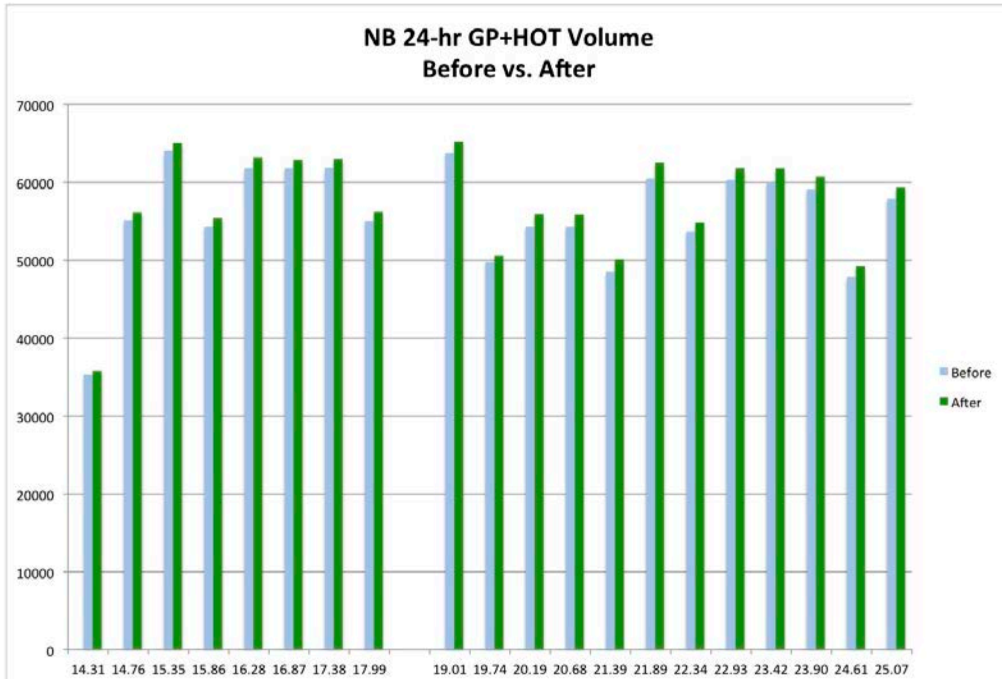


Figure 3-4: Combined 24-hour Weekday HOT and GP Traffic Volumes Before and After Access Rule Changes

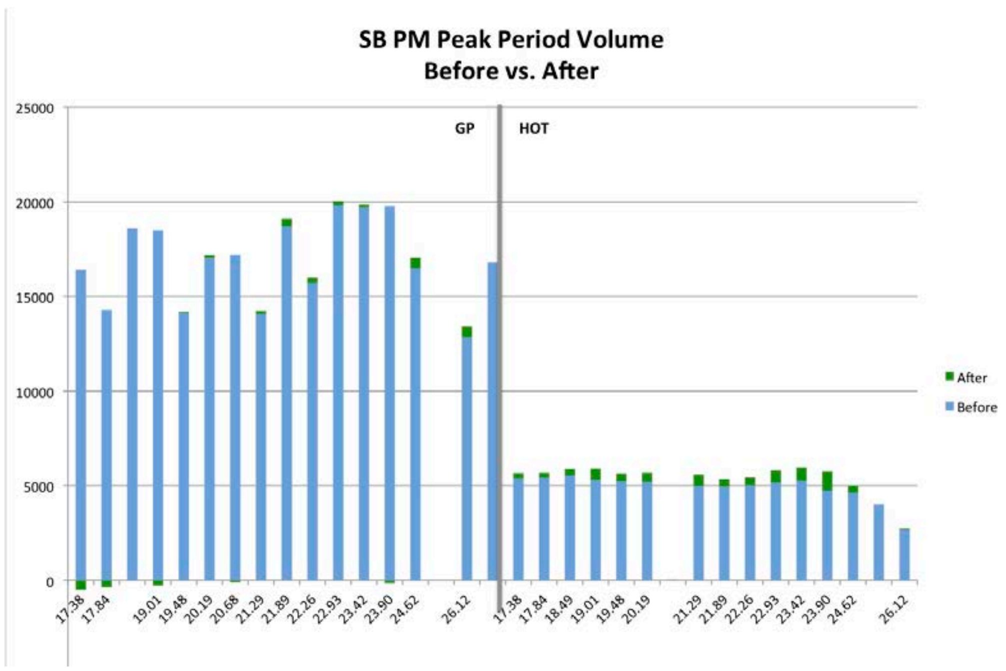


Figure 3-5: Southbound PM Peak Period HOT and GP Traffic Volumes Before and After Access Rule Changes

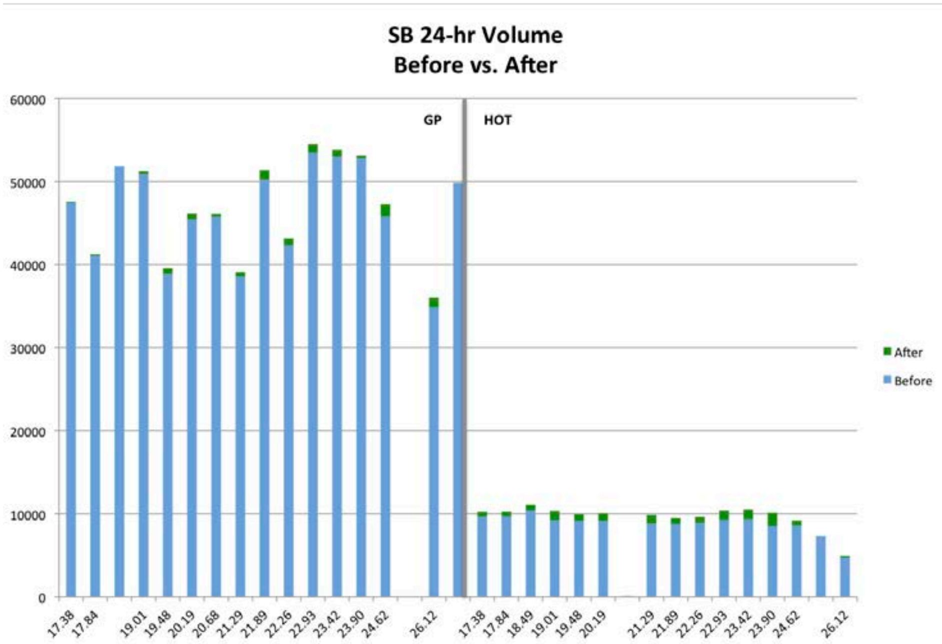


Figure 3-6: Southbound Weekday HOT and GP Traffic Volumes Before and After Access Rule Changes

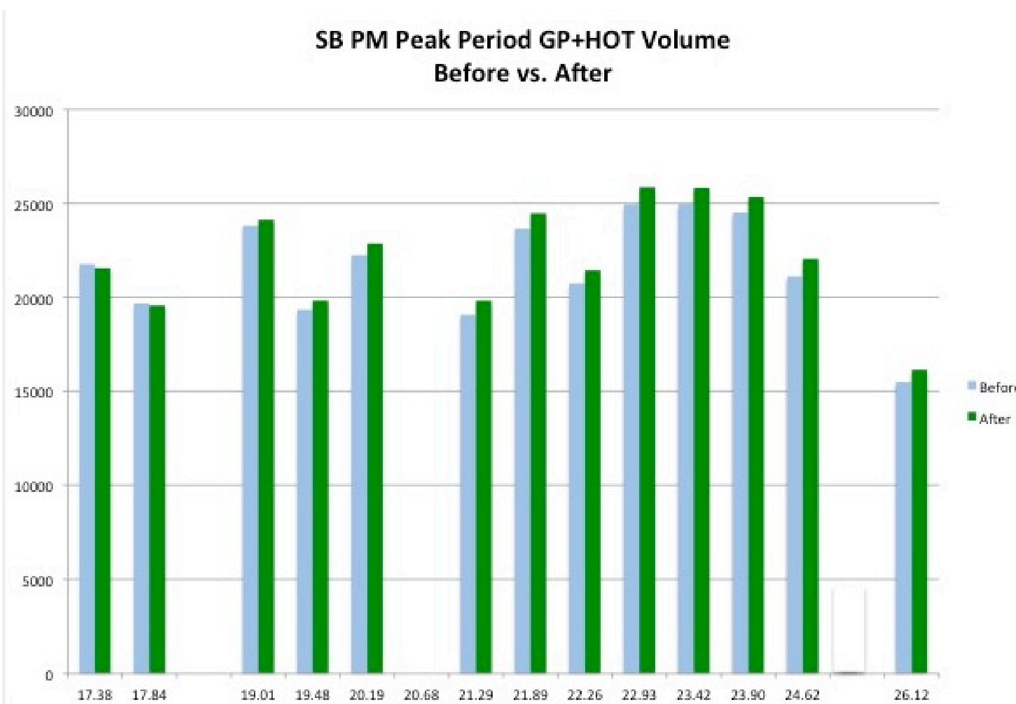


Figure 3-7: Southbound Combined Peak Period HOT and GP Traffic Volumes Before and After Access Rule Changes

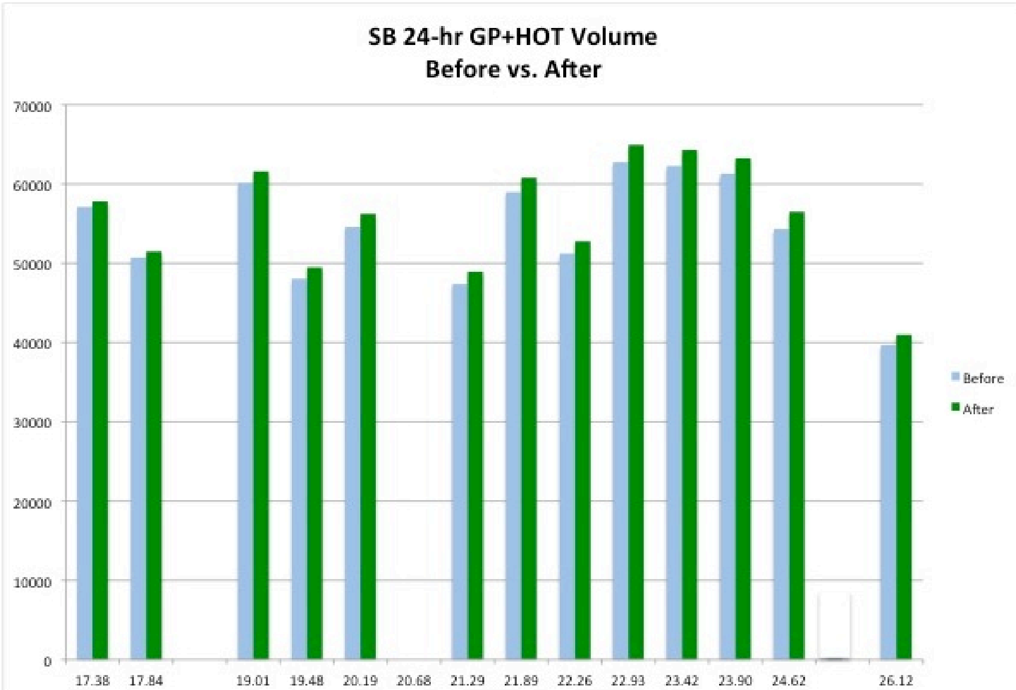


Figure 3-8: Southbound Combined HOT and GP Daily Traffic Volumes Before and After Access Rule Changes

Northbound Volume Details

Traffic volumes northbound at the various data collection locations along SR 167 follow a consistent weekday pattern. An example of the typical volume pattern is shown in Figure 3-9. That figure shows both general purpose and HOT lane traffic volumes. There are two general purpose lanes and one HOT lane at the location shown in Figure 3-9. This figure shows why it is necessary to examine the extended shoulders of the peak period, as traffic volumes in the corridor start increasing rapidly around 4:00 AM. Of particular interest is the early use pattern of the HOT lane (the red line in Figure 3-9), where a surge in traffic volume occurs before 5:00 AM, when the HOT tolls begin. Once toll collection starts, a drop in volume occurs, but HOT lane volumes increase again once more significant congestion begins forming in the general purpose lanes.

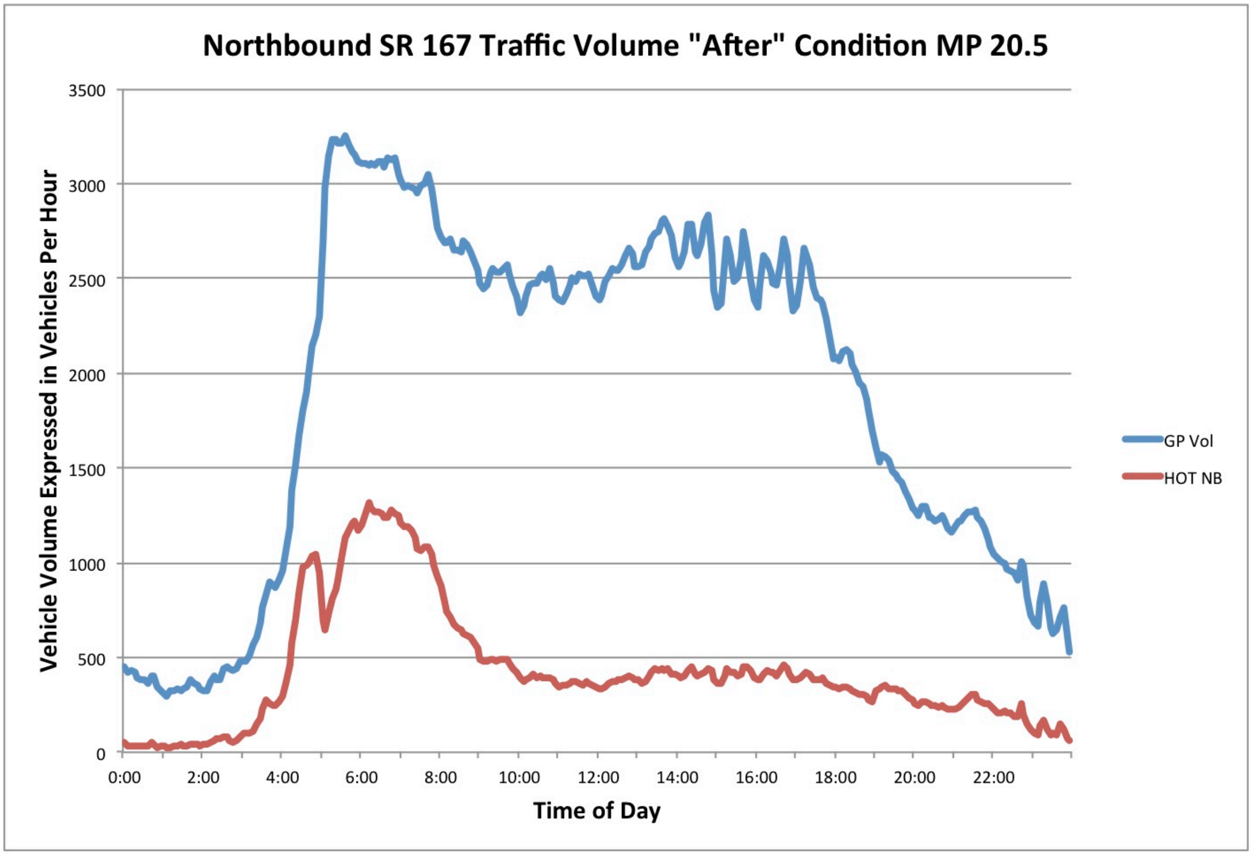


Figure 3-9: Typical Northbound Traffic Volume Patterns on SR 167

It is within the context of these traffic patterns that changes in traffic volumes caused by a combination of economic and population growth in the region and the change in HOT lane access rules occurred. Figure 3-10 illustrates the change in traffic volumes in the HOT lane from the seven-month Before period to the seven month After period. This figure shows the change in traffic volumes by time of day at three locations in the corridor: mileposts 15.5 near SR 18, milepost 20.5, which is just south of SR 516 in Kent, and milepost 24.5, which is a little south of Valley General hospital and SW 43rd St toward the northern end of the corridor. Figure 3-11 then illustrates the volume changes by time of day that occurred at those same locations in the GP lanes.

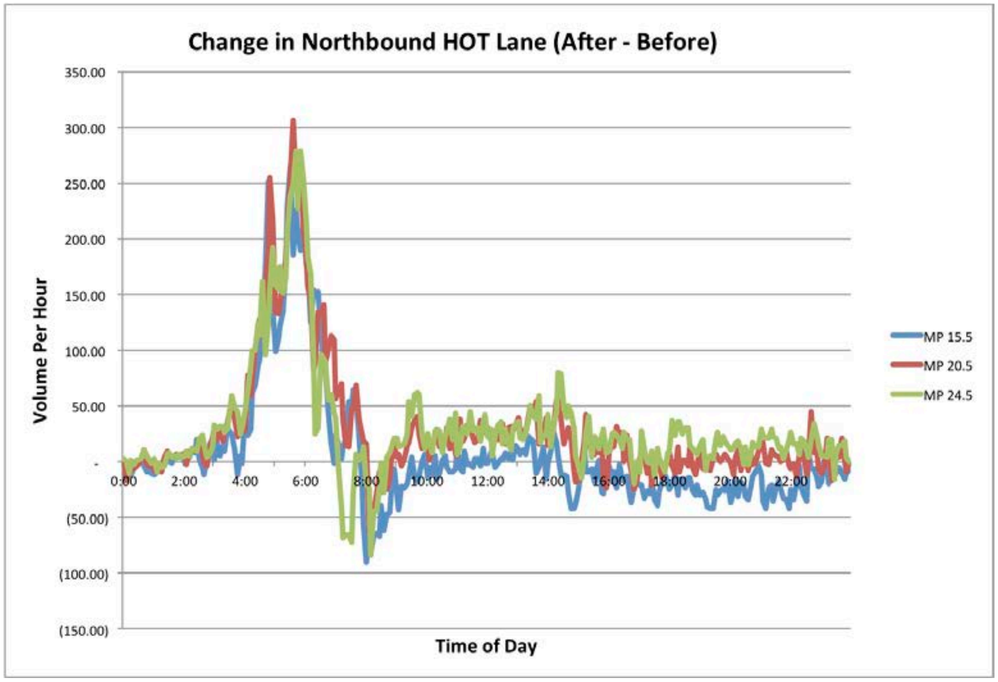


Figure 3-10: Example Northbound HOT Lane Volume Changes by Time of Day Before and After the Access Rule Changes

In Figure 3-10, it is apparent that while the absolute volume changed somewhat differently from one location to another, the basic pattern of volume change was similar at each of the three corridor locations illustrated. The After conditions show a marked increase in volume in comparison to the Before conditions starting at 4:00 AM. The increase in volume continued to growth until 5:00 AM, when the size of the increase dropped when tolling started, although the After traffic volumes were still higher than those observed in the Before period. By 8:00 AM—in the heart of the commute period—the HOT lane volumes observed in the After period fell below those observed in the Before period. The After period volumes then slowly increased relative to the Before volumes until around 10:00 AM, when they stabilized for the rest of the day.

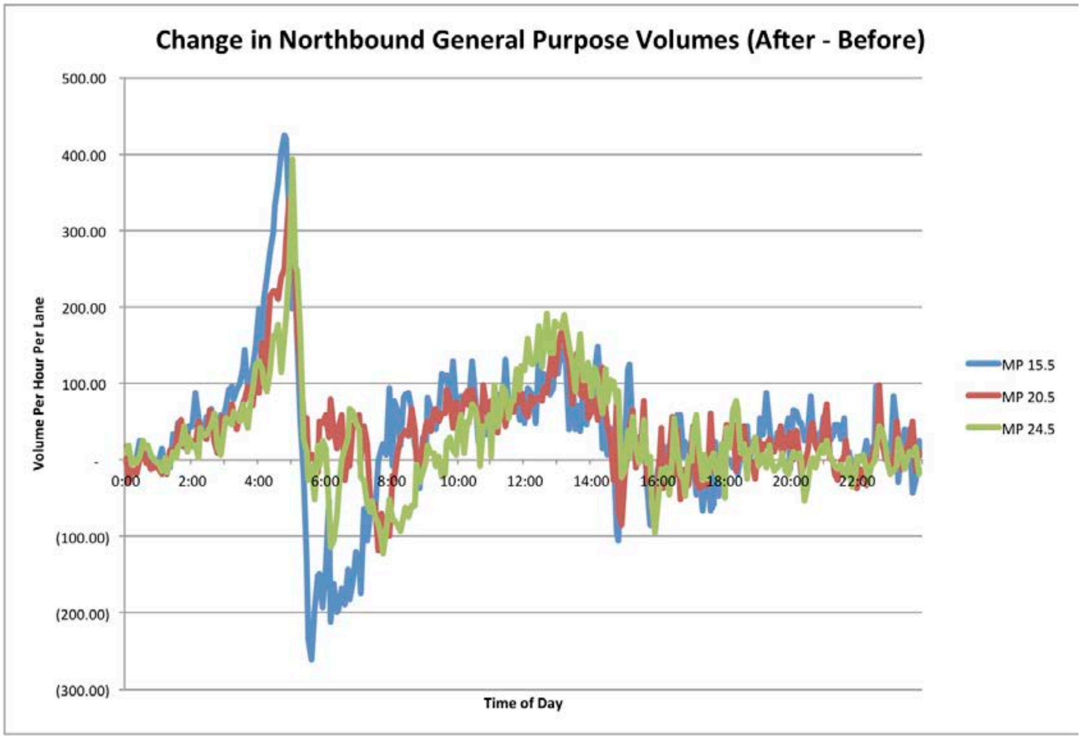


Figure 3-11: Example Northbound GP Lane Volume Changes by Time of Day Before and After the Access Rule Changes

Figure 3-11 shows that the change in general purpose lane volumes was even more dramatic at 5:00 AM, when tolling started, than it was in the HOT lane. The GP After condition showed a significant increase in GP lane volumes before 5:00 AM. Then at 5:00 AM, a dramatic decrease in volume at the southern-most location occurred for three hours, until 8:00 AM, when the After traffic volumes once again exceeded the volumes observed in the Before period. The two more northern locations in the corridor showed a slightly different pattern of changing volumes. Both of these locations experienced the early surge in traffic before 5:00 AM, followed by the decline in volume at 5:00 AM when tolling started. However, while the southern-most location showed volumes dropping well below those observed in the Before period between 6:00 and 8:00 AM, the two more northern count locations experienced traffic volumes similar to those observed in the Before period until after 7:00 AM, when volumes dipped. Volumes then rose at all three locations in the middle of the day, before returning to the same levels observed in the before period by 3:30 PM.

Southbound Travel Details

The southbound traffic volume patterns did not change as dramatically as the northbound travel patterns. The primary commute flow southbound occurs in the evening. Figure 3-12 illustrates the typical weekday traffic volume pattern on both the HOT and GP lanes after the HOT access rule change took place. Like travel northbound, it is possible to see a sizeable bump in HOT lane volume when tolling stops at 7:00 PM (19:00).

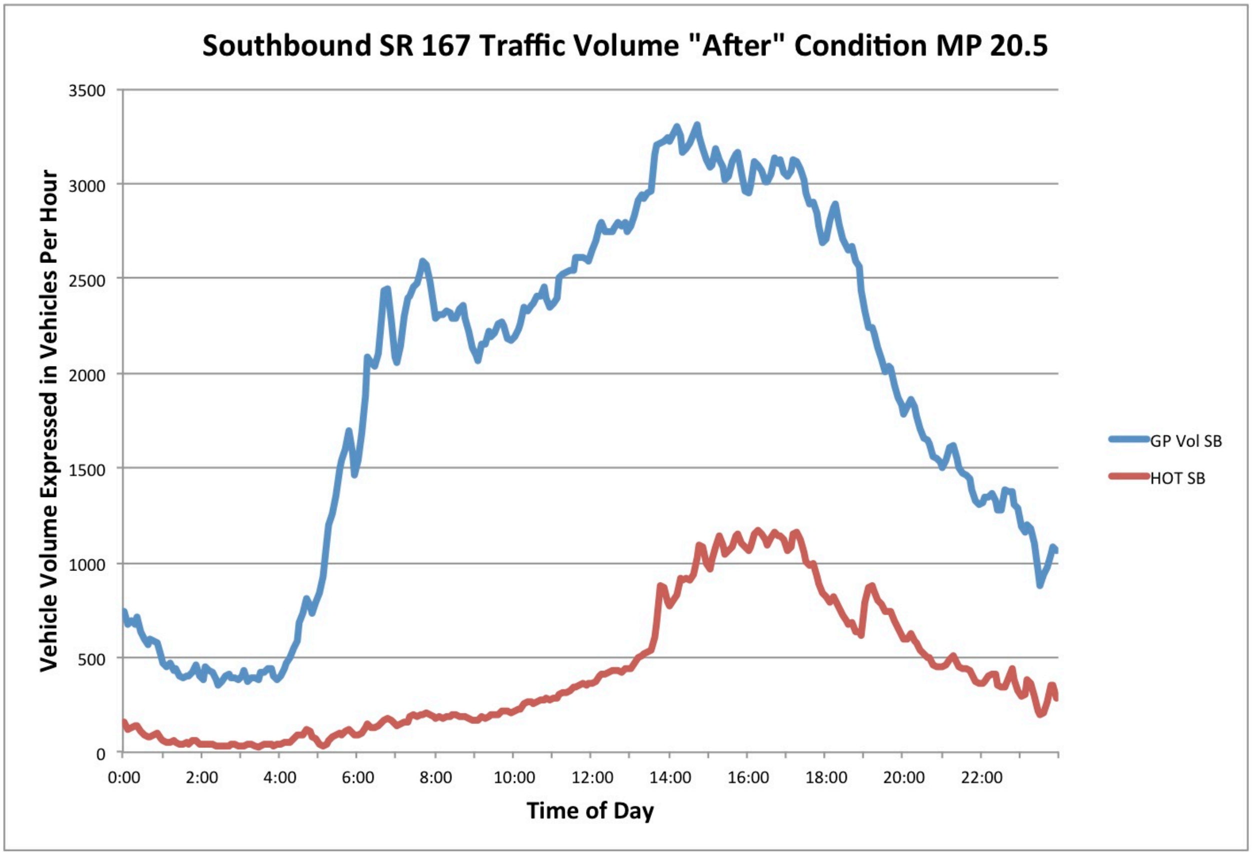


Figure 3-12: Typical Southbound Traffic Volume Patterns on SR 167

Figure 3- 13 shows the changes in traffic volumes on the southbound HOT lane. Unlike the northbound direction, there was no dramatic jump in Before/After traffic volume patterns at the time when tolling stopped (7:00 PM). One pattern that was consistent in both the northbound and southbound directions is that the southern-most data collection point experienced a slightly different shift in traffic volumes than the two more northern locations. For the southbound direction, the southern-most data collection location experienced a much smaller increase in traffic volume during the heart of the PM peak period than the two northern sections. This may

be because congestion in the corridor south of the HOT facility can limit the time savings obtained from the HOT lane, thus decreasing motorists' incentive to use the lane. As a result, a smaller number of drivers see the benefit of paying for the southbound trip in that location.

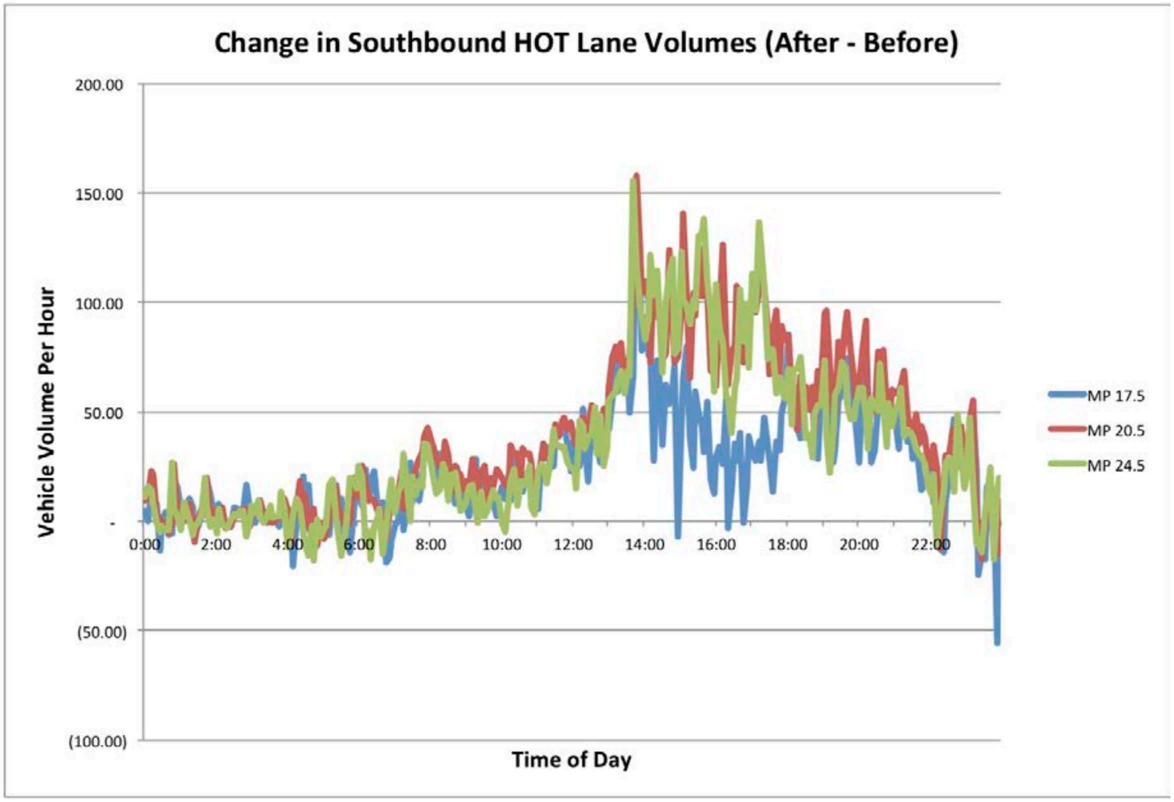


Figure 3-13: Example Southbound HOT Lane Volume Changes by Time of Day Before and After the Access Rule Changes

In the general purpose lanes (see Figure 3-14) the change in traffic volumes was fairly modest from the Before to the After period. There was moderate growth in the corridor (50 to 100 vehicles per hour) during most of the day. But during the peak period, the southern section of the corridor lost traffic volume (about 1,500 vehicles in the four-hour PM peak), while the northern end gained the same amount of traffic, and the volumes in the middle of the corridor remained fairly stable between the Before and After periods.

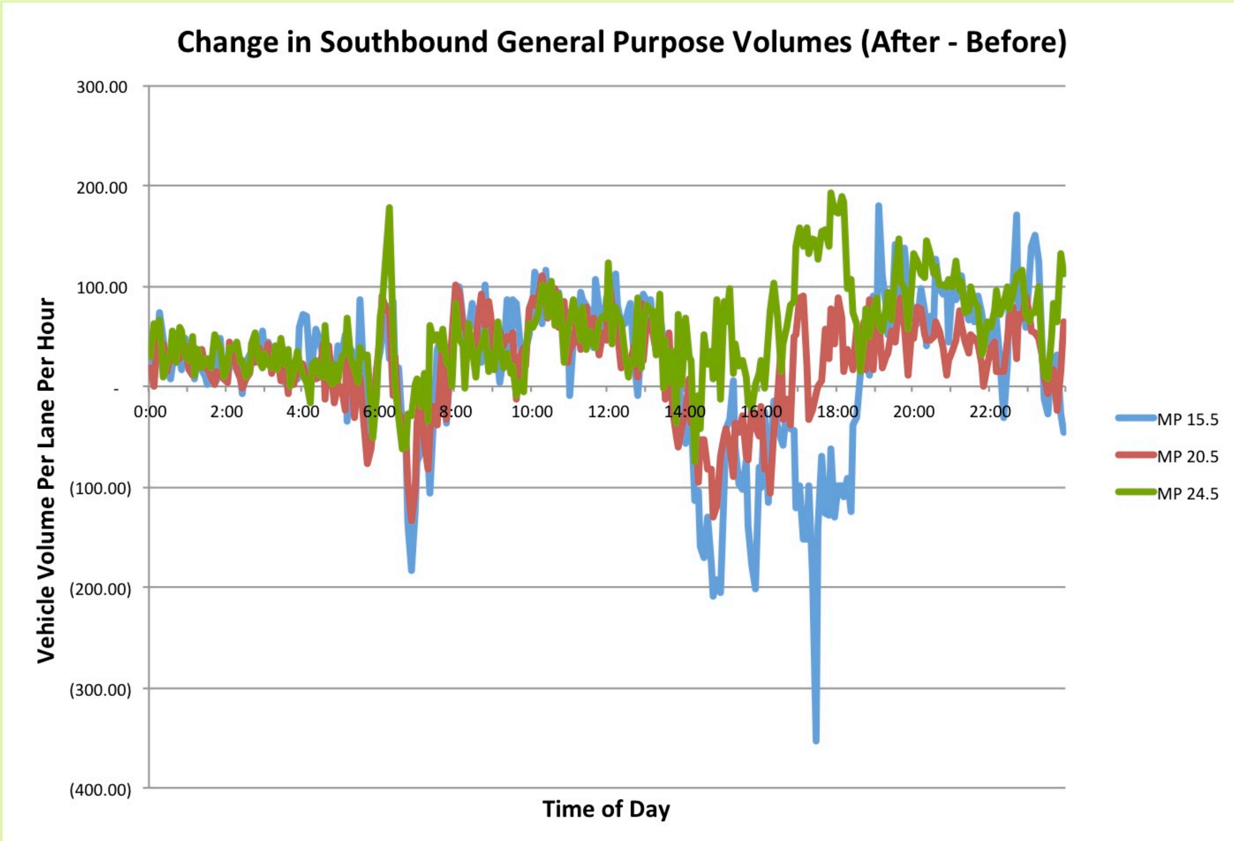


Figure 3-14: Example Southbound GP Lane Location Volume by Time of Day Before and After the Access Rule Changes

Figure 3-15 shows that part of the reason for the change in volumes may have been simply changes in the amount of congestion that formed and that congestion's effects on vehicle throughput. Figure 3-15 shows that the southern end of the southbound trip was congested more in the After period than it was during the Before period. That added congestion may have limited the GP traffic. At the same time, the northern end of the corridor experienced less congestion, and that decreased congestion may have allowed more vehicles to use the corridor.

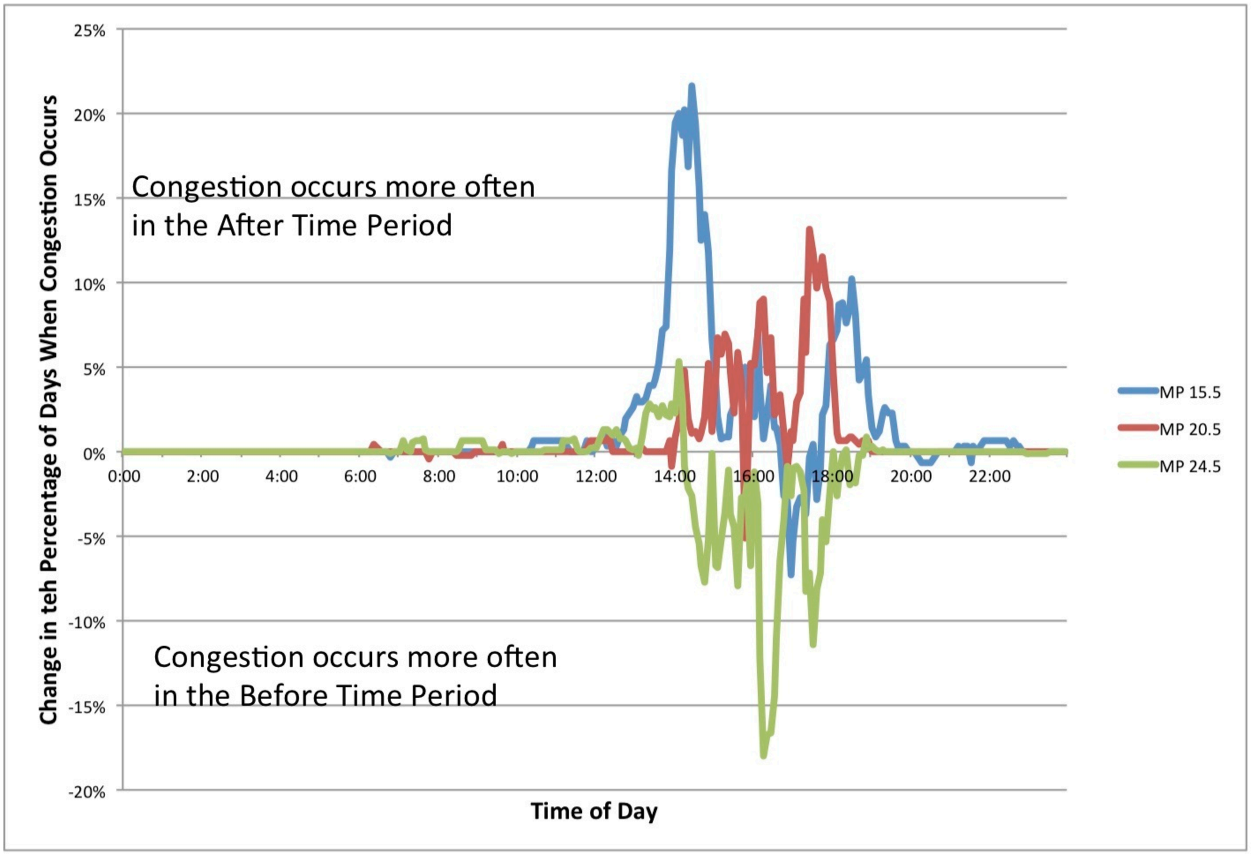


Figure 3-15: Change in the Frequency of Congestion Formation in the GP Lane Southbound: Before and After the Access Rule Changes

TRAVEL TIME AND RELIABILITY

Travel time and reliability in the SR 167 corridor generally worsened over time in the peak directions in the peak periods, the time periods when the HOT lane is meant to provide the most substantial travel benefits. Comparisons were made for three Before and After time periods: one (preliminary) comparison looked at the first two full months of operation of the new HOT lane access rules. The second (primary) comparison looked at the first seven months of operation of the new HOT lane access rules. The third (final) analysis examined the next five months of operation of the corridor. For the preliminary analysis, travel time and reliability for September and October 2013 were compared with travel time and reliability for September and October 2014. The primary before and after comparison used a Before period of September 2013 through March 2014 and an After period of September 2014 through March 2015. The final before and after comparison used a Before period of April 2014 through August 2014 and an After period of April 2015 through August 2015. A “control” time period was also examined, which compared January to June 2013 with January to June 2014 in order to understand background trends that were happening in the corridor before the change in HOT lane access rules.

Northbound Travel

Table 3-1 shows the mean travel times for the northbound (Auburn to Renton) trip for the AM peak period for both the GP and HOT lanes for all four analysis time periods. Mean travel times increased in the After period for all comparison periods for both the HOT and GP lanes. During the first seven months of operation, the peak mean 5-minute travel time grew in the dominant northbound AM direction for both GP (+2.1 minutes) and HOT lane travelers (+1.3 minutes), corresponding to a 2 mph drop in average GP trip speed and a 4 mph drop in average HOT lane trip speed. In the secondary, five-month analysis period, both HOT and GP lane performance improved marginally over times observed in the first seven months under the new rules. However, travel times were still slower than those observed before the introduction of the open access rules, indicating continuing year-over-year growth in congestion in the corridor. However that year-over-year growth is consistent with growth observed in the control period before implementation of the new access rules. That background congestion growth trend in the corridor prevents the project team from concluding whether the recent growth in congestion can be attributed to the change in access rules.

Table 3-1: Auburn to Renton Mean Travel Times in the AM Peak Period (minutes)

		Control	Sept - Oct	Sept - March	April - Sept
After HOT Access	HOT	12.3	17.2	15.5	15.4
Rule Change	GP	17.9	29.5	25.9	24.8
Before HOT Access	HOT	11.7	15.7	14.2	15.1
Rule Change	GP	17.1	26.6	23.8	23.6
Change	HOT	0.6	1.5	1.3	0.3
(After – Before)	GP	0.8	2.9	2.1	1.2

Figures 3-16 and 3-17 display a profile of weekday travel performance over an average 24-hour weekday, showing how average travel time (green), 95th percentile travel time (red), and frequency of congestion (blue) varied by the start time of the trip. Before (solid lines and blue histogram) vs. Primary After (data points shown as dots) data for each metric are displayed on the same graph to illustrate how those values changed at different times of the day. These comparisons show that in the Primary After period, the dominant northbound AM peak period GP trip had somewhat higher mean travel times in the initial "shoulder" of the AM peak period (beginning before 6:00 AM), while the associated HOT lane travel times were slightly higher starting at approximately 6:00 AM.

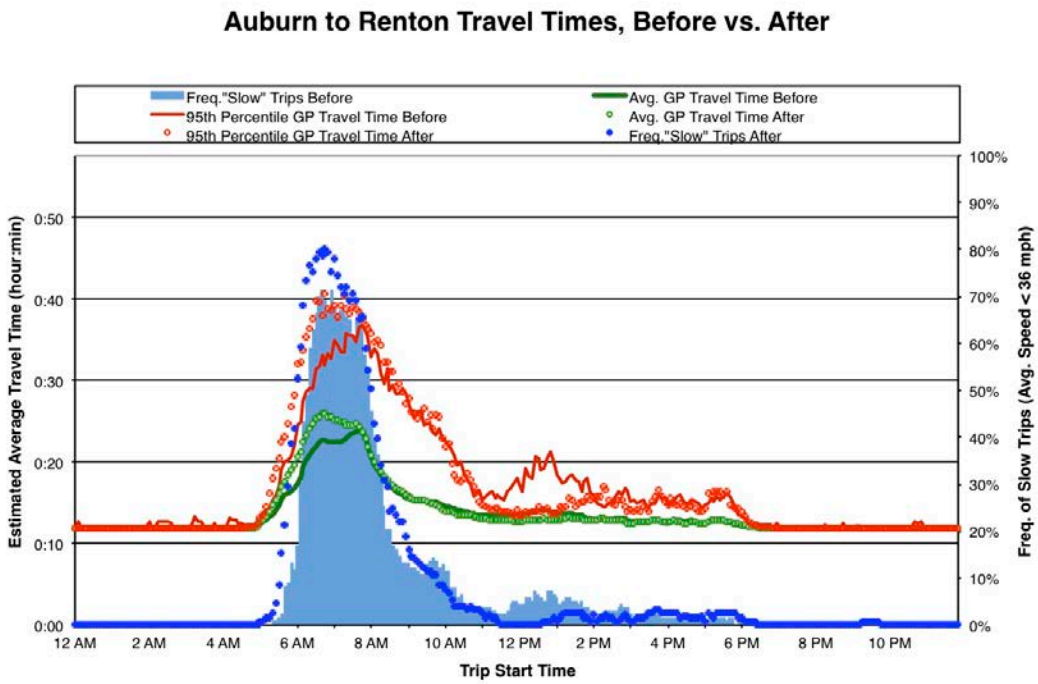


Figure 3-16: Average Weekday GP Lane 24-hour Travel Time Profile, Northbound Trip (Before vs. Primary After)

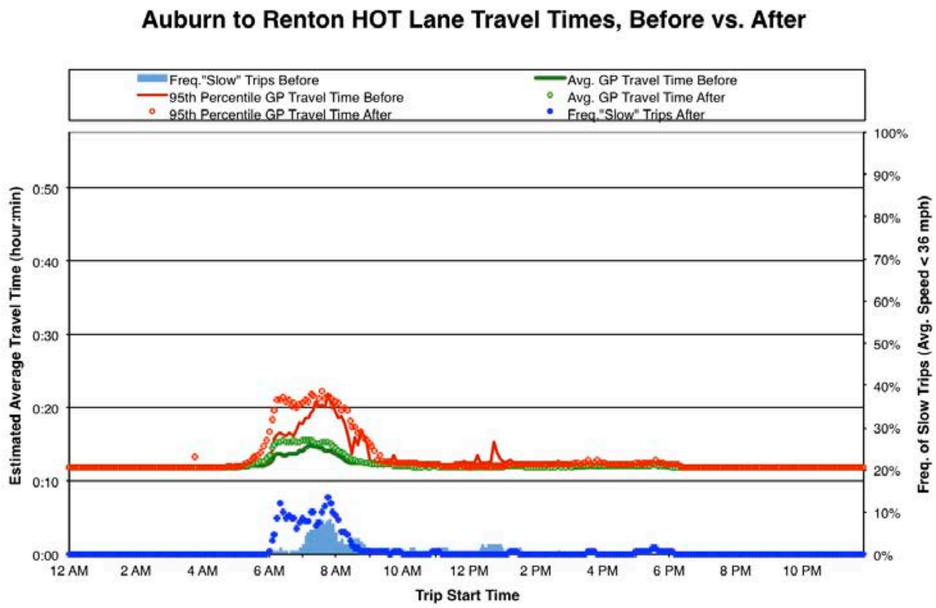


Figure 3-17. Average Weekday HOT Lane 24-hour Travel Time Profile, Northbound Trip (Before vs. Primary After)

At other times of the day (i.e., the non-dominant traffic movements) there was little to no change in travel time. The 95th percentile travel times were slightly higher for the AM northbound HOT lane trips, and more so for the AM northbound GP trips. (Note that 95th percentile values can be more susceptible than mean travel times to a relatively few days of outlier performance, so larger changes in the high Nth percentile values are not necessarily as easy to interpret as changes in mean travel times.)

Figure 3-18 shows the 50th percentile travel times for the general purpose lanes for October and November in 2013 and 2014 in order to give a sense of how routine travel times may vary from month to month. Figure 3-19 shows the change in 50th percentile general purpose travel times for December and February for this same trip. The 50th percentile travel time was selected for these graphics instead of the mean travel time because it is less susceptible to influence by a few very bad travel days. Only two months are illustrated in each graph so that it is possible to compare the Before and After travel time patterns on a monthly basis. In these graphics, the Before period is always the thin line, while the After period is a thick dotted line. In both graphics it is possible to see that congestion consistently grew in the After period relative to the Before period, although the changes in October are generally much larger than in November.

December generally showed more growth in congestion, but February shows a significant amount of added congestion late in the comment period. Overall, congestion typically started slightly earlier in the day and lasted slightly longer, and travel times were moderately longer throughout the peak period.

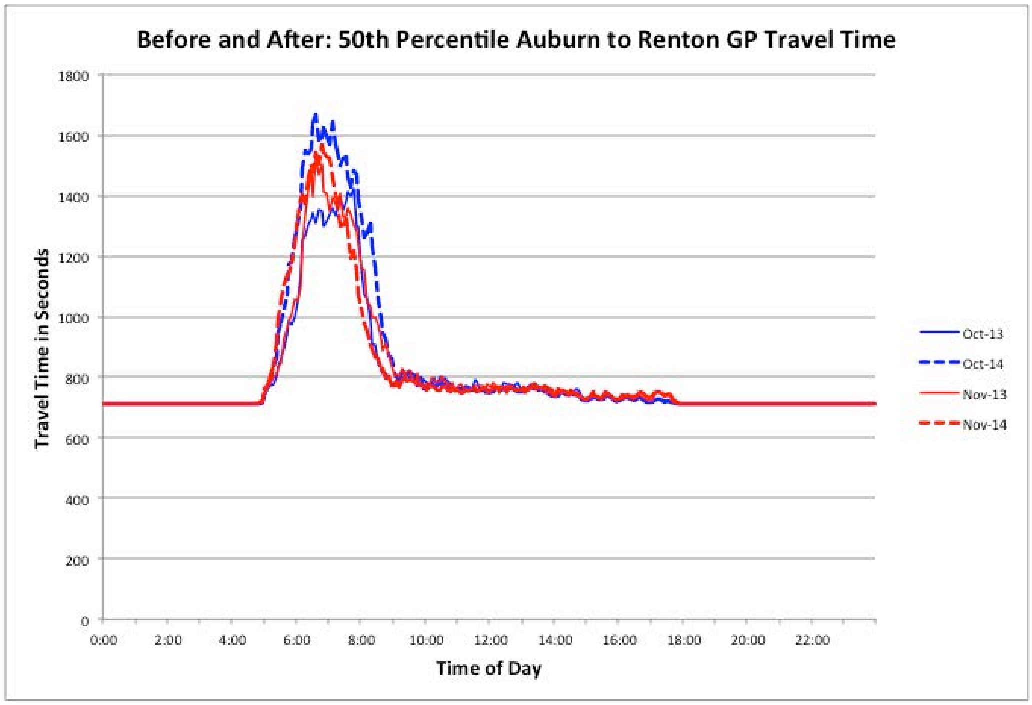


Figure 3-18: 50th Percentile General Purpose Lane Travel Times, Auburn to Renton October and November Before and After Periods

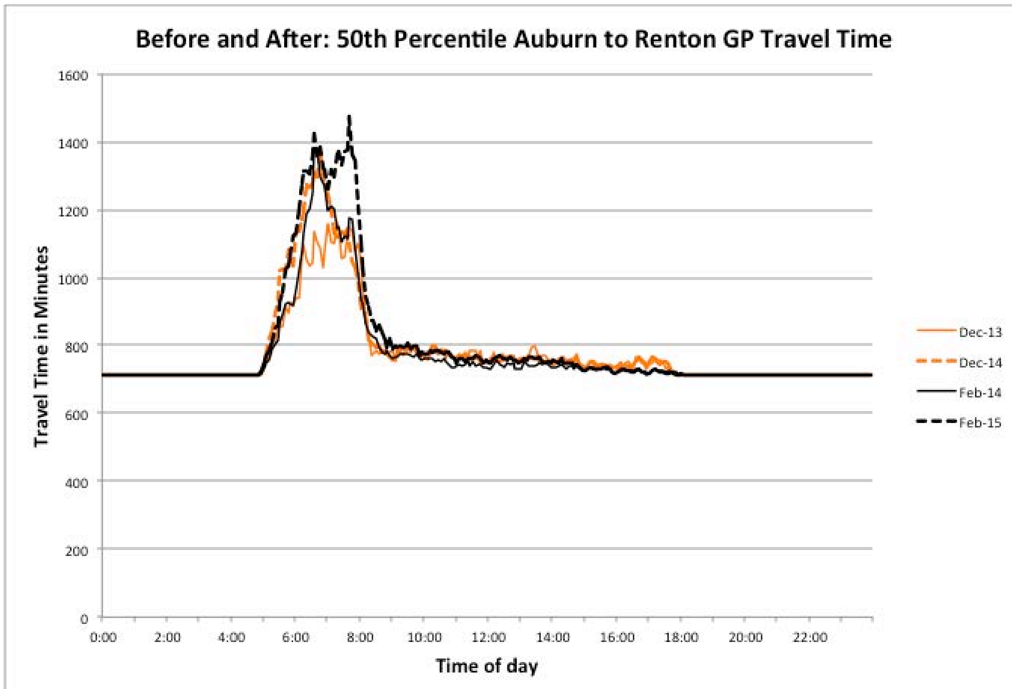


Figure 3-19: 50th Percentile General Purpose Lane Travel Times, Auburn to Renton October and November Before and After Periods

Figure 3-20 shows the 50th percentile travel times for the northbound HOT lane for October and November in 2013 and 2014. Figure 3-21 shows the change in 50th percentile general purpose travel times for December and February for this same trip. In addition to illustrating the consistent year over year slowing of travel times in the HOT lane, these graphics show that the December and February travel times were generally faster than those observed in October and November, although the effect of the growth in GP congestion late in the peak period in February is apparent in the growth in February travel times during that same time period. These overall faster HOT lane conditions in December and February are in part responsible for the lower HOT lane prices paid during those months (see the Revenue section).

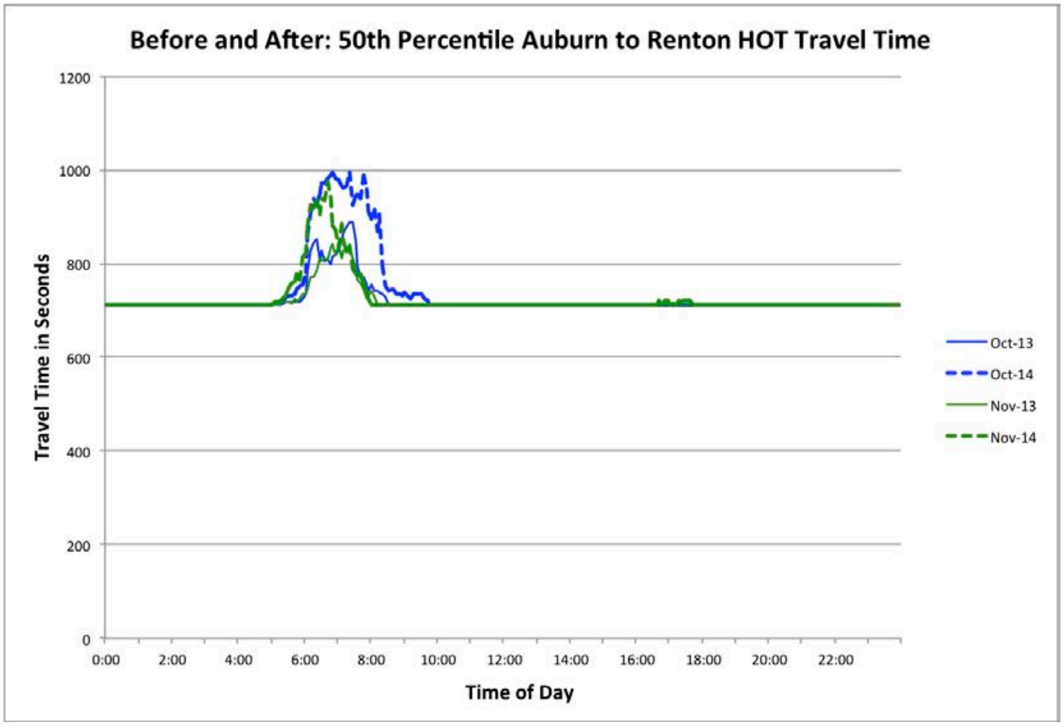


Figure 3-20: 50th Percentile HOT Lane Travel Times, Auburn to Renton October and November Before and After Periods

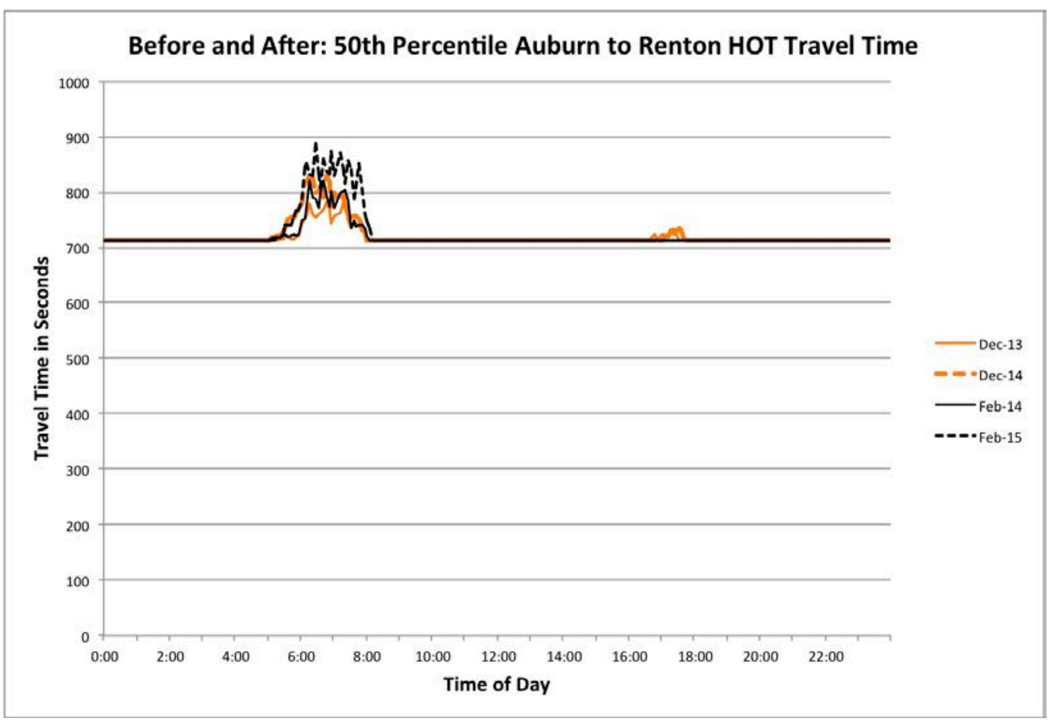


Figure 3-21: 50th Percentile HOT Lane Travel Times, Auburn to Renton December and February Before and After Periods

HOV Performance Standard

In Washington state, HOV lane performance is evaluated relative to the state HOV lane performance standard of achieving speeds of 45 mph or better at least 90 percent of the time during the peak hour. SR 167 HOT lane performance in both directions has met the state HOV lane performance standard every year since at least 2005 (when tracking began). This means the standard was met when SR 167 operated with an HOV lane, as well as following the 2008 conversion of the HOV lane to a HOT lane with limited access zones.

For the (dominant direction) northbound AM peak period, <u>before the start of the open access policy</u>, the HOT lane was able to meet or exceed the 45 mph state standard 91 percent of the time. However, <u>after the start of continuous access rules, it met the standard only 76 percent of the time.</u> An analysis examining all weekdays in 2015 showed that just over 77 percent of peak period HOT lane travel times met the standard. The degradation of the HOT facility was caused mostly by an increase in delays at the northern end of the corridor, much of which stemmed from queues backing up from the SR 167/I-405 interchange, although some additional slowing was apparent between mileposts 16.5 and 18.5 (near Emerald Downs).

While the average northbound AM peak trip speeds stayed above 45 mph in the HOT lanes both before and after the start of continuous access, as can be seen by comparing the 50th percentile travel times in figures 3-20 and 3-21, there was more day-to-day variability in HOT lane travel times in the After time period (particularly early in the test period), with the frequency of trips below 45 mph going up from 5 percent to 22 percent.

For the northbound HOT lane facility, the travel time in the corridor must remain below 950 seconds to meet the HOV lane performance standard. As can be seen in Figure 3-19, congestion in the HOT lane in October and November caused the 50th percentile travel times to rise above the standard during those months. In December and February, congestion and travel time in the HOT lane had decreased from what was seen early in the After study period, and as a result, the 50th percentile performance of the HOT lane in those two months returned to being well above the HOT lane performance standard. (That is, travel times are faster than the standard.)

Figure 3-22 illustrates the percentage of 5-minute time periods for both seven-month Before and After periods when trips on the northbound HOT lane failed the 45 mph performance standard. This graphic shows that even in the Before period, the corridor frequently failed the standard, although for a only very short period of time (roughly 30 minutes starting just before 8:00 AM). When averaged over the entire peak hour, the number of failures fell below the 10 percent threshold. In the After period, not only did the percentage of days in which the HOV lane fail increase in the peak of the peak, but the number of time periods during which this failure occurred also increased considerably. This increase in the length of time when congestion was present in the HOT lane in the peak period was most responsible for the northbound HOT lane failing the performance standard.

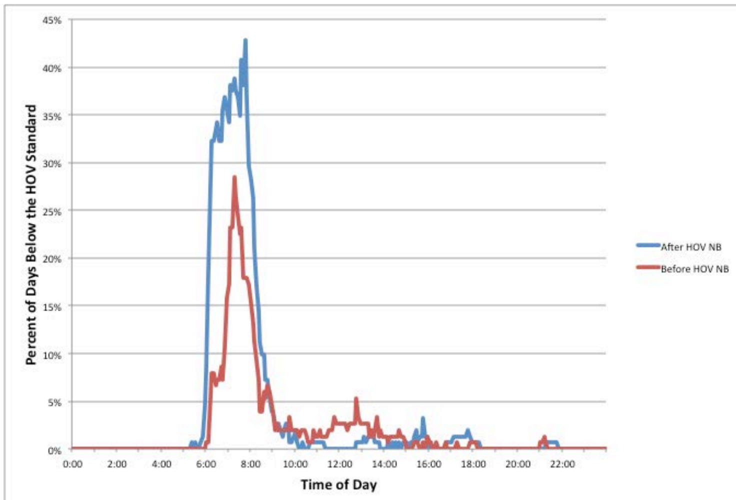


Figure 3-22: Percentage of Northbound HOT Lane Trips that Fail the HOV Lane Performance Standard of Averaging 45 mph by Time of Day

While these results for the After northbound AM peak period represent the first time that SR 167 HOT lane performance has dropped below the state HOV standard since tracking began, readers should note that the annual HOV lane performance standard metric is based on a full calendar year of weekday data. For the shorter time period used in this evaluation, a cluster of outlier travel times could have had an additional effect on the performance standard metric that would not be as noticeable for a full-year computation. That is, if the performance observed in December and February (Figure 3-21) were to continue in 2015, then the northbound HOT lane would still officially exceed the performance standard, whereas if the performance observed in October and November returns, the HOT lane will not meet the standard.

Southbound Travel

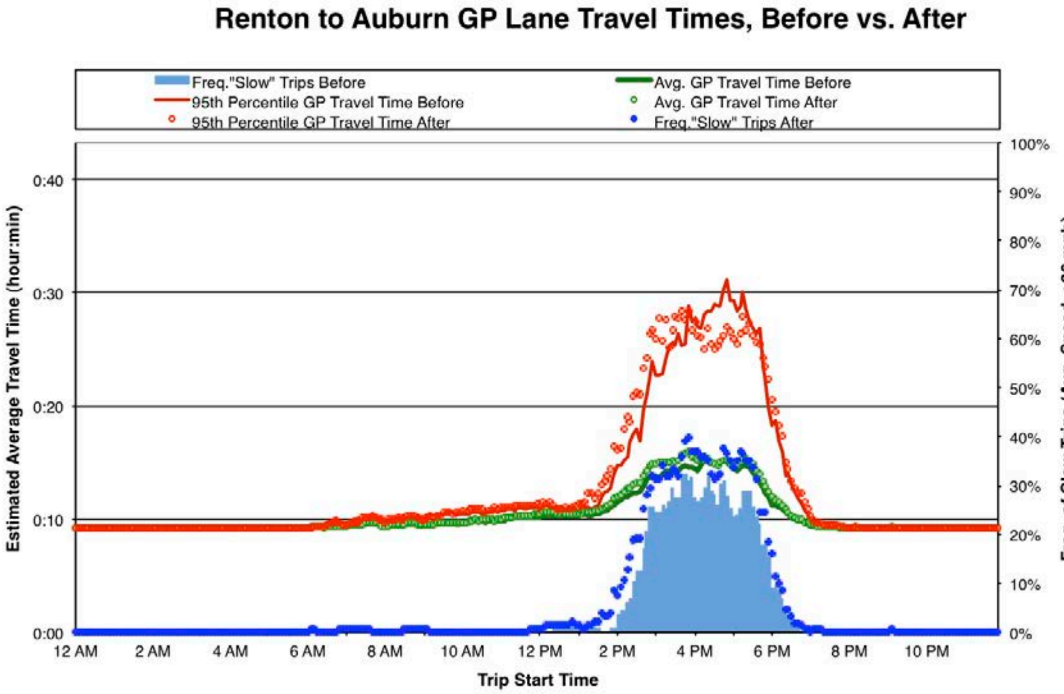
Table 3-2 shows the mean travel times for the southbound (Renton to Auburn) trip for the PM peak period for both the GP and HOT lanes for all three analysis periods.

Table 3-2: Renton to Auburn Mean Travel Times in the PM Peak Period (minutes)

		Control	Sept – Oct	Sept - March	April - August
After HOT Access	HOT	12.4	10.3	10.0	10.7
Rule Change	GP	19.3	17.4	15.9	18.4
Before HOT Access	HOT	12.1	10.2	9.8	10.3
Rule Change	GP	15.7	15.4	15.2	16.4
Change	HOT	0.3	0.1	0.2	0.4
	GP	3.6	2.0	0.7	2.0

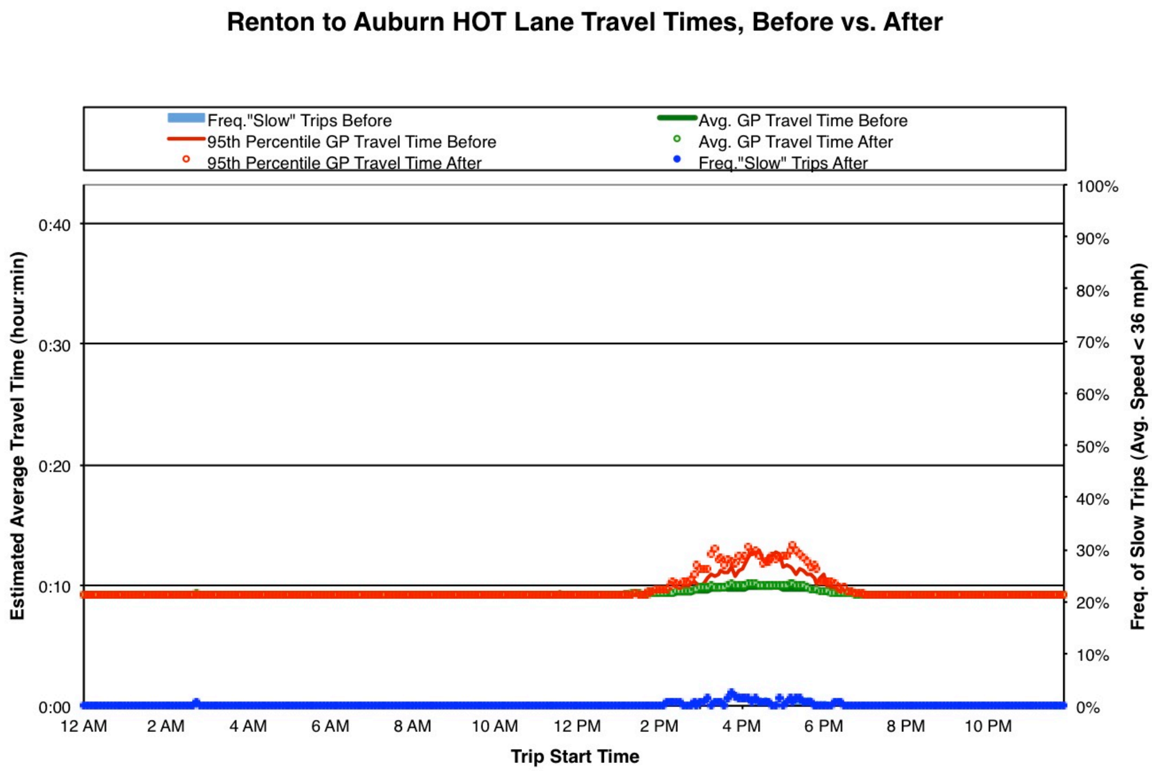
Mean travel times increased in the After period for all four comparison periods for both the HOT and GP lanes, but the increases after the change in HOT lane access rules were smaller in this direction than in the northbound direction. They were also smaller than the increases observed in the first six months of 2014 (compared to 2013) before the change in the HOT lane access rules. Unlike the northbound direction, the southbound direction of travel showed a larger increase in travel time during the April-August period of operation under the new access rules in comparison to the first seven months. However, this increase in travel time was still consistent with expectations based on the pre-implementation growth rate. This suggests that the change in southbound congestion was as much due to growth in the region as it was to changes in the HOT lane access rules.

Figures 3-23 and 3-24 display a profile of weekday travel performance over an average 24-hour weekday for the GP and HOT lanes, showing how average travel time (green), 95th percentile travel time (red), and frequency of congestion (blue) varied by the start time of the trip. Before (solid lines and blue histogram) vs. Primary After data (data points shown as dots) for each metric are displayed on the same graph to illustrate how those values changed at different times of the day.



Figures 3-23: Average Weekday GP Lane 24-hr Travel Time Profiles for the Southbound Trip (Before vs. Primary After)

These figures show that there was little change in either the size, timing, or duration of southbound PM peak period congestion. While the mean PM peak travel times increased slightly after the change in access rules, the 95th percentile travel times were actually slightly faster for most of the PM peak period. The one area of travel time degradation that can be observed in Figure 3-22 is the frequency with which "congested" (very slow) GP lane trips occurred. In the After period, congestion frequently formed earlier, and more often, in the general purpose lanes than in the Before period. That congestion formation would increase the demand for the HOT lane.



Figures 3-24: Average Weekday HOT Lane 24-hr Travel Time Profiles for the Southbound Trip (Before vs. Primary After)

If 50th percentile travel times are plotted for specific months, it is possible to more directly observe the changes in the travel time that occurred in the PM peak in both the HOT and GP lanes. Figure 3-25 shows the changes in October and November general purpose lane travel times from 2013 to 2014. Figures 3-26 and 3-27 show the HOT lane travel time changes in October, November, December and February. The graphics show that changes caused by the access rules on travel in the southbound direction were modest at best.

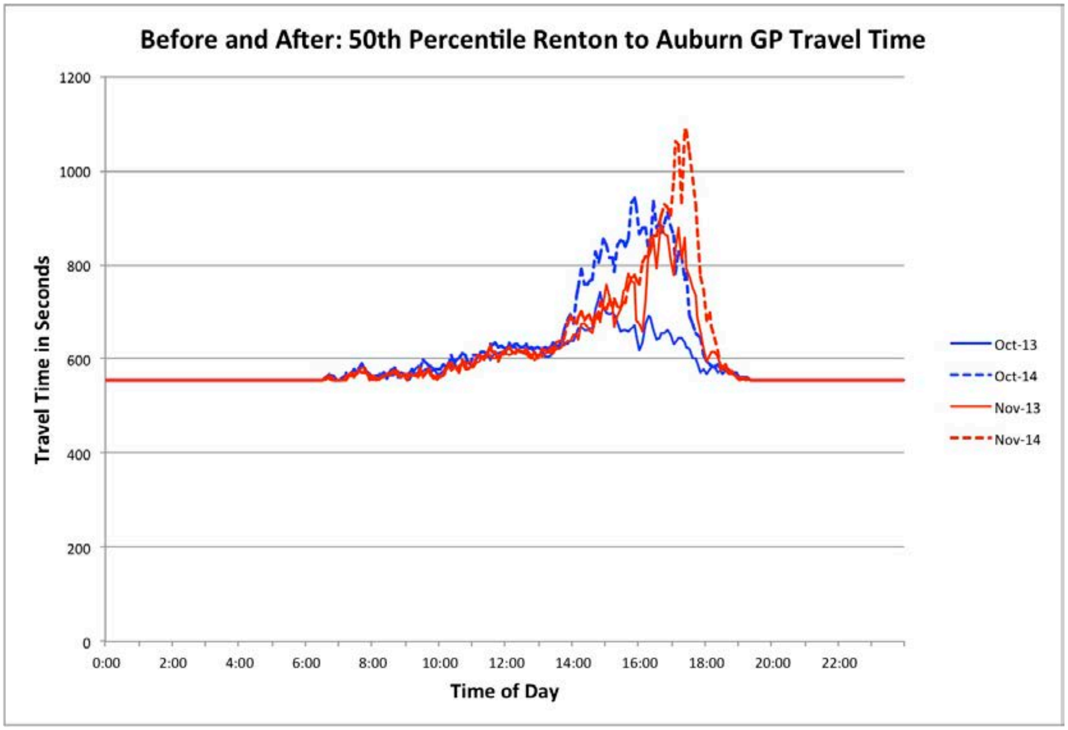


Figure 3-25: 50th Percentile GP Lane Travel Times, Renton to Auburn October and November Before and After Periods

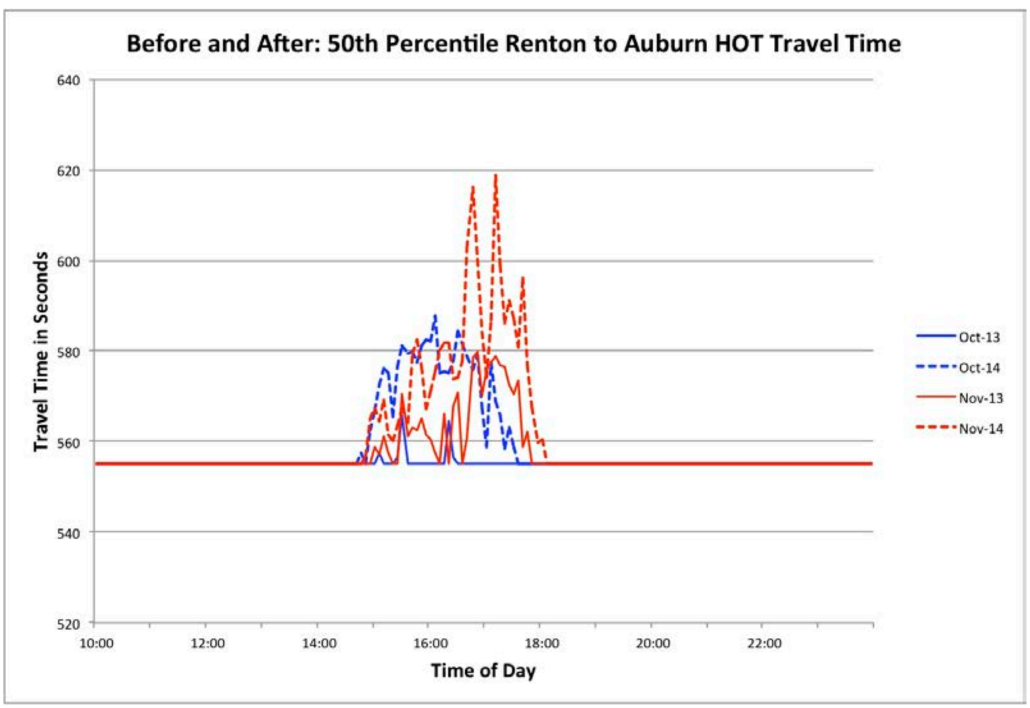


Figure 3-26: 50th Percentile HOT Lane Travel Times, Renton to Auburn October and November Before and After Periods

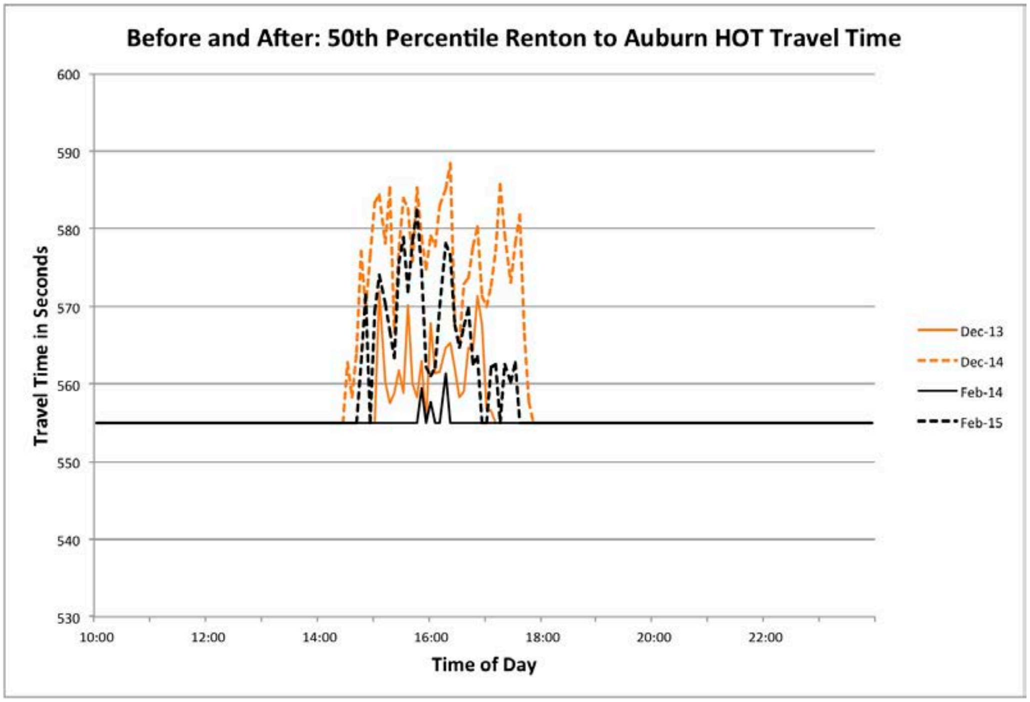


Figure 3-27: 50th Percentile HOT Lane Travel Times, Renton to Auburn December and February Before and After Periods

HOV Performance Standard

Using the state HOV lane standard as a performance standard for SR 167 HOT lane performance, the research team found that for the (dominant direction) southbound PM peak period, the HOT lane was able to meet or exceed the 45 mph standard over 97 percent of the time both before and after the start of continuous access. This was a continuation of a high level of speed and reliability that have been consistent during the past 10 years for SR 167's southbound PM HOV/HOT lane commute.

Figure 3-28 illustrates the periods of the day when the HOT lane failed the standard in the southbound direction. Even the peak or the peak period met the 90 percent standard (i.e., it failed less than 10 percent of the time). In addition, little difference was observed between the Before and After conditions.

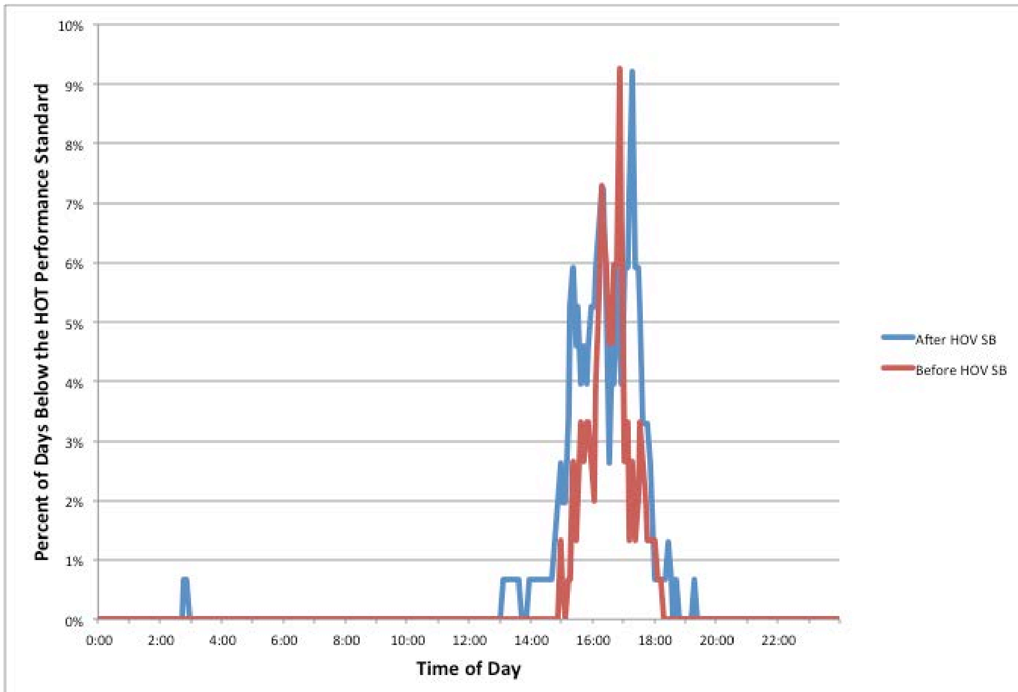


Figure 3-28: Percentage of Southbound HOT Lane Trips that Fail the HOV Lane Performance Standard of Averaging 45 mph by Time of Day

FRICTION BETWEEN HOT AND GP LANES

Lane Friction

One specific performance concern with the change in HOT lane access rules was that the unfettered ability for vehicles to enter and exit the HOT lane would cause the HOT lane to slow down relative to the GP lanes. The term "friction" is used to describe the fact that a lane (in this example, an HOV or HOT lane) generally slows down "in sympathy" when the neighboring (GP) lane slows. Specifically, it is thought that HOV/HOT lane performance (speeds) can be influenced by congestion and slower speeds in the adjacent GP lane, making travel in the HOT lane slower than it would otherwise be if it were a function of only congestion factors existing within the HOT lane itself (e.g., as in a barrier-separated HOT lane). A "friction effect" means that even if the HOT lane is congestion-free, travelers in that lane might feel inhibited from moving at free flow speeds because of slow adjacent GP traffic (i.e., there was a high speed differential between the two lanes). This friction effect might occur because travelers in the HOT lane were concerned that slow GP vehicles would suddenly change lanes into the HOT lane (while traveling at a slow speed), and therefore HOT lane travelers would need to operate at slower speeds as well to be prepared to react. Also, HOT lane vehicles attempting to merge into the GP lane (e.g., to access an upcoming exit) might feel the need to travel slower than the HOT lane conditions allowed in order to keep pace with and merge smoothly into the slower GP lanes. Even if those factors influenced only some HOT lane travelers, the other HOT lane users might also be required to travel more slowly because HOT lane travelers in front of them would be moving more slowly in response to GP lane conditions, and the single lane configuration of the HOT lane makes it impossible for them to pass slower moving vehicles in front of them. Finally, some HOT lane users might evaluate their own speed on the basis of the high speed differential between their lane and the adjacent GP lane, and react by slowing their own speeds.

Preliminary analyses for this project showed different operating conditions for HOV lanes than were found on the SR 167 HOT lanes while those lanes operated with controlled access. Figure 3-29 shows the relationship of HOV lane speed and GP lane speed at a site on I-405 where the HOV lane has continuous access. Figure 3-30 shows this same relationship for a northbound site on SR 167. The slope of the linear relationship between HOV and GP speeds for the I-405 site is roughly 0.8, which is similar to that found at other HOV sites investigated in the preliminary analysis. The slope of the line for the SR 167 HOT lane is less than 0.4. This difference strongly suggests that, under restricted conditions, the HOT lane was much less affected by GP lane speed than the HOV lane.

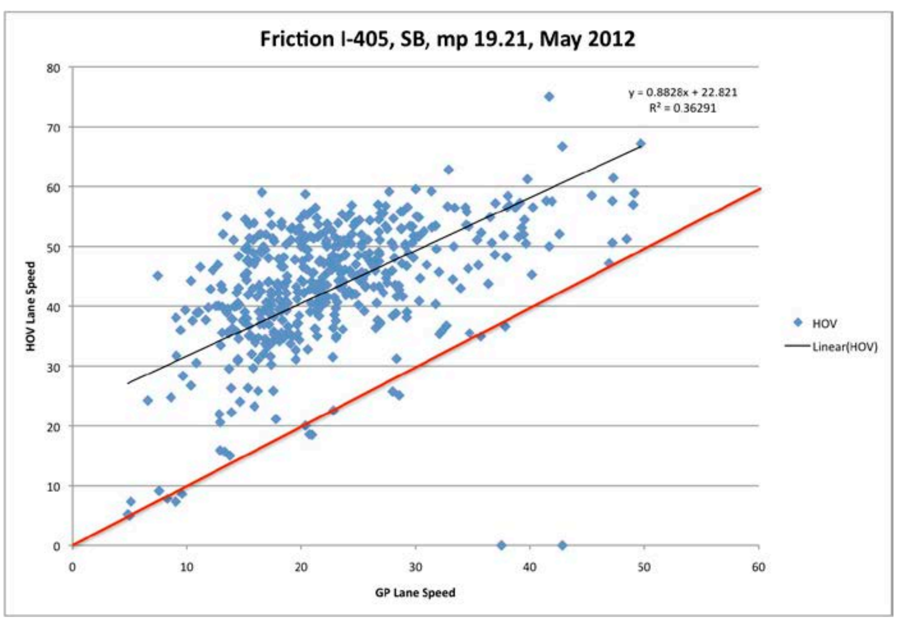


Figure 3-29: HOV Lane versus GP Lane Speeds for GP Lane Speeds Below 50 mph

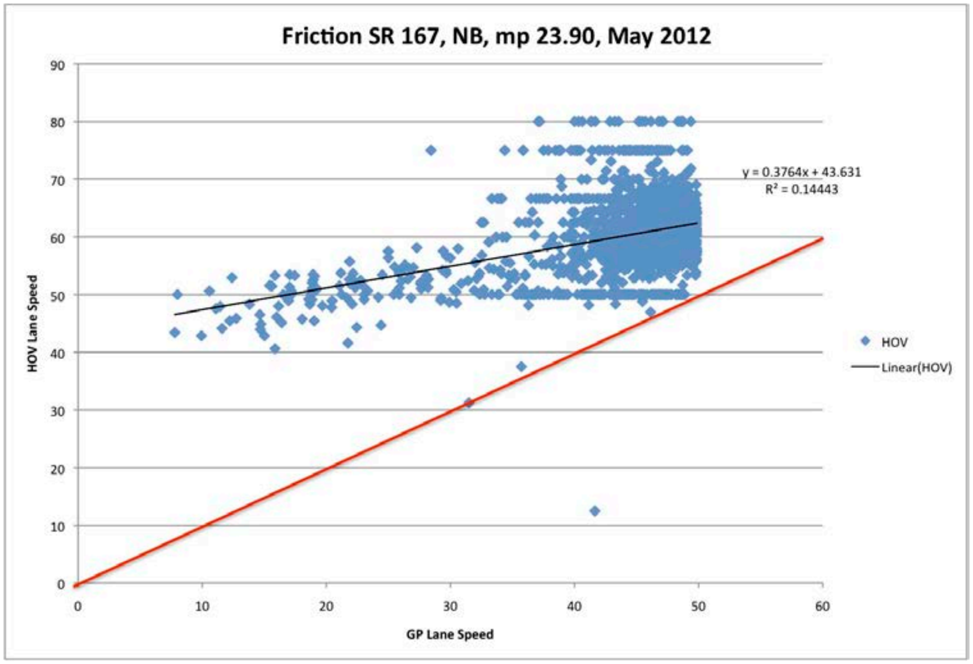


Figure 3-30: HOT Lane versus GP Lane Speeds for GP Lane Speeds Below 50 mph

To examine the effects of changing the HOT access rules on lane friction, the relationship between speeds in the GP lane immediately next to the HOT lane and the HOT lane was computed for both before and after the access rules were changed and those outcomes were then compared. Linear fits between HOT and GP lane speeds were computed for each sensor location along the SR 167 HOT lane corridor, in both directions. Of the 37 northbound and southbound locations evaluated, 30 had sufficient data to estimate a linear regression equation for both Before and After time periods.

Findings: Changes to Lane Friction

Of the 30 locations evaluated in the initial seven-month analysis, 25 showed a higher slope after the start of continuous HOT lane access (i.e., a higher positive correlation between HOT lane speeds and adjacent GP lane speeds) versus before the start of continuous access, suggesting that with the opening of continuous HOT lane access, the friction effect became somewhat stronger. This pattern continued in the analysis of April-August, when 27 of the 30 locations showed a greater impact of GP lane performance on HOT lane speeds.

Friction between the HOT and GP lanes increased in all locations southbound, as well as for the majority of northbound SR 167. That is, for any given speed below 50 mph in the GP lane, the HOT lane now operates (on average) more slowly than it did before the change in access rules. This result is illustrated in Figure 3-31, which shows the change in the slope of the line comparing HOT and GP lane speeds at milepost 22.26 in the southbound direction. Figures 3-32 and 3-33 show the change in the coefficient for the slope of the linear regression line for each data collection location in the corridor.

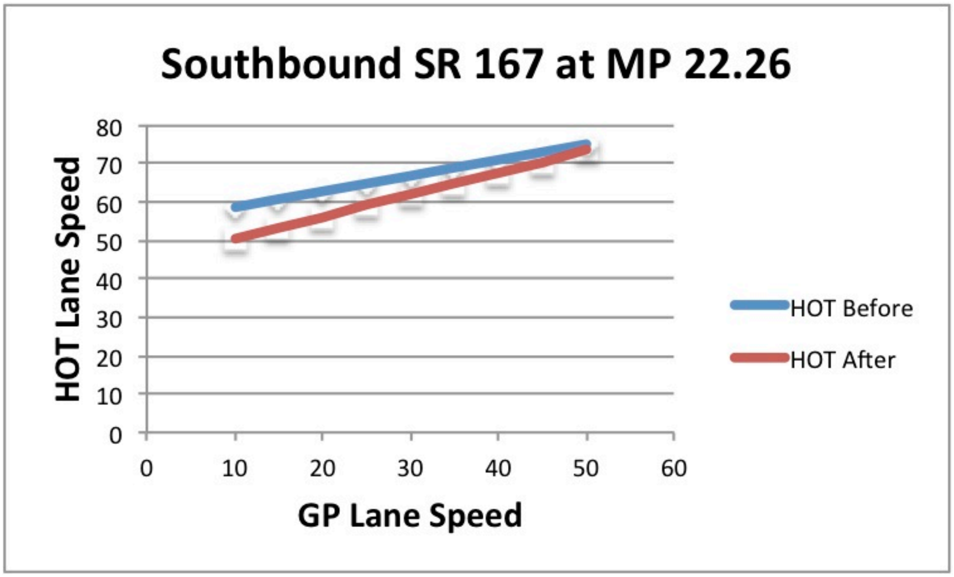


Figure 3-31: Changing Relationship of GP and HOT Lane Speeds, Southbound at Milepost 22.26

Northbound the change was not universal. Figure 3-32 shows that five of the 18 data collection locations in the corridor did <u>not</u> show an increase in lane friction. All but one of those locations were between S 288th St and SR 516.

The implications of the increase in friction are that as the GP lane slows down, the HOT lane slows down, which in turn causes prices to rise in the HOT lane, as the toll pricing algorithm attempts to maintain higher speeds in the HOT lane. The result is an increase in the price paid per vehicle for similar GP travel conditions. This partly explains the rise in prices in the HOT lane described later in the Revenue Chapter. (See the HOT lane price graphics.)

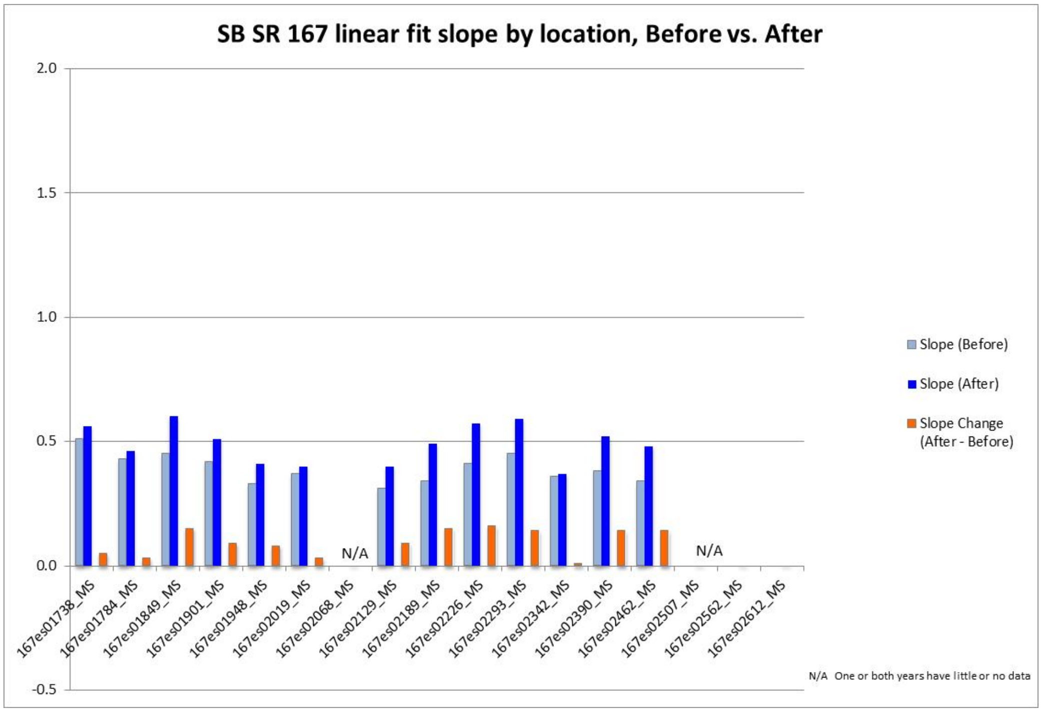


Figure 3-32: Change in the Slope of the Line Comparing HOT Lane Speeds to GP Lane Speeds, Southbound

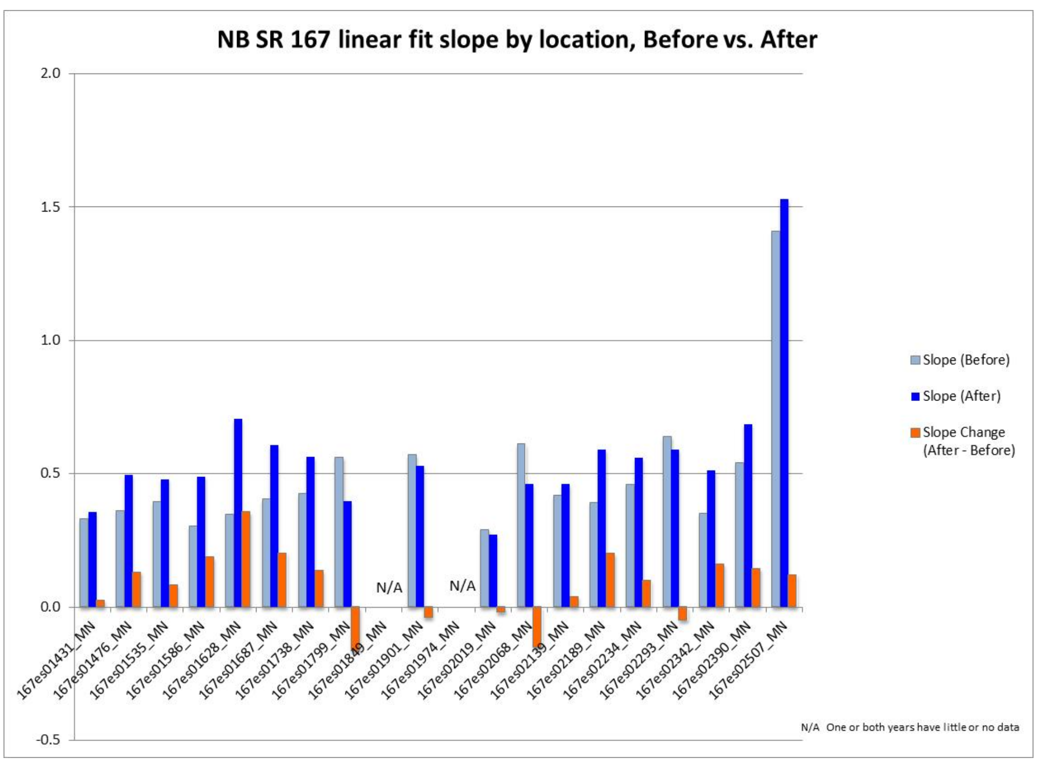


Figure 3-33: Change in the Slope of the Line Comparing HOT Lane Speeds to GP Lane Speeds, Northbound

CHAPTER 4: CORRIDOR ORIGIN AND DESTINATION PATTERNS

One of the questions of interest to WSDOT was whether the change in HOT lane access rules changed when and where customers used the HOT lane. That is, now that motorists could legally enter and exit the HOT lane when and where they wished, did that new freedom change when and where they actually entered and exited the HOT lane?

To answer this basic question, the project team used the toll tag records collected in the corridor to determine when and where tags were observed. Toll tag gantries observe Good-to-Go tags in both the HOT lane (which results in a toll charge) and the neighboring GP lane (which does not result in a toll charge). The toll gantries do not observe toll tags in the right-most GP lane.

From these data, the research team was able determine when in the corridor toll tags were first observed and last observed.[3] This allowed the project team to create an origin/destination pattern within the corridor. It also allowed the project team to determine at which gantry a HOT lane toll was paid. (Tolls are paid at the first gantry that a vehicle passes under. That toll covers the cost of the HOT lane use for the length of the remaining corridor, regardless of the length of the trip in that corridor. In addition, the toll paid for the trip is the price paid at that first gantry, even if the price at subsequent gantries is higher than what was paid at the first gantry.)

One limitation in this analysis is that it relied on detailed tag reads collected at the toll gantries. Those data were not available before January 2014. As a result, it was not possible to perform a seasonally adjusted comparison of origin/destination (O/D) pattern changes, as data were not available for September 2013–December 2013. For this specific analysis, the Before time period was January 2014–July 2014, and the After period was September 2014–February 2015.

SUMMARY FINDINGS: ORIGIN/DESTINATION PATTERN CHANGES

While small changes in the origin/destination patterns of HOT lane users were observed in the toll tag data, the observed changes in patterns were overshadowed by the month-to-month variation in those patterns. The same basic use pattern remained constant in the corridor, but

[3] One limitation to this analysis was that the location where some vehicles actually entered or left the corridor was missed because the right-most GP lane is not observed.

specific events appear to have temporarily changed when travelers chose to enter and/or leave the HOT lane. These temporary patterns were far larger than any long-term change caused by the HOT lane access rule change, and the presence of several of these temporary changes strongly suggests that no major change in when drivers chose to enter or leave the HOT lane (i.e., at which gantry they first entered the HOT lane, and which gantry they last passed before exiting the HOT lane) occurred.

NORTHBOUND ORIGIN/DESTINATION PATTERNS

In aggregate, changes in the O/D patterns observed between the Before and After periods in the corridor were modest. Table 4-1 shows the O/D pattern of vehicles in the corridor after the HOT lane toll access rules were changed. It shows the patterns for all observed northbound toll tag trips observed between 5:00 AM and 7:00 PM. In this table, the origin (the first gantry at which a tag was observed) is the row. The destination (the last gantry at which the tag was observed) is the column. So in Table 4-1, 5.68 percent of all northbound trips were first observed at 15th St. SW in the HOT lane and were last observed at S 212th St. in the GP lane.

Table 4-2 shows the difference in those patterns between the Before and After periods. Where the percentage of trips for a given origin/destination pair decreased, that number is shown in red.

Interestingly, the only O/D movements to lose trips were travel patterns that were first observed in the general purpose lanes at the first two gantry locations in the corridor (15th St. SW and SR 18). The majority of those trips appear to have shifted to being first observed in the HOT lane at the corresponding HOT gantries. (Note that these are changes in the percentage of all trips, and these numbers do not account for changes in total volume.) All other origins gained modestly in terms of the percentage of travel in the region. The third gantry location (15th St. NW) showed percentage gains in trips starting in both the HOT and GP lanes.

As for destinations, the fifth gantry location (SR 516) was the only location that exhibited major changes. It showed a 2 percent decline in the percentage of observed vehicles in the HOT lane and a 2.5 percent increase in observed vehicles in the GP lane, suggesting that under the new access rules, more vehicles exited the HOT lane earlier than they had previously.

Table 4-1: Northbound Origin/Destination Patterns After the HOT Lane Access Rule Change

	SR 18 HOT	15th St NW HOT	S 277th HOT	SR 516 HOT	S. 212th HOT	15th St. SW GP	SR 18 GP	15th St NW GP	S 277th GP	SR 516 GP	S. 212th GP	Grand Total
15th St. SW HOT		0.07%	0.23%	0.45%	1.37%	0.00%	0.09%	0.70%	0.45%	1.19%	5.68%	10.24%
SR 18 HOT		0.00%[4]	0.09%	0.26%	0.55%		0.00%	0.23%	0.26%	0.68%	2.11%	4.19%
15th St NW HOT			0.00%	0.06%	0.20%			0.00%	0.05%	0.19%	0.97%	1.46%
S 277th HOT				0.00%	0.08%					0.09%	0.85%	1.01%
SR 516 HOT					0.00%					0.01%	0.58%	0.59%
S. 212th HOT											0.00%	0.00%
15th St. SW GP		0.20%	0.73%	1.32%	2.41%	0.59%	0.35%	2.85%	1.87%	5.11%	22.46%	37.91%
SR 18 GP		0.12%	0.38%	0.89%	1.21%		0.79%	1.39%	1.24%	3.16%	9.29%	18.47%
15th St NW GP			0.15%	0.29%	0.63%			1.05%	0.41%	1.25%	4.57%	8.35%
S 277th GP				0.13%	0.44%				0.54%	0.94%	3.95%	6.00%
SR 516 GP					0.18%					2.08%	1.61%	3.87%
S. 212th GP											7.90%	7.90%

In this table, rows are the origin – the gantry at which a vehicle was first observed, and columns are the destination – the gantry at which a vehicle was last observed

[4] Values of 0.00% indicate that some vehicles were observed in this lane at this gantry, but the fraction of vehicles observed is less than 0.00% of all vehicles observed in this direction.

Table 4-2: Changes in Northbound Origin/Destination Patterns
Northbound SR 167 (“After” Percentage Minus “Before” Percentage)

	SR 18 HOT	15th St NW HOT	S 277th HOT	SR 516 HOT	S. 212th HOT	15th St. SW GP	SR 18 GP	15th St NW GP	S 277th GP	SR 516 GP	S. 212th GP	Grand Total
15th St. SW HOT		0.00%[5]	0.04%	0.02%	0.27%	0.00%	0.02%	0.31%	0.25%	0.62%	1.90%	3.44%
SR 18 HOT		0.00%	0.03%	0.05%	0.08%		0.00%	0.12%	0.16%	0.36%	0.62%	1.42%
15th St NW HOT			0.00%	0.04%	0.09%			0.00%	0.04%	0.10%	0.39%	0.65%
S 277th HOT				0.00%	0.03%				0.00%	0.05%	0.37%	0.45%
SR 516 HOT					0.00%					0.00%	0.27%	0.28%
S. 212th HOT											0.00%	0.00%
15th St. SW GP		-0.08%	-0.23%	-1.07%	-0.47%	0.10%	-0.06%	-0.07%	0.08%	0.94%	-0.79%	-1.66%
SR 18 GP		-0.10%	-0.25%	-1.02%	-0.91%			-0.41%	-0.29%	-0.27%	-4.53%	-7.85%
15th St NW GP			0.04%	0.00%	0.05%				0.17%	0.49%	0.87%	1.95%
S 277th GP				-0.01%	0.02%					0.21%	0.32%	0.70%
SR 516 GP					-0.01%						-0.30%	0.10%
S. 212th GP					0.00%						0.53%	0.53%

In this table, rows are the origin – the gantry at which a vehicle was first observed, and columns are the destination – the gantry at which a vehicle was last observed

[5] Values of 0.00% indicate that some vehicles were observed in this lane at this gantry, but the fraction of vehicles observed is less than 0.00% of all vehicles observed in this direction.

Changes in the patterns of where paying customers first entered the HOT lane were voluble at times. A good example of this volubility is the use of the northbound gantry at 15th St. NW. That gantry had a large spike in use per day during November 2014 (see Figure 4-1). But by December, the traditional pattern had reasserted itself. Many of the customers paying at 15th St. NW in November typically entered at the 15th St. SW gantry, which showed a significant decrease in use during that same November time period (see Figure 4-2). However, the 15th St. SW gantry saw an even bigger decrease in use in February 2015. In that month, the HOT lane gantry at SR 18 showed a dramatic increase in use (see Figure 4-3). It is not clear exactly why these shifts occurred, but these very dramatic pattern changes during an entire month significantly influenced the "origin" portion of the origin/destination patterns observed in the toll tag data and shown in Table 4-2.

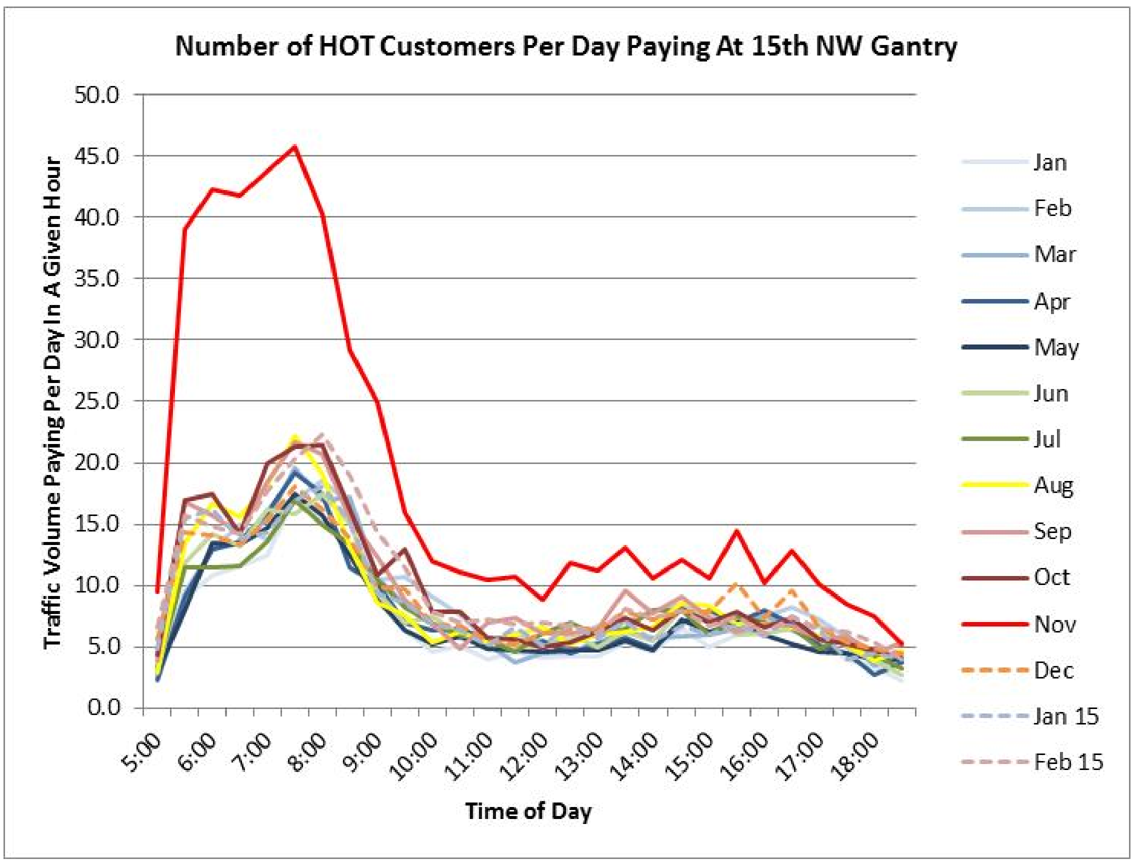


Figure 4-1: The Average Number of Single Occupant Vehicles Paying to Use the Northbound HOT Lane Each Month at the 15th St. NW Gantry

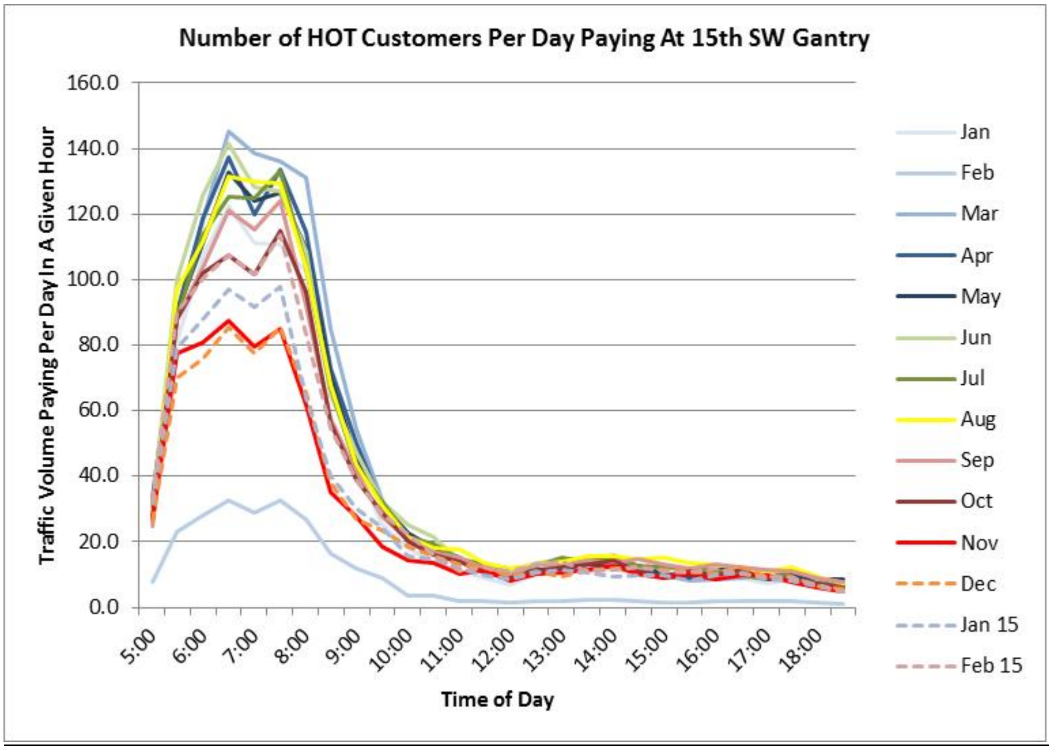


Figure 4-2: The Average Number of Single Occupant Vehicles Paying to Use the Northbound HOT Lane Each Month at the 15th St. SW Gantry

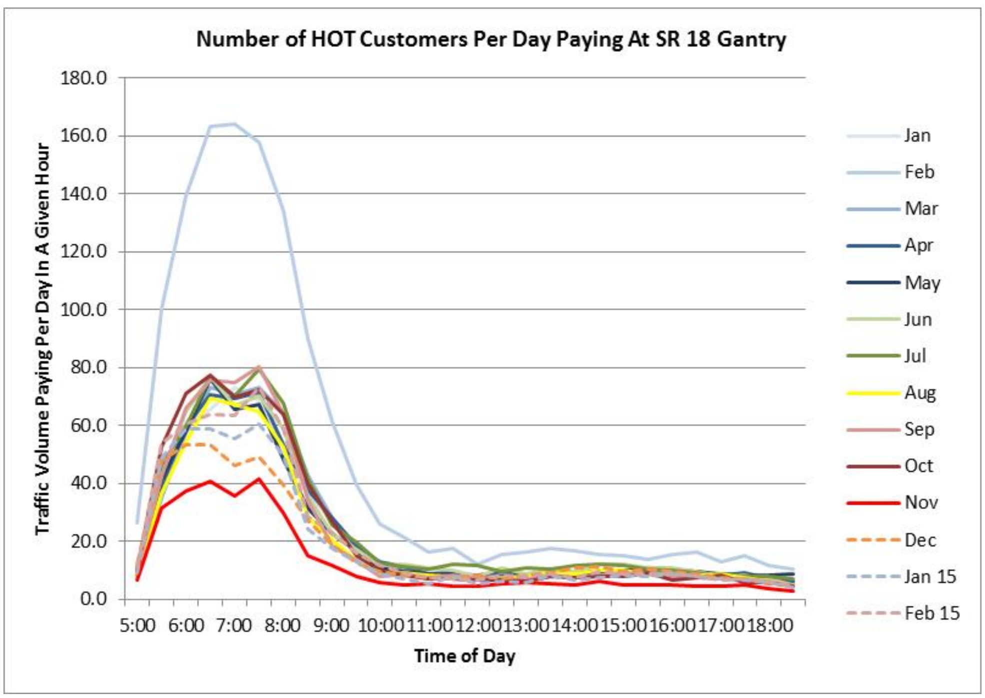


Figure 4-3: The Average Number of Single Occupant Vehicles Paying to Use the Northbound HOT Lane Each Month at the SR 18 Gantry

SOUTHBOUND ORIGIN / DESTINATION PATTERNS

Like the northbound direction of travel, the southbound direction of travel showed relatively modest changes in where within the corridor paying customers entered and exited the facility. Table 4-3 shows the fraction of trips in the After period that were observed starting and ending at each southbound gantry. Table 4-4 shows the change in those fractions from the Before period. The largest shifts were vehicles first observed at the first two HOT toll lane gantries, while in the Before period, those vehicles were observed at the I-405 gantry in the general purpose lanes.

Table 4-3: Southbound Origin/Destination Patterns After the HOT Lane Access Rule Change

	41st St HOT	84th Ave HOT	SR 516 HOT	I-405 GP	41st St GP	84th Ave GP	SR 516 GP	Grand Total
I-405 HOT	0.0[6]%	0.2%	0.8%	0.0%	0.9%	0.9%	7.4%	10.2%
41st St HOT			0.2%			0.3%	2.4%	2.9%
84th Ave HOT			0.0%			0.0%	1.5%	1.6%
SR 516 HOT							0.0%	0.0%
I-405 GP	1.0%	0.6%	1.9%	1.6%	4.5%	3.5%	32.2%	45.3%
41st Ave GP		0.2%	0.8%		2.1%	1.9%	14.2%	19.3%
84th St GP			0.4%			4.1%	9.4%	14.0%
SR 516 GP							6.7%	6.7%

In this table, rows are the origin – the gantry at which a vehicle was first observed, and columns are the destination – the gantry at which a vehicle was last observed

Table 4-4: Changes in Southbound Origin/Destination Patterns Southbound SR 167 ("After" Percentage Minus "Before" Percentage)

	41st St HOT	84th Ave HOT	SR 516 HOT	I-405 GP	41st St GP	84th Ave GP	SR 516 GP	Grand Total
I-405 HOT	0.0%	0.0%	0.2%		0.5%	0.5%	2.6%	3.8%
41st Ave HOT		0.0%	0.1%		0.0%	0.2%	0.9%	1.1%
84th St HOT			0.0%			0.0%	0.3%	0.3%
SR 516 HOT							0.0%	0.0%
I-405 GP	-0.9%	-0.3%	-0.3%	-0.5%	1.4%	-0.2%	-4.5%	-5.4%
41st Ave GP		-0.1%	0.0%		0.6%	0.2%	-1.0%	-0.3%
84th St GP			0.1%			0.8%	-0.5%	0.3%
SR 516 GP							0.0%	0.0%

In this table, rows are the origin – the gantry at which a vehicle was first observed, and columns are the destination – the gantry at which a vehicle was last observed

[6] Values of 0.0% in this table indicate that some vehicles were observed in this lane at this gantry, but the fraction of vehicles observed is less than 0.00% of all vehicles observed in this direction.

Unlike the northbound direction of travel, southbound travel did not experience significant shifts in usage patterns from one month to another. The largest shift in traffic occurred at the 84th Ave S. gantry, which experienced a modestly large increase in the number of users in July 2014 (see Figure 4-4). These additional customers appear to have come mostly from the SW 41st Street gantry (see Figure 4-5). All other gantries exhibited reasonably consistent usage patterns, with only modest changes from one month to the next.

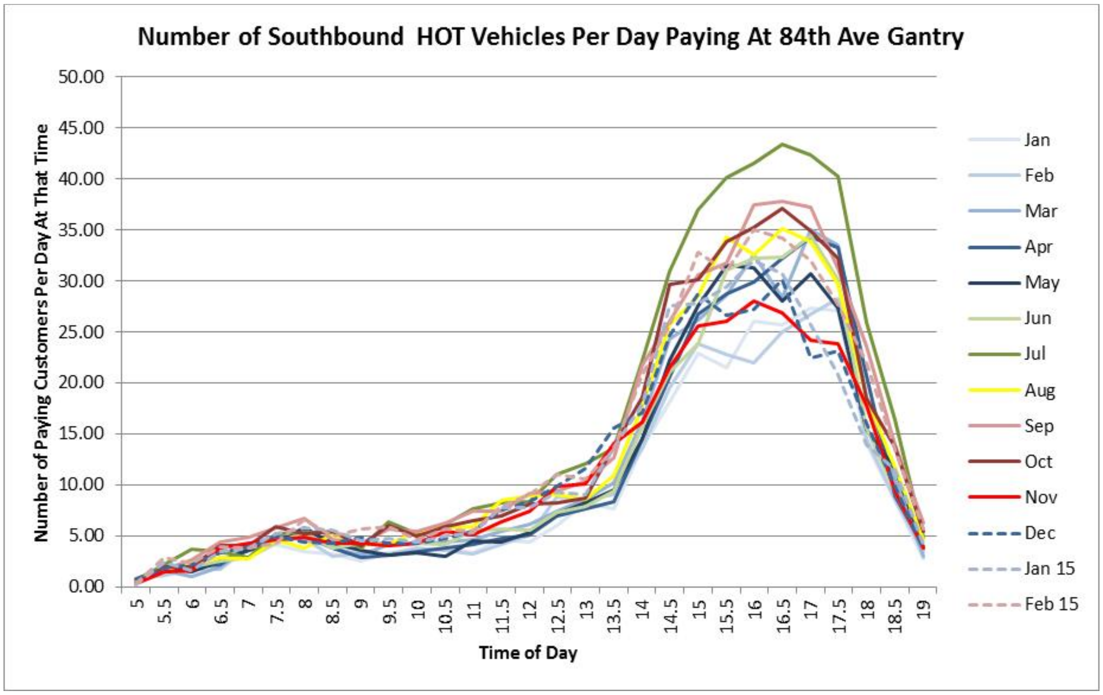


Figure 4-4: The Average Number of Single Occupant Vehicles Paying to Use the Southbound HOT Lane Each Month at the 84th Ave S. Gantry

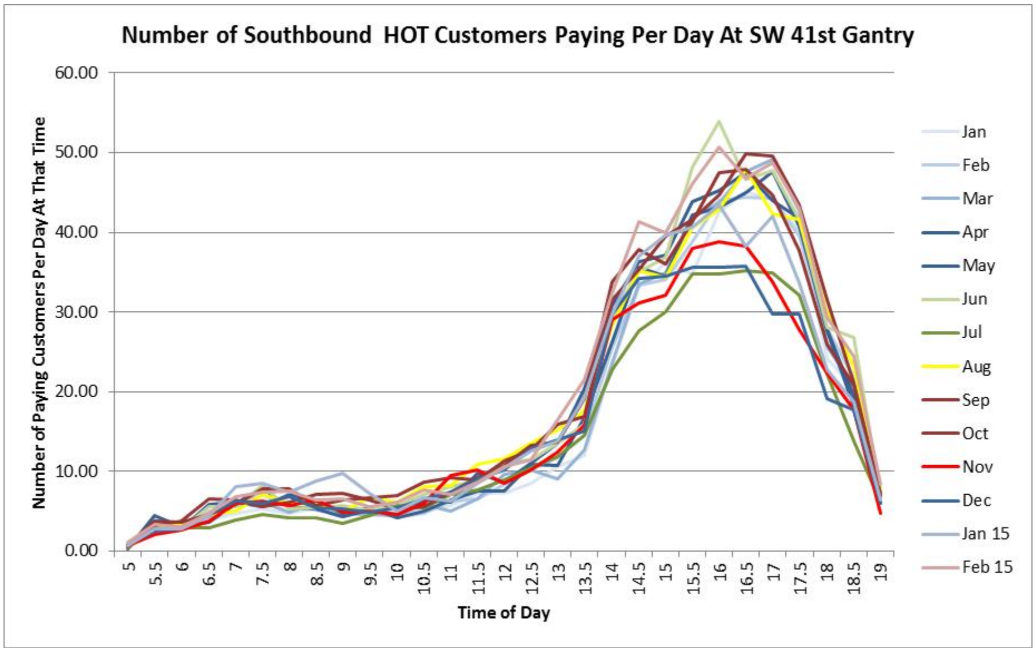


Figure 4-5: The Average Number of Single Occupant Vehicles Paying to Use the Southbound HOT Lane Each Month at the SW 41st St. Gantry

CHAPTER 5: REVENUE COLLECTION

One of the key performance measures for the corridor is the revenue being collected. If violations of the lane are high, revenue collection will decrease. If traffic volumes in the HOT lane increase, revenue collection should increase. If lane friction increases, the price paid by single occupant vehicles will increase, but the combination of slower HOT lane speed and higher price could result in a smaller number of paying customers and thus a decrease in total revenue. The combination of all of these factors, along with the effects of changing general purpose lane volumes and performance all interact and are reflected in the total amount of revenue collected in the corridor. This chapter examines how revenue—and the prices being charged—changed after the HOT lane access rules were changed.

Toll revenues used in this report were generated directly from the toll tag data collected in the field and the toll rates reported by WSDOT. Because the toll revenues were directly computed in this report to track when and where travelers used the HOT lanes, the total revenue statistics used in this analysis differ slightly from those reported by WSDOT's Toll Division. This is because when WSDOT actually charges customers, it includes a small "grace period" when toll rates change, and it was not possible for the evaluation team to duplicate the grace period. WSDOT applies the grace period because the toll gantries are slightly downstream of the variable message signs (VMS) that display the current toll price. During the time vehicles take to travel between the VMS and the gantry, the toll price may change. The toll tag is observed not when the motorist sees the VMS sign but when the tag passes the gantry. Therefore, WSDOT applies the grace period to ensure that toll customers do not pay a price that is higher than what they observed on that sign. The grace period is slightly different for each gantry because of different distances between the VMS and the toll gantry. The differences caused by the team's inability to duplicate the grace period are not significant, but they did cause this report's total revenue estimates to differ slightly from WSDOT's official values.

A number of detailed revenue and price evaluations were performed. The changes in revenue observed are discussed within the context of the roadway performance changes described in the earlier chapters of this report.

PRICE ALGORITHM CHANGE IN DECEMBER 2014

One limitation in the direct before and after price and revenue comparison was that WSDOT changed the pricing algorithm on December 4, 2014. As will be seen in the remainder of this chapter, prices for using the HOT lane during the peak periods increased markedly in the fall of 2014. This resulted in considerable negative public comment. In response, WSDOT reviewed the prices being charged versus the performance of the HOT lane.

As a result of that evaluation, WSDOT determined that the pricing algorithm was keeping the price for entering the HOT lane too high after congestion in the HOT lane had started to ease. WSDOT then changed the algorithm so that prices fell more quickly as congestion eased. This means that for most of December 2014 and all of January and February 2015, the prices were set with an algorithm that reduced prices more quickly than the algorithm that was operating during the first eight months of 2014. This further complicated our ability to determine the impacts of the change in HOT lane access rules on revenue collection.

PRICE PER HOT LANE CUSTOMER

The term "customer" used in this section refers to a GoodToGo toll tag-equipped vehicle that passes under a toll gantry in the HOT lane. It does NOT include carpools using the HOT lane without a toll tag. However, note that not all "customers" pay a toll. When the HOT lane's performance falls below the adopted standard, the operating rules are changed to "HOV Only"—and no paying customers should enter the lane. However, it is clear from the data that many tag-equipped vehicles continue to use the HOT lane even when the signs say "HOV Only." These vehicles are <u>not</u> charged a toll. (The toll value is set to zero.[7])

Including or not including these tagged vehicles in the priced lanes can change the average price per trip by as much 25 cents for a month (see Figure 5-1). This topic is covered in more detail later in this chapter.

[7] It is unclear whether these vehicles are carpools that have forgotten to remove or shield from their toll tags, or whether they are single occupant vehicles that are ignoring the HOV Only sign. A limited number of these vehicles are daily users of the HOT lane, regardless of the cost posted. This suggests that at least some "HOV Only" tagged vehicles are SOV drivers that simply do not read the VMS signs.

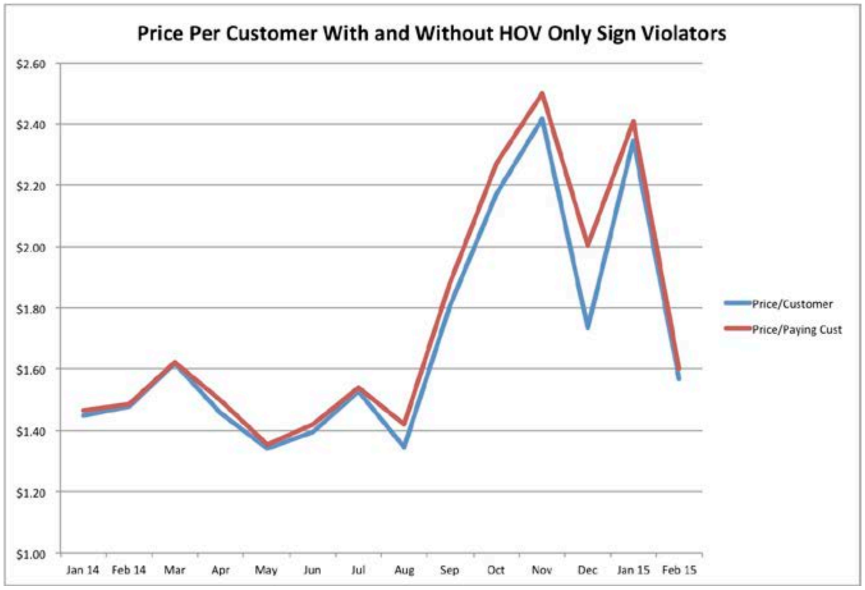


Figure 5-1: Comparison of Price per Customer with and without Tagged Vehicles That Use the HOT Lane During "HOV Only" Periods Northbound SR 167 HOT Lane

Similarly, the "average price per SOV trip" changes if weekend use of the corridor is included in the computation, as weekend congestion and prices are typically much lower than weekday, peak period prices. Unless otherwise noted, the "price per vehicle" values reported in this chapter are for weekdays and include only the volume of paying customers. Tagged vehicles that are not charged a price for using the HOT lane are considered violators, except on those days when the HOT lane has clearly been opened to all traffic.

Summary Price Changes

Figure 5-2 shows a summary comparison of the northbound and southbound average weekday prices per customer by month. It is missing the months of March and April 2015, as a computer error within the WSDOT archive system prevented data from those months from being fully downloaded from all tag readers. As a result, the evaluation team was uncertain about whether the data available in those two months accurately reflected the actual corridor performance. These months are therefore not considered in this graphic. Figure 5-2 clearly shows that after the access rules were changed to allow free entry and exit, the prices charged were routinely higher than prices charged before the rule change. However, in February 2015 prices returned to levels similar to those that were common before the change in access rules.

Since then, prices have stabilized. Average prices are now slightly higher than they were before the access control change, but they are considerably lower than those experienced in the first few months of open access operations.

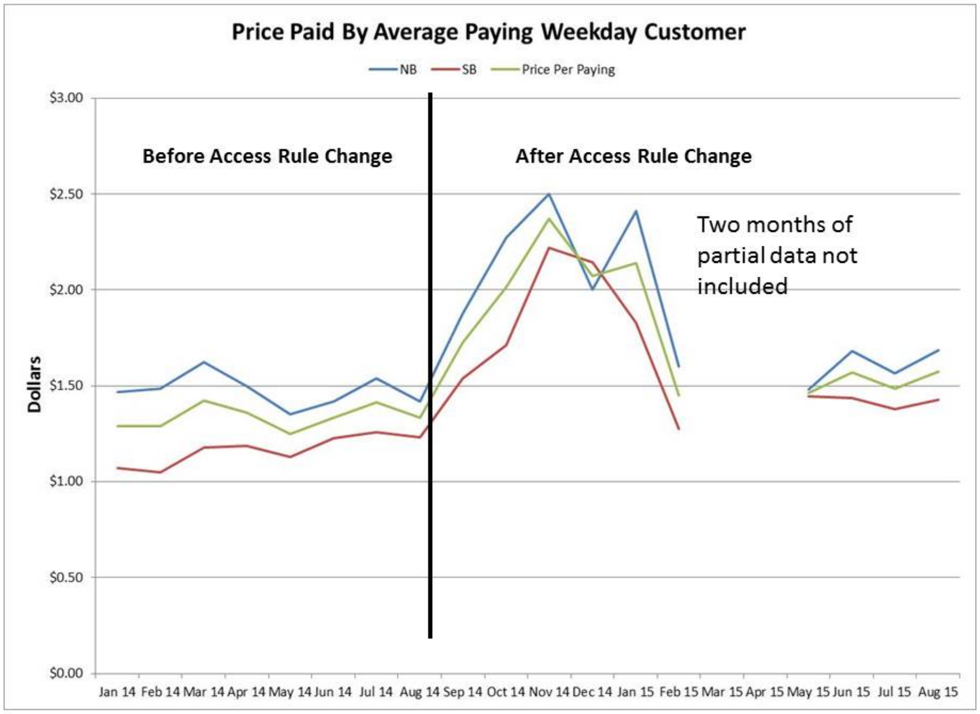


Figure 5-2: Northbound, Southbound, and Average Weekday Price per Paying Customer

With the exception of December 2014, the northbound prices were always higher than the southbound prices per paying customer. The lower price per paying customer traveling northbound in December 2014 was in part due to the fact that December 2014 was by far the least congested month for northbound traffic (using average travel times as the measure) of the seven months examined since the change in access rules. This was in large part due to the effect on morning commute traffic of the large number of people taking winter vacations.

Southbound in December 2014, neither the traffic congestion nor the price per vehicle, was significantly different than that experienced in the early months after the access rule change. However, congestion southbound in the corridor was actually slightly worse in December 2014 than in either January or February 2015.

Figure 5-3 shows the average monthly northbound and southbound weekend price per paying customer in the corridor. Significant increases in the price per paying vehicle are as apparent in the weekend data as they are in the weekday data shown in Figure 5-2, although at their peak, the rise in weekend prices (~60 cents) was only half of that experienced on weekdays (~$1.00). The increase in price on the weekends was more substantial in the northbound direction than in the southbound direction. And once again, there was a substantial decrease in that average monthly price in February 2015. Also interesting is the fact that northbound weekend prices were much higher than southbound weekend prices.

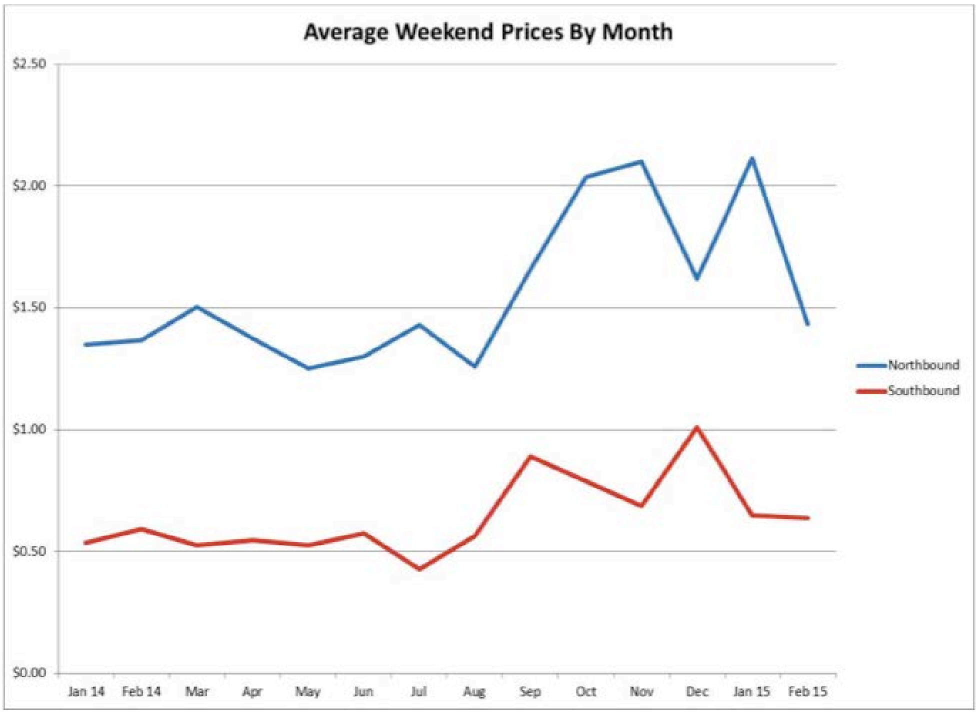


Figure 5-3: Northbound and Southbound Average Weekend Price per Paying Customer

<u>Northbound Prices per Customer</u>

In the first few months after implementation of the new HOT lane access rules, the average price being paid to use the HOT lane increased markedly. Figure 5-2 illustrates the average weekday price per paying customer for each month from January 2014 through February 2015. Figure 5-4 provides more detail about how average prices charged to customers typically change over the course of the weekday. The sharp increases in price in October and November that caused WSDOT to re-evaluate the performance of its pricing algorithm are very visible. A drop in prices from October and November is apparent in December, partly as a result of the pricing algorithm change, but also in part due to highly variable weekday traffic conditions in December, which experienced both heavy congestion (and very high prices) on some days early in the month, and virtually no congestion (and very low prices) during the weekdays centered around the Christmas holiday. Prices increased again in January 2015, but dropped back to those more typically found in the Before period in February 2015. Figure 5-4 also shows the stabilization of average prices that occurred after February. The average prices for all months from February 2015 through August 2015[8] are in between those of the first five months (September 2014 and January 2015) and the "Before" period months (January 2014 and August 2014). It can be seen in this figure how prices are currently higher than in the Before period, but not as high as in the initial period of Open Access operation.

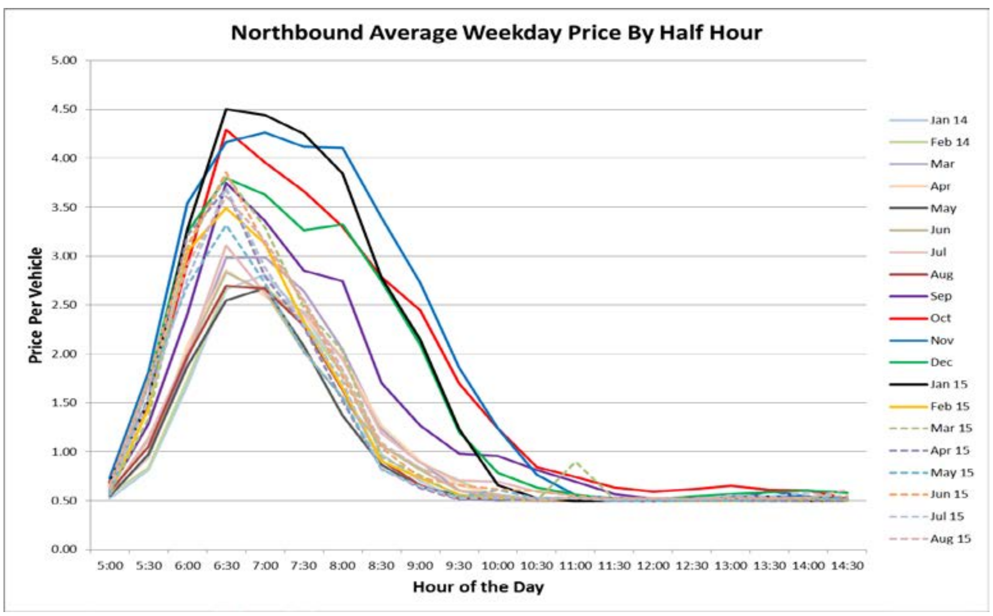


Figure 5-4: Average Weekday Price Paid per Paying Customer by Half Hour by Month Northbound SR 167 HOT Lane

Figure 5-4 shows prices northbound by time of day by month. (Prices are shown only through 2:30 PM. They do not change appreciably in the PM peak period, as congestion is modest for that movement.) The months after the change in HOT lane access rules are shown in dark lines, with prices for the last five-month period shown as dashed lines, and the months before the rule change are shown in lighter lines. Figure 5-4 illustrates not only how in the initial After period prices increased earlier in the day and more quickly, but that they stayed higher

[8] Note that the March and April statistics in this graphic are based on partial months of data.

longer in the peak period than in the months before the change (January 2014 – July 2014, with August 2014 having mixed operations). Prices now peak earlier than before implementation of the open access rules, and they typically rise higher than those in the Before period but drop back to minimal levels at roughly the same time as in the Before period.

What is also apparent in Figure 5-4 is the fact that during the initial After period prices often remained high well after the typical peak of the northbound commute period (7:00 to 7:30 AM). On northbound SR 167, travel times in the GP lane typically decreased substantially by 8:30 AM, and the HOT lane was free flowing by 9:00 AM. In the early months after the access rule change, prices were routinely greater than $3.00 during these periods, when typically they had been in the $1.00 to $1.50 range.

Even though WSDOT changed the tolling algorithm in early December, January 2015 still had the highest average price ($4.50 per paying customer at 6:30 AM) and one of the longest durations of average prices above $3.00. (The average price did not drop below $3.00 until after 8:30 AM.) Not until February of 2015 did the average HOT lane prices start to resemble the prices observed in the first seven months of 2014, before the HOT access rules were changed. But even in February 2015, the peak prices seen at 6:00 and 6:30 were higher than prices in any of the months before the access rule change. However, thanks in part to the revised tolling algorithm, prices declined rapidly after 7:30 in February 2015, and by 8:00 they were are similar to prices typically found in the Before period.

Looking at the prices paid in December 2014 in even more detail illustrates the high level of price variability in the corridor. (This in turn highlights a limitation in the use of "average price" as a performance measure, since the average does not describe the scope of this variability and can mask both very high and very low prices.) Figure 5-5 shows the average price per half hour for each day in December, but based on only those tagged vehicles that actually paid a HOT toll. Figure 5-6 shows the same mean prices by half hour by day, but it includes tagged vehicles entering the HOT lane after the price was set to zero for HOV Only operations. The daily price graphs in these two figures show the dramatic shift from very high prices to a price of "zero" as a result of the shift to "HOV Only" conditions, which occurred frequently in the heart of the peak period.

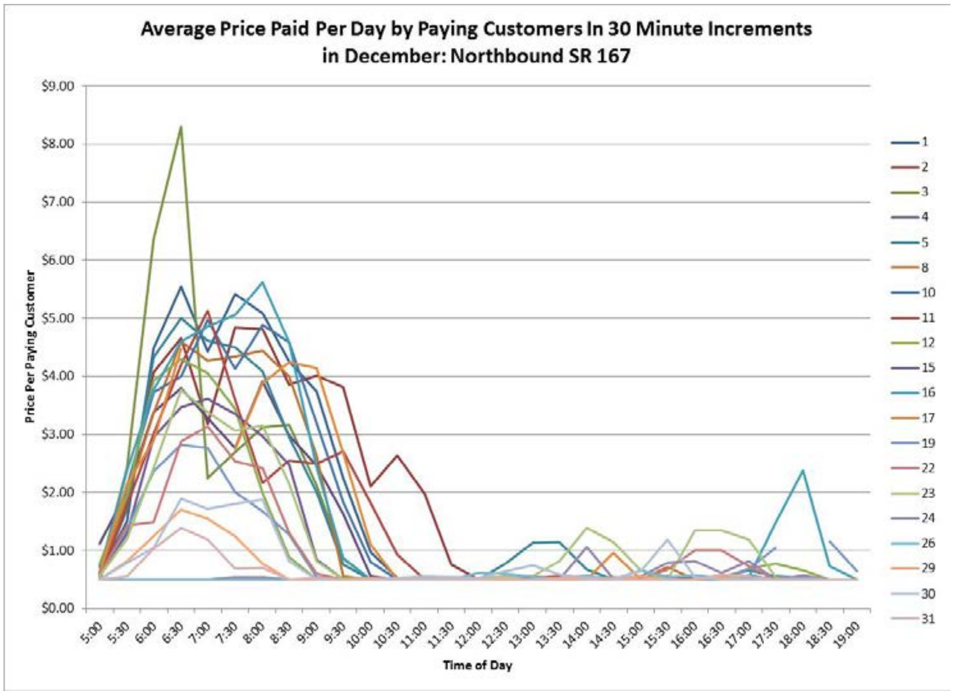


Figure 5-5: Average Price Paid per Paying Customer by Half Hour by Day Northbound SR 167 HOT Lane

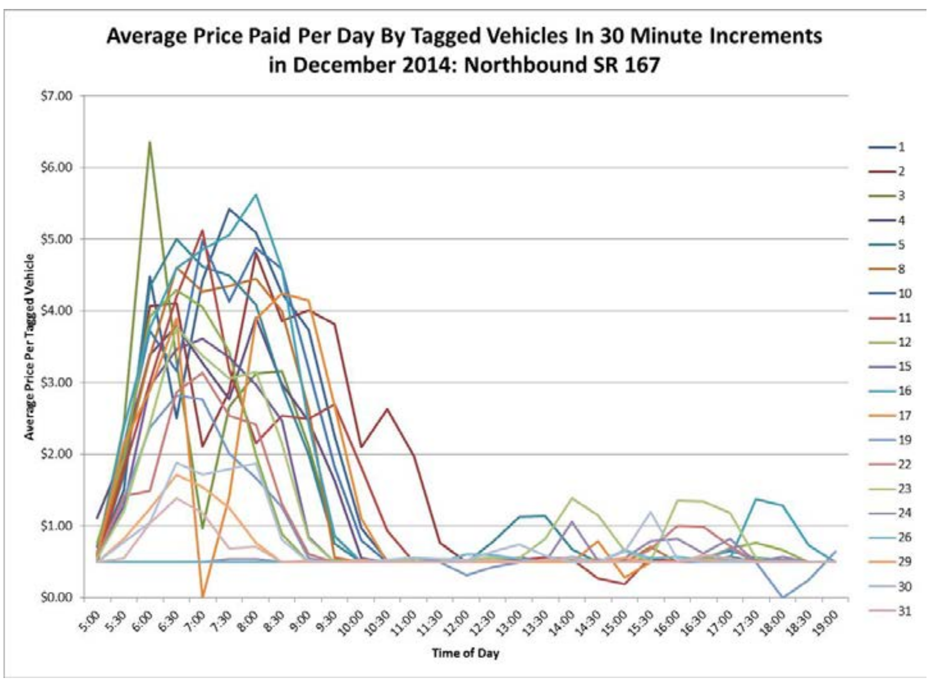


Figure 5-6: Average Price Paid per Tagged Vehicles by Half Hour by Day Northbound SR 167 HOT Lane

In Figure 5-5, the maximum price paid in a half-hour increment on December 3rd was over $8, which occurred at 6:00 AM. The price actually peaked at $9 at about 6:15 in the morning, before the HOT lane converted to HOV Only operations. HOV Only operations lasted until just after 6:50 AM. This did the following:

1) dramatically reduced the mean price paid per customer reported for that day
2) significantly reduced the average price paid for each of the half hours that contained partial "HOV Only" prices
3) dramatically reduced the total revenue collected for that day, since it converted a period when maximum revenue was being collected into a period when no revenue was collected
3) significantly reduced the number of "paying customers" of the HOT lane, even if a large number of tagged vehicles continue to use the lane (thus limiting how much of the intended operational benefit WSDOT was getting from the HOV Only signs).

The first two of these effects can be seen by comparing Figure 5-5 and Figure 5-6. In Figure 5-6, on December 3rd, the peak price per tagged vehicle in the 6:00 AM half hour was just over $6 instead of being over $8 as shown in Figure 5-5. By 7:00 AM the average price per tagged vehicle was $1, while the actual price paid once the lanes legally reopened to paying customers was $2.25, from which it then once again climbed to above $3.

Also seen in both Figure 5-5 and Figure 5-6 is the very low prices charged on the 29th, 30th, and 31st of December. These are not officially "holidays," but many workers take them as vacation (e.g., the Boeing 737 manufacturing plant in Renton is closed to allow all Boeing employees to take that week off) and therefore traffic volumes and congestion were down significantly, greatly reducing the demand—and thus price—for HOT lanes.

Figure 5-7 shows the maximum price paid by customers for use of the northbound lanes during any given half-hour period during each month for which data were available to the project team. At no time during the seven months before the access rule change did prices northbound exceed $6.25. After the rule change, prices hit the maximum value of $9.00 multiple times in four consecutive months. February 2015 was the first month since September 2014 that the northbound corridor did not reach the maximum allowed $9 toll at least once during the month.

The public's reactions to these very high prices were reflected in the public attitude survey that is summarized in Chapter 2 of this report (i.e., many responses in the survey mentioned the high prices).

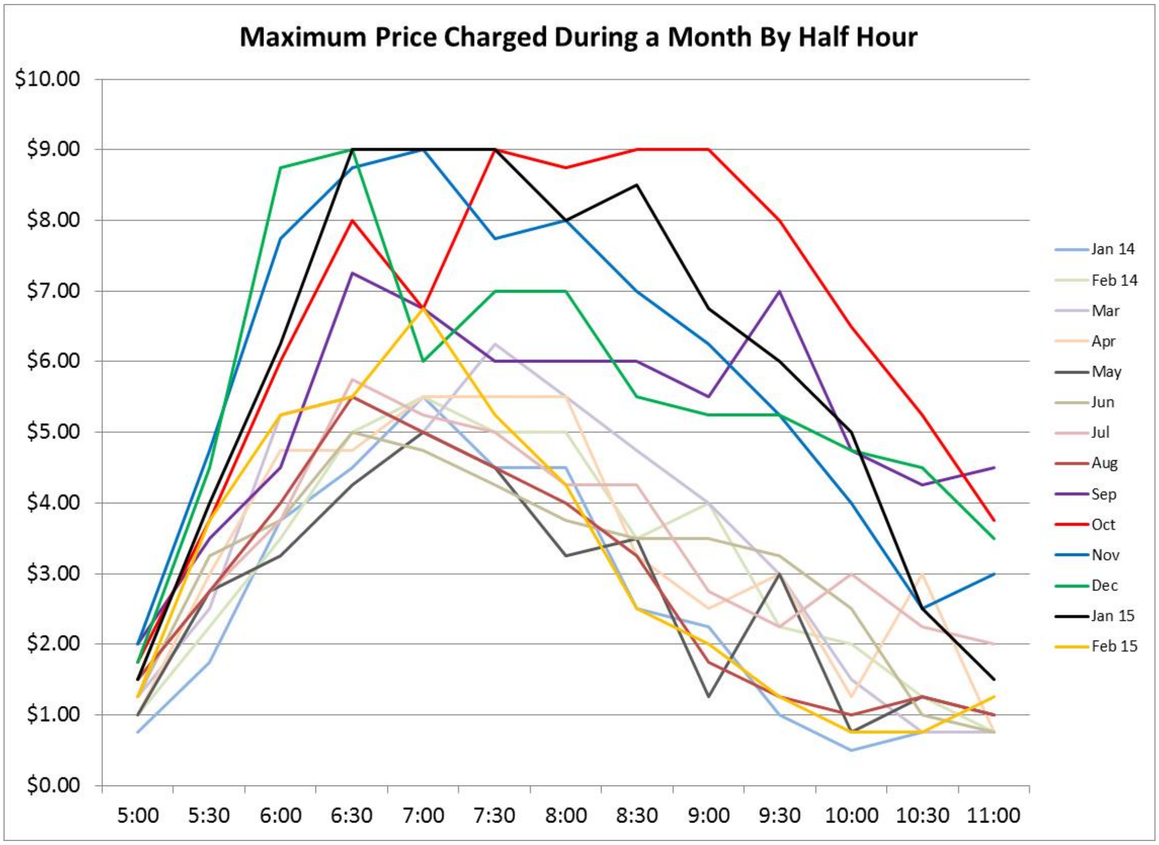


Figure 5-7: Maximum Price Paid by a Customer by Half Hour by Month Northbound SR 167 HOT Lane

Some of these extreme prices can be explained by roadway performance. For example, in October, the HOT lane had significant performance issues. The 80th percentile travel time in the corridor at 8:30 AM was 979 seconds, which equates to averaging 43 mph for the entire corridor. At that average speed, the pricing algorithm would have been actively raising the price to reduce vehicle volumes and increase vehicle speeds. And since that speed was the 80th percentile, at least 20 percent of all October weekdays experienced even worse congestion at 8:30 in the morning. Therefore, it is not surprising that prices were high. (The crash analysis described in the last chapter of this report indicated that many of the crashes that occurred in the corridor in October and November happened northbound in the AM peak period, helping to disrupt traffic flow and increasing pressure on the HOT lane).

Figure 5-8 shows the 80th percentile travel times northbound in the morning peak period for the After months as well as three months for the Before period. It can be seen that the HOT travel times were generally greater (slower) and frequently were in a range (above 980) at which the tolling algorithm was actively trying to improve corridor performance. This was not as common an occurrence in the three Before months illustrated.

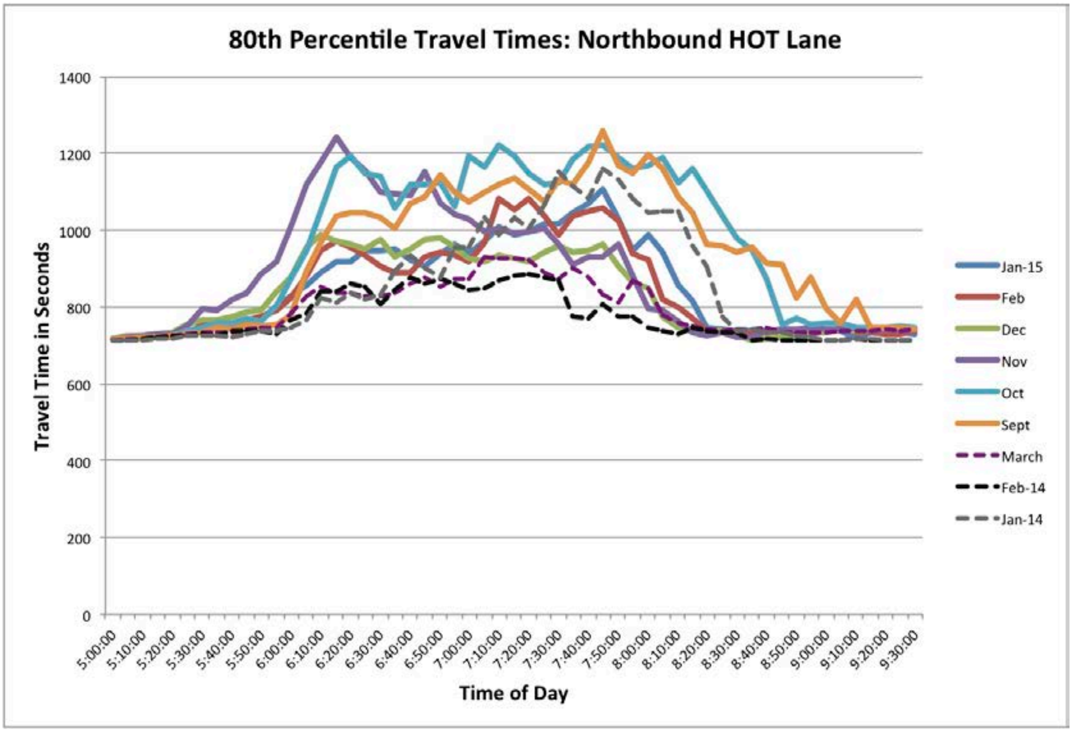


Figure 5-8: 80th Percentile Travel Times by Time of Day and Month
Northbound SR 167 HOT Lane

Southbound Prices per Customer

In the southbound direction, prices also rose considerably after the access rules were changed. Figure 5-9 illustrates the average price paid per paying customer (i.e., not including tagged vehicles entering the HOT lane despite the "HOV Only" sign and paying no toll as a result) for each half hour of the afternoon commute for each month for which pricing data were analyzed. The steep increase in prices that caused negative public reaction and resulted in the change in the HOT pricing algorithm are also obvious, with all of the months between September 2014 and January 2015 showing prices well above those experienced before the HOT lane access change. The decrease in February and continuing price stability since then is also apparent, with southbound afternoon prices mirroring the pattern seen northbound in the AM. That is, prices are now slightly higher than in the Before period but lower than during the first few months of the new access rules.

Southbound, unlike northbound, prices continued to rise even in December after the algorithm change. Southbound prices then dropped in January 2015 (again unlike the northbound direction, where they rose in comparison to December) and continued to drop so that February 2015 shows a price outcome that is similar to that observed before the HOT lane access rule change.

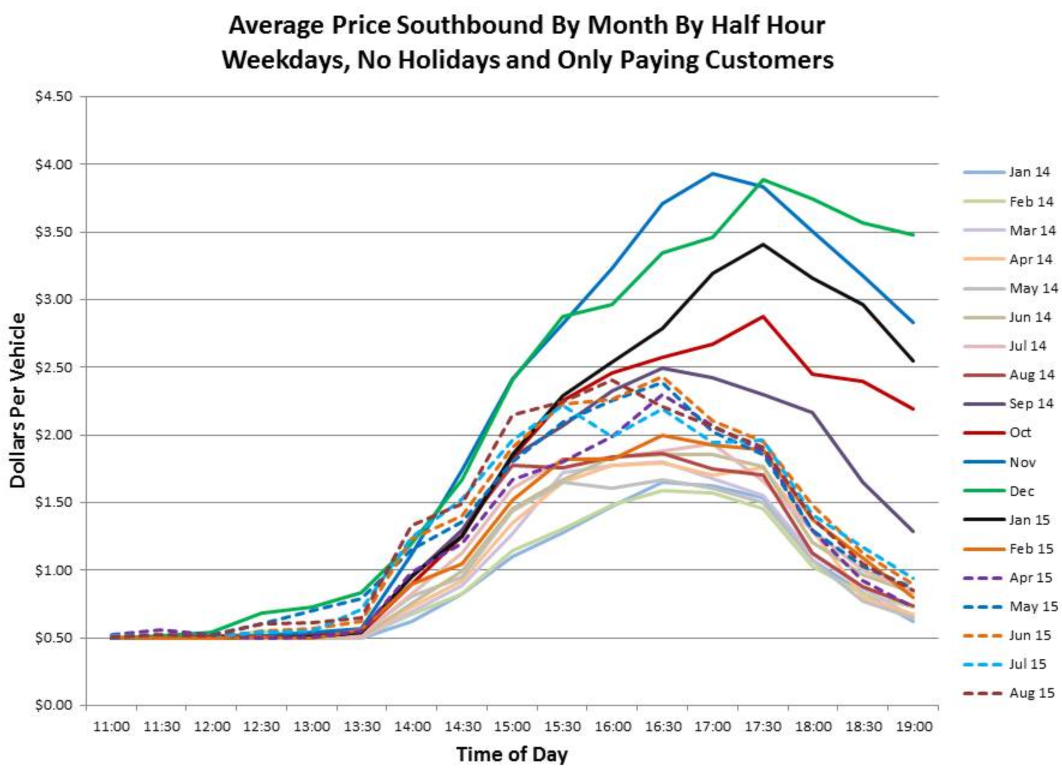


Figure 5-9: Average Weekday Price Paid per Paying Customer by Half Hour by Month – Southbound SR 167

If Figure 5-9 is compared to Figure 5-4, it can be seen that the average peak prices in the southbound PM movement were slightly lower than the prices found in the northbound peak period. In the After period, southbound prices also remained high until 7:00 PM, the end of the tolling period for the day. This suggests that the period during which tolls are charged should be extended later into the evening.

The frequent need for HOT lane prices to remain high into the early evening may also be responsible in part for the fact that in December 2014 the average prices paid southbound exceeded the prices paid northbound (see Figure 5-2).

December prices remained high late into the commute period despite the change in the WSDOT toll algorithm designed to more quickly lower the price. The algorithm change was designed to more quickly lower the HOT lane price when demand was low, but if the HOT lane was still somewhat congested, then prices would remain in place, and this was true late into the day in both December 2014 and January 2015.

Figures 5-10 and 5-11 illustrate the daily December toll rates charged southbound, Figure 5-10 based on only paying customers (no "violators" of the "HOV Only" signs) and Figure 5-11 including all tagged vehicles. These figures show that prices in the southbound direction remained above \$3.00 per vehicle on half of the non-holiday weekdays in December. This is true in both figures. On only three weekdays in December was the HOT lane price below \$1.00 when the tolls were ended at 7:00 PM.

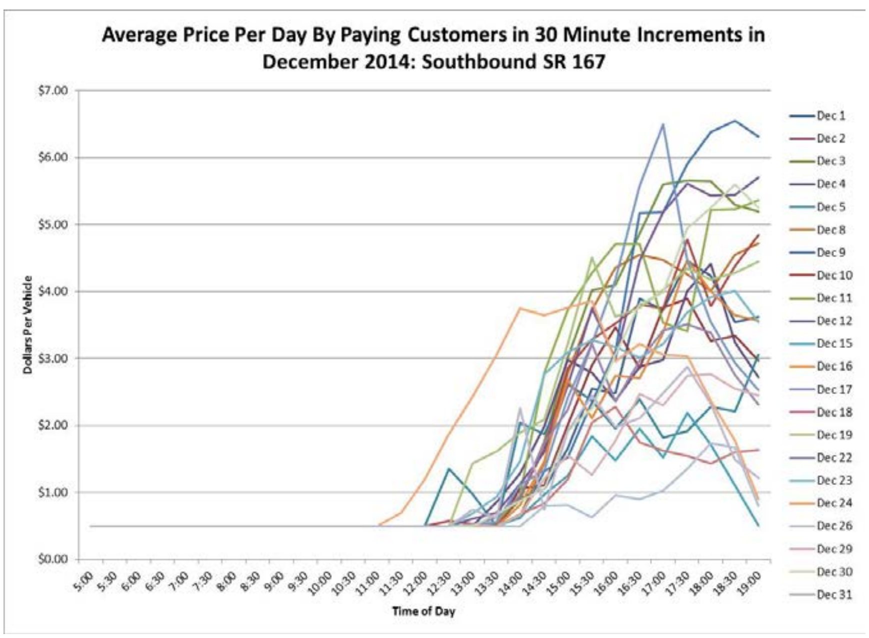


Figure 5-10: Average Price Paid per Paying Customer by Half Hour by Day Southbound SR 167 HOT Lane

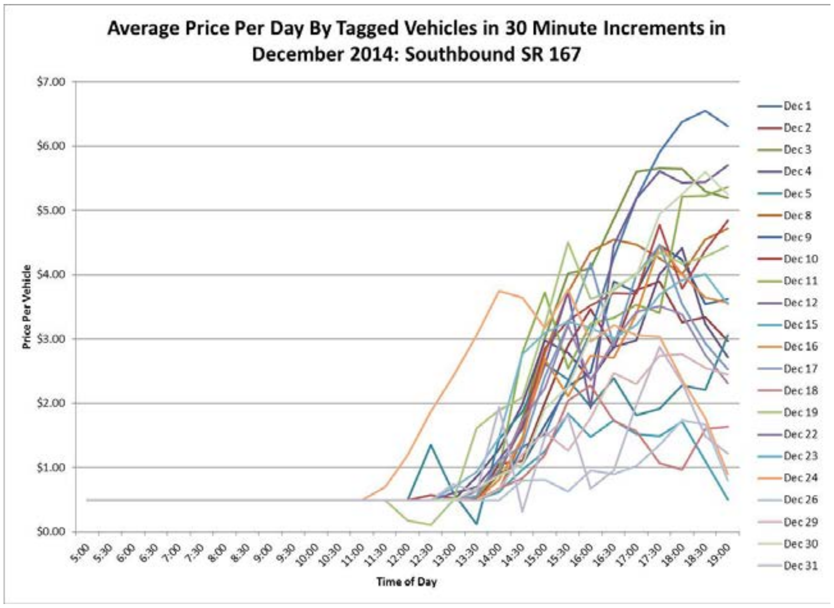


Figure 5-11: Average Price Paid per Tagged Vehicle by Half Hour by Day Southbound SR 167 HOT Lane

These figures also show that the prices set and the revenue generated in the last weekdays days of December 2014 were not as significantly affected in the southbound direction as they were in the northbound direction. Northbound, the AM commute period had very low HOT lane prices because of low commute volumes. Southbound, December 30th had prices that exceeded $5.00 per customer even at 7:00 PM. It is likely that even though many people were on vacation, they were out traveling in the late afternoon for personal reasons, and those volumes were sufficient to form congestion and increase HOT lane use. Similarly on December 31st, congestion was bad enough that the HOV Only designation was imposed a little after 2:00 PM and remained in effect essentially[9] until after 5:00 PM.

While southbound prices can reach the maximum $9 value, this occurred less frequently southbound than northbound. Figure 5-12 shows the maximum price paid during each half hour for each month of the analysis. The $9 maximum price was reached only in two months, November 2014 and January 2015. December 2014 reached a maximum price of only $8.75. But southbound HOV Only pricing occurred on 12 different days in December.

[9] There were some short periods between 2:00 and 5:00 PM in which no tagged vehicles were reported. It is unclear whether the HOV Only designation was removed or simply no tagged vehicles were using the facility at that time.

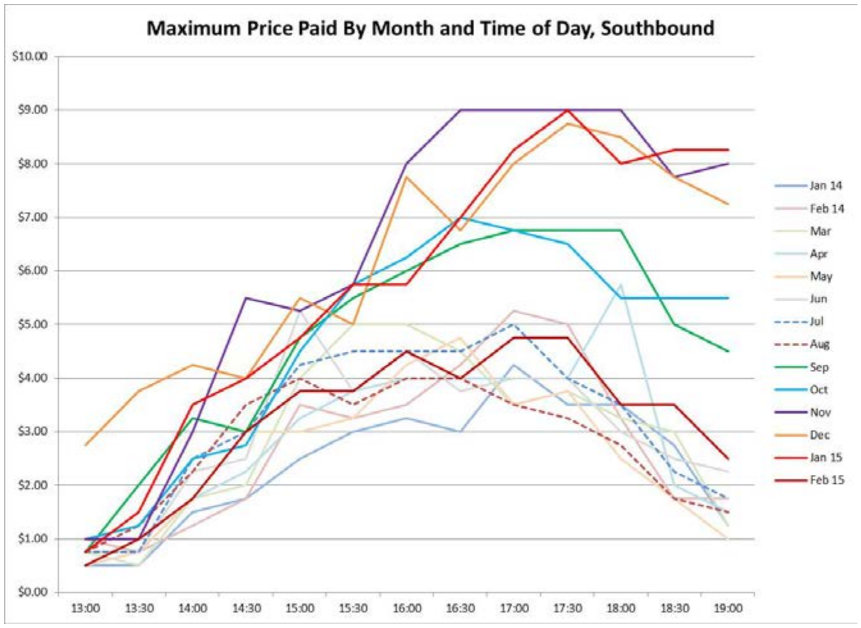


**Figure 5-12: Maximum Price Paid by Half Hour by Month
Southbound SR 167 HOT Lane**

Figure 5-13 shows the monthly mean travel times for the southbound general purpose lanes for the first six months after the HOT lane access rules changed. It also shows the mean travel time southbound for January and February 2014. Figure 5-13 shows that GP travel times were consistently slower than they were in early 2014. It also shows that February 2015 travel times were the lowest to occur since the change in HOT lane access rules, and that December 2014 travel times were similar to those seen in October and November, which helps explain why southbound prices remained high despite the Christmas holidays.

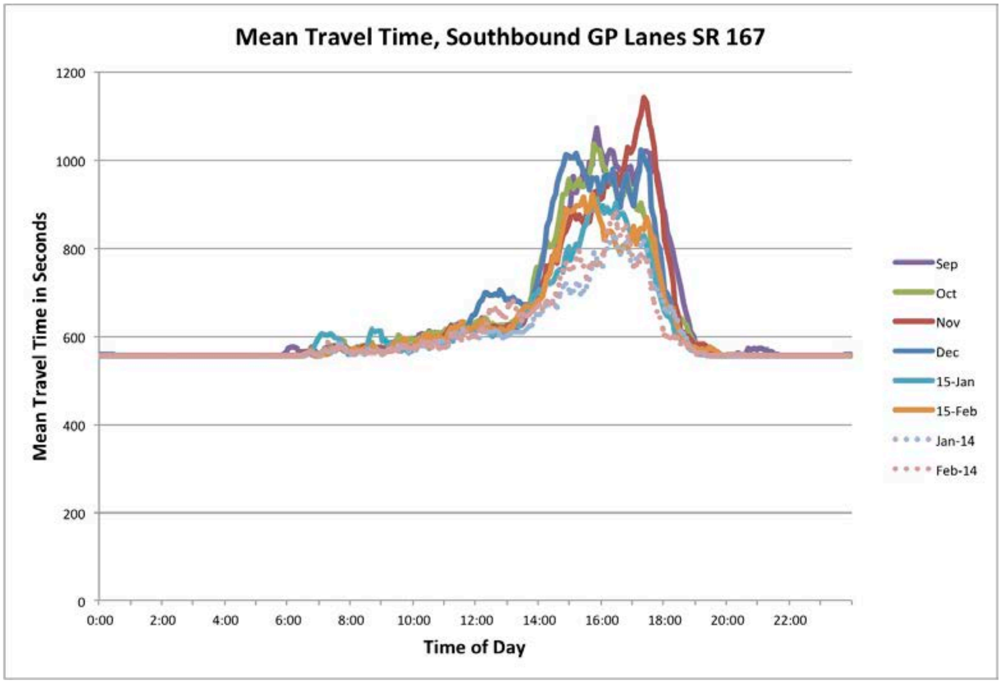


Figure 5-13: Mean Travel Time by Month, Southbound General Purpose Lanes

TOTAL REVENUE

Figure 5-14 shows the total revenue collected by month from January 2014 through August 2015. Revenue totals are shown for northbound and southbound directions separately, as well as for the total of both directions. Revenue collections were up substantially for the first five months since the change in HOT lane access rules, but in February, they dropped back to a value typically found before the change in access rules. However, the price increases before February were not steady. The maximum revenue month was October, with decreases in total revenue occurring in both directions in November (likely due to the fewer number of work days in the month). December revenue continued to drop northbound (in part because of the Christmas holiday commute traffic reduction, and in part because of the two full days of "HOV Only" operation). But southbound, December revenues increased. During April 2015 through August 2015, total revenue per month continued to be somewhat volatile, although typically higher than the revenue obtained before the access rule change. However, total revenue per month has now stabilized below the amounts experienced after the open access rules were first implemented.

Using the number of workdays to normalize the amount of revenue collected to reflect the average price paid per workday (non-holiday weekdays) produced the results shown in Figure 5-15. In this figure, the effects of both the algorithm change and the December holidays become clear. Total workday (non-holiday weekdays) revenue per workday grew from the change in access rules to the end of November. It then declined both north- and southbound in December before rebounding partially in January 2015, only to drop again in February 2015 as congestion eased. From April 2015 through August 2015 the total revenue collected per workday remained higher than before the change to open access but was still lower than that being taken in during the first few months of the new access rules.

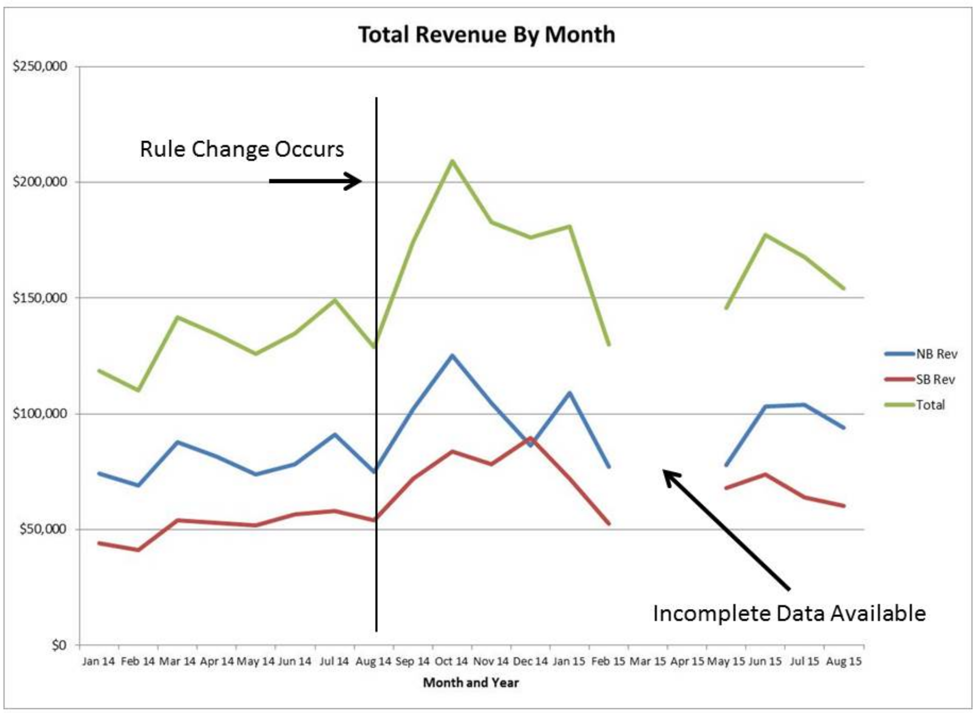


Figure 5-14: Total HOT Lane Revenue, SR 167 Corridor

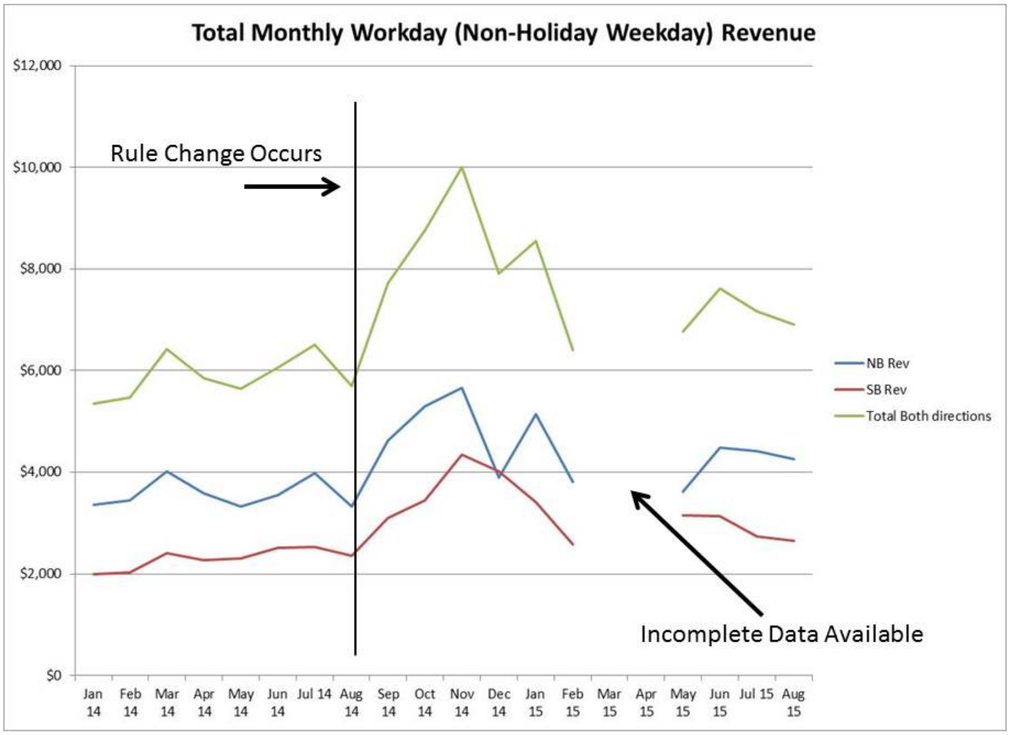


Figure 5-15: Total HOT Lane Revenue per Day, Both Directions, for Non-Holiday Weekdays in the SR 167 Corridor

NUMBER OF PAYING CUSTOMERS

The final metric examined in the revenue category is the number of paying customers. It is clear from the NW Region loop data that traffic volumes in the HOT lane increased. The big question is whether those additional vehicles were paying customers, new carpools, or violators. Figure 5-16 shows the total monthly volume of tagged vehicles between 5:00 AM and 7:00 PM (when SOVs pay to use the HOT lane). Total volumes of vehicles remained flat until November and then dropped, in part because of the smaller number of workdays in November and in part because of rising prices.

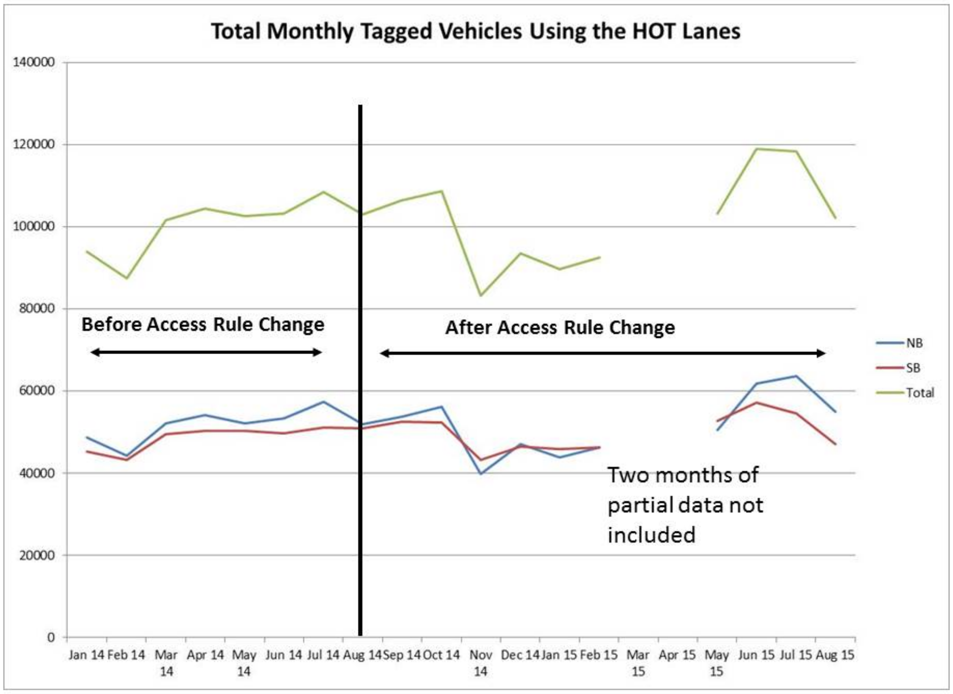


Figure 5-16: Total Numbers of Tagged Vehicle Customers Using the SR 167 HOT Lane Between 5:00 AM and 7:00 PM

Figure 5-17 shows the number of those tagged vehicles that actually paid a toll during weekdays for each of the months in the analysis. Figure 5-17 shows a more pronounced increase in paying customers in July (before the HOT lane rule change) and a more pronounced drop in customers in November (affected by three holidays that fall on weekdays during the month), with a smaller growth in December from that November low.

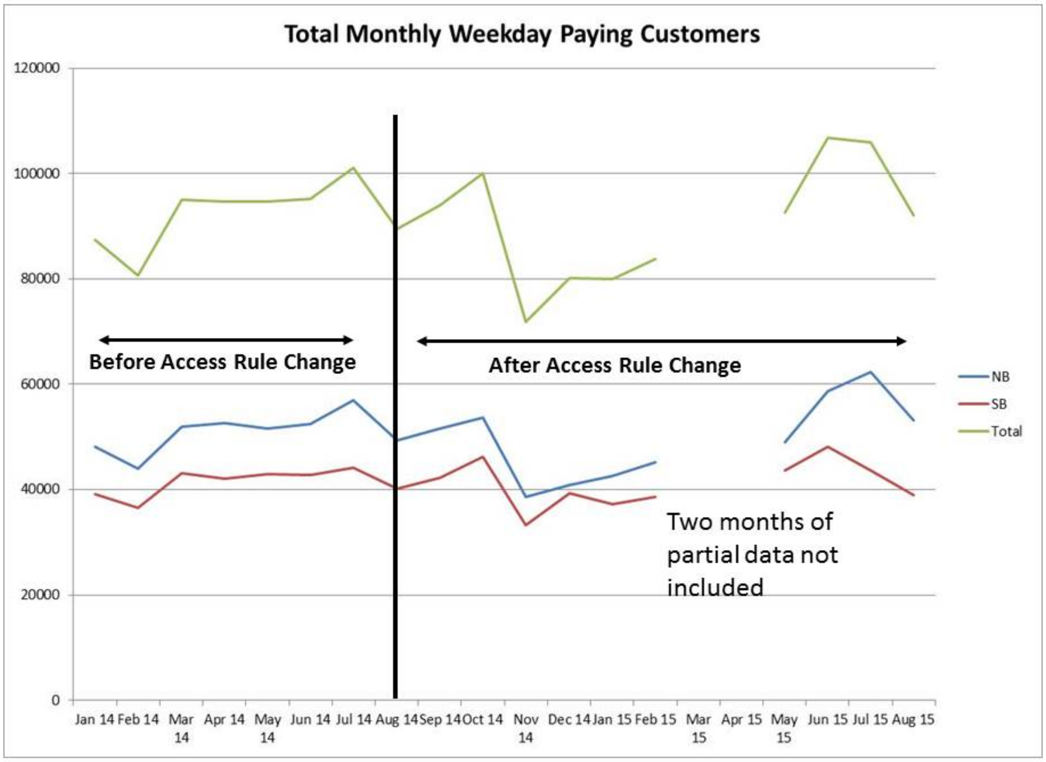


Figure 5-17: Total Numbers of Tagged Vehicle Customers Using the SR 167 HOT Lane Between 5:00 AM and 7:00 PM

Figure 5-18 normalizes the number of paying weekday customers for the number of weekdays in each month. In this version of the customer graph, the most pronounced drop occurred in December, caused by the loss of two complete weekdays when the HOT lane was open to all traffic without charge. But the initial overall trend is still clear: the total number of paying customers each weekday decreased when the access rules changed, despite the overall increase in HOT lane traffic volume. However, note that this analysis was not a "year-over-year" comparison, since the project team did not have access to tolling data before January 2014. For the two months that can be compared year to year, the number of paying customers per day was down in January 2015 in comparison to January 2014 but was slightly greater in February 2015 than in February 2014. This downward trend in the number of paying customers reversed itself in the additional study period. As prices in the corridor came back down, the average number of paying customers grew. The majority of that growth was northbound. The change in southbound use was less consistent from a month to month basis, with an increase in paying customers in May and June 2015 (versus 2014), but a modest decline in July and August.

In general, however, the drop in paying customers after the access rule changes means that either carpooling or violations increased.

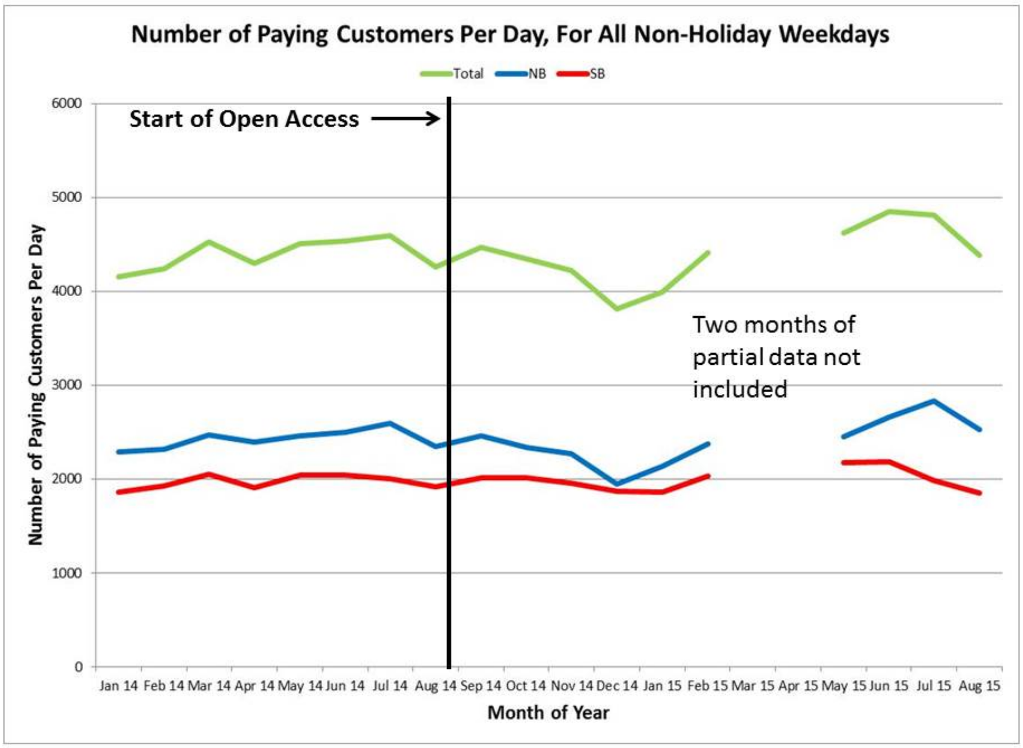


Figure 5-18: Total Paying SR 167 HOT Lane Customers per Weekday

The evidence shows that a number of vehicles that carry electronic toll tags routinely use the HOT lane, regardless of whether signs governing the lane's operation state that the lane is reserved for HOVs only. Given that these vehicles continue to use the lane even when the HOV Only sign is present suggests that many of them also pay (and sometimes pay quite a lot) to use the HOT lane without regard to the price posted. When the HOV Only sign is lit, they are violating the HOT lane rules, and enforcement of the facility has not hindered their use of the facility. (They are, in fact, very good revenue producers for the facility.) But this suggests that other violations may also be growing in the corridor.

In contrast, as noted in the analysis of the public attitude survey data, just under 4 percent of the "aware" survey responders indicated that they carpool more often as a result of the new access rules, and only 1 percent said they carpool less. This suggests that at least some additional carpooling is taking place in the corridor.

So without more concrete corroborating evidence, it is only possible to speculate whether violations of the HOT lane are up, or whether additional carpools are using the HOT lane as a result of the new access rules.

CHAPTER 6: TOLL EVASION

One of the major concerns with the use of open access to the HOT lanes was whether motorists would take advantage of the increased ability to move into and out of the HOT lane to avoid paying tolls at the toll gantries. This chapter of the report describes the analysis performed to examine whether toll evasion increased after implementation of the new access rules. Specifically, we examined whether HOT lane users appeared to exit the HOT lane just before a gantry with toll system detectors, then reenter the HOT lane after the gantry, thereby gaining the travel benefits of the HOT lane without paying the HOT lane fee.

SUMMARY FINDINGS

Two different approaches were used to determine whether an increase in toll evasion was occurring in the corridor because of the change in HOT lane access rules. Neither analytical approach was able to detect significant toll gantry avoidance movement.

This does not mean that toll avoidance is not taking place. But it is not taking place in the form of lane changing movements near the toll gantries designed to avoid paying tolls at those gantries.

One interesting "toll avoidance" mechanism that was noticed in the data was that significant numbers of toll tagged equipped vehicles were still entering the toll lanes when the tolling signs stated "HOV Only." In these instances, no toll is charged to those toll tag equipped vehicles. It is unclear whether those vehicles were in fact carpools—and the drivers have not removed their toll tags—or whether the vehicles were single occupant vehicles that were intentionally or unintentionally violating the "HOV Only" sign posting.

METHODOLOGY

Because of a lack of both manual observation points and CCTV camera locations that could effectively observe movements into and out of the HOT lane in the corridor near the toll gantries, it was not possible to visually observe whether vehicles were weaving around the toll gantries to evade paying the toll. Instead, traffic volume data were collected near the HOT lane toll gantry locations to attempt to detect whether travelers in the HOT lane appeared to be temporarily maneuvering around the gantries to avoid detection and associated fees.

Changes in traffic patterns were investigated to indirectly determine whether these types of HOT lane violations were occurring, and whether they had changed following the start of continuous access. Specifically, the time-of-day patterns of volumes at consecutive HOT lane traffic sensor locations along the corridor were checked to determine whether volumes near a toll gantry differed from volumes observed at detectors located upstream and downstream from those gantries. This analysis is illustrated in Figure 6-1. A substantial increase in volume at points A and C in Figure 6-1, relative to the volume at the gantry itself (Point B), would indicate that drivers were avoiding the toll gantry, especially if the volume at Point E increased relative to volumes at points D and F. This analysis was performed for HOT lane data collection locations near each gantry along the length of the SR 167 corridor, during the Before and After periods. The analysis was performed with data collected during the peak periods, when the HOT lane was likely to be used to achieve a performance benefit, i.e., when the GP lane was likely to be congested. Therefore, data were used from the dominant peak period directions of GP travel of 5:00-10:00 AM (northbound) and 2:00-8:00 PM (southbound).

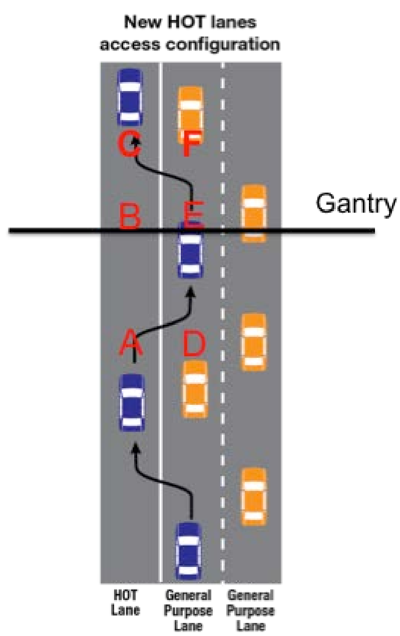


Figure 6-1: Using Volume Counts to Determine Toll Avoidance

Table 6-1 shows the mileposts for each gantry location and the closest sensor to that gantry.

Table 6-1. SR 167 Gantry Locations and Nearest Sensor

Gantry location	Nearest sensor	Difference
NB		
14.05	14.31	-0.26 (downstream)
15.43	15.35	+0.08
17.00	16.87	+0.13
19.02	19.01	+0.01
20.65	20.68	-0.03 (downstream)
23.29	23.42	-0.13 (downstream)
SB		
25.23	25.07	-0.16 (downstream)
23.30	23.42	+0.12
20.13	20.19	+0.06
18.58	18.49	-0.09 (downstream)

The gantry sensor location was critical for detecting possible avoidance maneuvers; the ideal gantry sensor location was close enough to the gantry that it would not inadvertently detect HOT lane vehicles that had either not yet made an avoidance lane change or had not yet moved back into the HOT lane after an avoidance lane change. A travel time threshold of 10 seconds (at 60 mph) was used to define the desired proximity to the gantry; this corresponds to 0.17 miles.

Taking into account a variety of data quality and data availability factors, Table 6-2 is a summary of all candidate gantry locations and their status in the toll avoidance evaluation.

Table 6-2. Summary of SR 167 Gantry Data Evaluation

Gantry Location	Status
NB	
14.05	Gantry sensor is farther from gantry; no upstream HOT lane loop
15.43	Gantry sensor is in former limited access zone
17.00	Gantry sensor is in former limited access zone
19.02	OK
20.65	OK
23.29	OK
SB	
25.23	Insufficient data quality at gantry sensor
23.30	Gantry sensor is in former limited access zone
20.13	Insufficient data quality at upstream sensor
18.58	OK

The result is that four gantry locations were used as primary test locations for possible toll avoidance, both before and after continuous HOV lane access began: MP 19.02 NB, 20.65 NB, 23.29 NB, and 18.58 (SB). In addition, three secondary test locations were determined (MP 15.43 NB, 17.00 NB, and 23.30 SB), though for those locations only After conditions could be evaluated (see Figure 6-2).

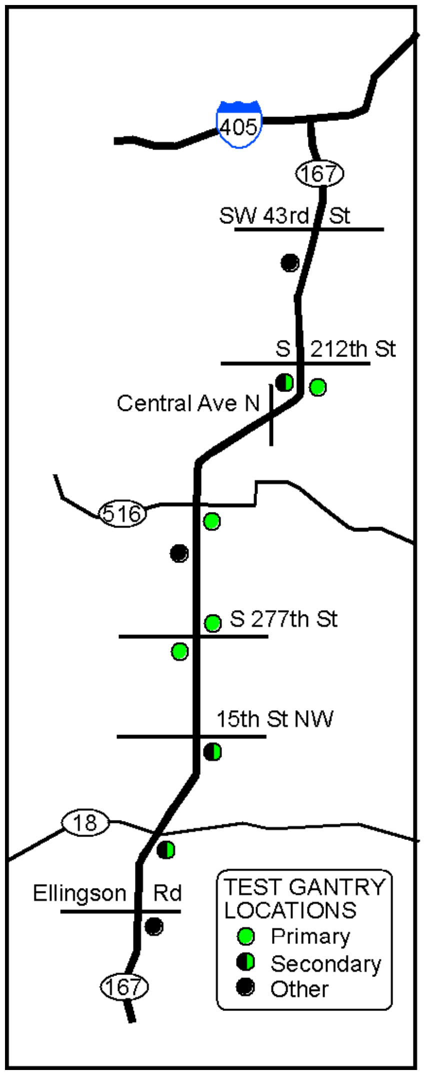


Figure 6-2. Primary and Secondary Toll Avoidance Gantry Test Locations

METHOD 1: VOLUME CHANGES ALONG THE HOT LANE CORRIDOR

This approach looked at changes in volume between consecutive locations as a way to detect gantry avoidance. This is a logical approach if one assumes that in the absence of gantry avoidance, the change in vehicle volume from one location to the next downstream location would be minimal. That is, travelers are willing to pay the toll fee if they receive significant travel time benefits, and therefore they want to stay in the HOT lane for some distance to accrue that benefit, rather than move in and out of the lane or use the HOT lane for only a short distance.

Volumes were compared hourly for the "upstream to gantry" segment (i.e., How much did volumes change from the upstream loop to the gantry loop?), the "gantry to downstream" segment (i.e., How much did volumes change from the gantry loop to the downstream loop?), and the net "upstream loop to downstream loop" segment (i.e., How much did volumes change from the upstream loop to the downstream loop?). This comparison was tabulated hour by hour, for each of the 302 weekdays in the Before and After periods, at each of the test locations. To more easily evaluate the data and avoid removing potentially valuable data, all the hourly volume change data for each segment were summarized as a distribution of the volume differences. Overall volume changes for each segment were also summarized across each seven-month period. Figures 6-3 and 6-4 show the distribution of the hourly volume differences, by segment.

Volume comparisons were then made to determine whether HOT lane travelers appeared to be temporarily moving out of the HOT lane into the adjacent GP lane just before the gantry (to avoid being detected and paying the associated toll fee), then moving back into the HOT lane shortly after the gantry (to continue to take advantage of the higher traffic performance in the HOT lane). If this were occurring, one would expect to see a temporary drop in vehicle volume at the gantry location relative to the upstream volume, as vehicles attempted to avoid detection, followed by a higher vehicle volume at the downstream location, relative to the gantry volume, as avoiders rejoined the HOT lane to continue to benefit from its higher travel performance.

The Method 1 results for the four primary test locations are as follows:

- For the Before condition at all three NB detector locations, vehicle volumes dropped noticeably from the upstream to the gantry location. The average volume drop from the upstream loop to the gantry loop was between 4 percent and 11 percent. However, there was also a volume drop from the gantry to the downstream location, albeit of a smaller magnitude (0 to 2 percent). The net change from the upstream to downstream sensor was therefore dominated by the volume drop from upstream to the gantry (6 to 12 percent).

- The After results for these three primary examples show that in the northbound direction, the trend of dropping volumes from upstream to gantry to downstream continued. The average volume drop from the upstream loop to the gantry loop was between 3 percent and 7 percent, meaning that fewer vehicles left the HOT lane than were found in the Before condition. The volume drop from the gantry to the downstream location was 2 to 5 percent, meaning that fewer vehicles entered the HOT lane. The net change from the upstream to downstream sensor was a decrease of 6 to 12 percent, similar to the range observed in the Before period.

Therefore, the hypothesized temporary drop in volume at the gantry followed by a rebound in volume downstream did not occur. A possible factor is the location of the gantry upstream from a major interchange that might attract HOT lane travelers and therefore permanently reduce the downstream volume in the HOT lane. For example, each of the three NB locations has a significant downstream off-ramp destination within 1.5 miles:

MP 19.01: Downstream is West Willis St. (SR 516) exit
MP 20.65: Downstream is 84th Ave S/Central Ave exit
MP 23.29: Downstream is S.180th St. exit

Even if some of the lower NB volumes observed at the gantry were the result of gantry avoidance, that volume change might be difficult to detect if the magnitude of vehicles leaving the HOT lane to access an upcoming exit was high.

- The SB location in the Before period showed somewhat different results, with volume going up from the upstream location to the gantry, then dropping from the gantry to the downstream location. The average volume increase from the upstream loop to the gantry loop was 4 percent. Volume then dropped by 3 percent from the gantry to the downstream loop, for a net increase of 1 percent. This location (MP 18.58, just north of S. 277th St.) is approaching the end of the SB HOT lane corridor (near MP 17.38).
- In the After condition, instead of increasing, volumes dropped by less than 1 percent from upstream to the gantry, then dropped 4 percent from the gantry to the downstream sensor.

The drop in volume after the gantry in both the Before and After conditions southbound indicates that a significant number vehicles were not avoiding the gantry and then jumping into the HOT lane.

The conclusion is that the available data are not able to detect a significant gantry avoidance movement.

A factor that might be influencing these results, both northbound and southbound, is the close proximity of upstream sensors to the original HOT lane access zones. Because lane changing was allowed in those zones in the Before period, those Before results would have shown greater volume changes simply because of vehicles entering and exiting the HOT lane at those locations. This would potentially mask any before vs. after change in volume trends that was associated with toll avoidance.

DISTRIBUTION OF HOT LANE VOLUME CHANGE	BEFORE			AFTER		1. Gantry at MP 20.65 NB
Vol. Difference:	Upstream to Gantry	Gantry to Downstream	Net (Downstream - Upstream)	Upstream to Gantry	Gantry to Downstream	Net (Downstream - Upstream)
<-150	134	0	142	0	1	6
-100 to -150	292	0	292	11	5	84
-50 to -100	147	5	147	158	122	338
0 to -50	147	431	142	477	522	274
equals zero	18	44	17	10	6	4
0 to 50	15	272	14	95	98	48
50 to 100	1	3	0	4	1	1
100 to 150	0	0	0	0	0	0
>150	1	0	1	0	0	0
Sample size	755	755	755	755	755	755
Total vol by loop	652929	579619	576974	688267	666441	645187
Change, by segment (vol)	-73310	-2645	-75955	-21826	-21254	-43080
Change, % of starting seg. loop	-11%	0%	-12%	-3%	-3%	-6%
	Upstream Loop	Gantry Loop	Downstream Loop	Upstream Loop	Gantry Loop	Downstream Loop

DISTRIBUTION OF HOT LANE VOLUME CHANGE	BEFORE			AFTER		2. Gantry at MP 19.01 NB
Vol. Difference:	Upstream to Gantry	Gantry to Downstream	Net (Downstream - Upstream)	Upstream to Gantry	Gantry to Downstream	Net (Downstream - Upstream)
<-150	0	1	2	20	4	281
-100 to -150	32	0	73	156	44	240
-50 to -100	358	7	461	362	403	181
0 to -50	321	648	183	196	285	42
equals zero	18	28	21	9	3	2
0 to 50	20	71	10	12	9	2
50 to 100	0	0	0	0	0	0
100 to 150	0	0	0	0	0	0
>150	6	0	5	0	7	7
Sample size	755	755	755	755	755	755
Total vol by loop	692801	659026	648233	787756	732371	695971
Change (vol)	-33775	-10793	-44568	-55385	-36400	-91785
Change (% of total vol at that loop	-5%	-2%	-6%	-7%	-5%	-12%
	Upstream Loop	Gantry Loop	Downstream Loop	Upstream Loop	Gantry Loop	Downstream Loop

Figure 6-3. Method 1: Distribution of Volume Changes (Primary Test Locations)

DISTRIBUTION OF HOT LANE VOLUME CHANGE	BEFORE			AFTER		1. Gantry at MP 20.65 NB
Vol. Difference:	Upstream to Gantry	Gantry to Downstream	Net (Downstream - Upstream)	Upstream to Gantry	Gantry to Downstream	Net (Downstream - Upstream)
<-150	134	0	142	0	1	6
-100 to -150	292	0	292	11	5	84
-50 to -100	147	5	147	158	122	338
0 to -50	147	431	142	477	522	274
equals zero	18	44	17	10	6	4
0 to 50	15	272	14	95	98	48
50 to 100	1	3	0	4	1	1
100 to 150	0	0	0	0	0	0
>150	1	0	1	0	0	0
Sample size	755	755	755	755	755	755
Total vol by loop	652929	579619	576974	688267	666441	645187
Change, by segment (vol)	-73310	-2645	-75955	-21826	-21254	-43080
Change, % of starting seg. loop	-11%	0%	-12%	-3%	-3%	-6%
	Upstream Loop	Gantry Loop	Downstream Loop	Upstream Loop	Gantry Loop	Downstream Loop

DISTRIBUTION OF HOT LANE VOLUME CHANGE	BEFORE			AFTER		2. Gantry at MP 19.01 NB
Vol. Difference:	Upstream to Gantry	Gantry to Downstream	Net (Downstream - Upstream)	Upstream to Gantry	Gantry to Downstream	Net (Downstream - Upstream)
<-150	0	1	2	20	4	281
-100 to -150	32	0	73	156	44	240
-50 to -100	358	7	461	362	403	181
0 to -50	321	648	183	196	285	42
equals zero	18	28	21	9	3	2
0 to 50	20	71	10	12	9	2
50 to 100	0	0	0	0	0	0
100 to 150	0	0	0	0	0	0
>150	6	0	5	0	7	7
Sample size	755	755	755	755	755	755
Total vol by loop	692801	659026	648233	787756	732371	695971
Change (vol)	-33775	-10793	-44568	-55385	-36400	-91785
Change (% of total vol at that loop	-5%	-2%	-6%	-7%	-5%	-12%
	Upstream Loop	Gantry Loop	Downstream Loop	Upstream Loop	Gantry Loop	Downstream Loop

Figure 6-4. Method 1: Distribution of Volume Changes (Primary Test Locations, continued)

METHOD 2: VOLUME CHANGE DIFFERENCES ALONG THE HOT LANE CORRIDOR

The second method used to look for toll gantry avoidance focused on changes in volume at each individual location over time, then compared those **volume change profiles** between locations. This approach treated existing volumes at each location as a baseline condition, and focused on how those volumes changed over time and whether the nature of those volume changes varied from location to location in a way that suggests gantry avoidance.

Using that approach, method 2 looked at each of the three relevant sensor locations near a gantry (upstream from the gantry, at the gantry, and downstream from the gantry) individually. For each of the sensors, the change in hourly volumes (at each location, not between locations) was computed during the peak periods (e.g., volume change from 5:00 to 6:00 AM, from 6:00 to 7:00 AM, etc.). These hourly changes at each location were then compared, hour by hour, between the locations that define three segments: upstream to gantry sensor, gantry to downstream sensor, and upstream to downstream sensor.

For example, for a given gantry and a given weekday, we computed the 5:00 to 6:00 AM change for the upstream location and the 5:00 to 6:00 AM change for the gantry location. We then computed the difference in those hourly changes. We continued with this for every hour of every weekday peak period, in the Before and After periods. A distribution of the differences in those volume changes was then developed, similar to the summarizing approach used in Method 1. We did the same for gantry vs. downstream changes in hourly volumes, as well as the net upstream to downstream changes. The results of this analysis are shown in figures 6-4 and 6-5.

If gantry avoidance were not occurring, we would expect minimal differences in the hourly changes for each segment. For example, the change in volume at the upstream sensor from 5:00 AM to 6:00 AM should be similar to the change in volume for 5:00 AM to 6:00 AM at the gantry sensor, if no gantry avoidance was occurring. If the change from upstream to gantry sensor was larger, though (e.g., +100 vehicles at the upstream location, versus +25 vehicles at the gantry location, for 5:00 AM to 6:00 AM), this might suggest that the other vehicles (75, in the example) left the HOT lane. If in turn the volume change at the downstream sensor for that same hour was +100 vehicles, this might suggest that those 75 vehicles left only temporarily and then returned to the HOT lane, perhaps to avoid the gantry-based detector.

However, the Method 2 results for the four primary examples showed that for all cases, the distribution of hourly vehicle volume changes from the upstream to the gantry location or from the gantry to the downstream location did not change significantly; the differences generally were centered around zero. These results also did not change significantly between the Before period and the After period. These results differ from those of Method 1, which revealed a distribution of results generally skewed in one direction or another, and usually a drop in volume at the gantry location that did not rebound at the downstream location.

The conclusion once again is that the available data are not able to detect vehicle lane changing behavior that would indicate that a significant gantry avoidance movement was occurring, at least in the vicinity of the gantries.

DISTRIBUTION OF DIFF. IN HOT LANE VOLUME CHANGE — **1. Gantry at MP 20.65 NB**

Vol. Difference:	BEFORE: Upstream to Gantry	BEFORE: Gantry to Downstream	BEFORE: Net (Downstream - Upstream)	AFTER: Upstream to Gantry	AFTER: Gantry to Downstream	AFTER: Net (Downstream - Upstream)
<-150	0	0	0	0	1	0
-100 to -150	0	0	0	1	1	5
-50 to -100	34	7	33	13	22	29
0 to -50	200	283	184	192	232	171
equals zero	16	25	14	7	13	8
0 to 50	175	279	204	344	288	265
50 to 100	147	10	132	41	43	98
100 to 150	28	0	35	6	4	24
>150	4	0	2	0	0	4
Sample size	604	604	604	604	604	604

DISTRIBUTION OF DIFF. IN HOT LANE VOLUME CHANGE — **2. Gantry at MP 19.01 NB**

Vol. Difference:	BEFORE: Upstream to Gantry	BEFORE: Gantry to Downstream	BEFORE: Net (Downstream - Upstream)	AFTER: Upstream to Gantry	AFTER: Gantry to Downstream	AFTER: Net (Downstream - Upstream)
<-150	2	1	2	0	2	2
-100 to -150	1	0	2	6	2	10
-50 to -100	32	3	28	70	8	88
0 to -50	237	272	230	245	201	189
equals zero	17	23	18	9	8	4
0 to 50	271	301	275	184	335	164
50 to 100	39	4	46	82	44	98
100 to 150	3	0	2	8	2	45
>150	2	0	1	0	2	4
Sample size	604	604	604	604	604	604

Figure 6-5. Method 2: Distribution of Differences in Volume Changes (Primary Test Locations)

DISTRIBUTION OF DIFF. IN HOT LANE VOLUME CHANGE — **3. Gantry at MP 23.29 NB**

	BEFORE			AFTER		
Vol. Difference:	Upstream to Gantry	Gantry to Downstream	Net (Downstream - Upstream)	Upstream to Gantry	Gantry to Downstream	Net (Downstream - Upstream)
<-150	11	0	11	1	0	5
-100 to -150	41	2	47	8	5	8
-50 to -100	64	20	49	64	23	59
0 to -50	123	260	142	229	240	228
equals zero	16	22	13	9	9	6
0 to 50	217	268	188	218	273	198
50 to 100	99	29	114	68	42	65
100 to 150	27	3	28	6	10	24
>150	6	0	12	1	2	11
Sample size	604	604	604	604	604	604

DISTRIBUTION OF DIFF. IN HOT LANE VOLUME CHANGE — **4. Gantry at MP 18.58 SB**

	BEFORE			AFTER		
Vol. Difference:	Upstream to Gantry	Gantry to Downstream	Net (Downstream - Upstream)	Upstream to Gantry	Gantry to Downstream	Net (Downstream - Upstream)
<-150	4	0	3	1	1	1
-100 to -150	18	0	14	15	0	23
-50 to -100	115	1	96	86	2	86
0 to -50	223	304	228	226	301	218
equals zero	22	49	23	13	19	14
0 to 50	254	390	255	268	392	224
50 to 100	89	10	101	105	35	105
100 to 150	24	0	22	35	3	58
>150	6	1	13	6	2	26
Sample size	755	755	755	755	755	755

Figure 6-6. Method 2: Distribution of Differences in Volume Changes (Primary Test Locations, continued)

CHAPTER 7: COLLISION FREQUENCY AND SEVERITY

To examine whether the change in HOT lane access rules changed the safety of travel in the corridor, vehicle crash data were collected and examined. Crash rates and crash characteristics were compared for before and after the HOT access rules changed. For this analysis, crash data were available through the end of April 2015. Consequently, the majority of comparisons used an "After" time period of September 1, 2014, to April 30, 2015. The "Before" period was for September 2, 2013, to April 30, 2015. However, crash data were also extracted for 2011 and 2012 to allow a more complete understanding of the historical crash patterns within the corridor. In addition, partial data were available for May 2015. These data are presented but were not used in the analysis because they did not represent all crashes in May.

Crashes were examined separately for northbound (increasing) and southbound (decreasing) directions of SR 167. In addition to examining the corridor as a whole, the research team emphasized crashes in the HOT and left-most GP lanes, since those are the lanes most affected by vehicles getting into and out of the HOT lanes and were therefore most affected by the change in access rules.

SUMMARY FINDINGS

SR 167 showed a modest increase in the number of vehicle crashes occurring in the corridor since the change in operating rules that allows open access to the HOT lane. However, the evidence remains insufficient to indicate that the increase in crashes was a direct result of the rule change. Crash rates in the corridor were already growing in the beginning of 2014, before the change in access. In addition, the change was too small and too variable to be statistically significant, given the variability in the number of crashes occurring over time.

Changes in crash rates are discussed by corridor direction below.

NORTHBOUND (INCREASING) DIRECTION

The primary northbound congestion in the corridor occurs during the morning commute period, although there is a small amount of congestion northbound in the afternoon.

Consequently, the majority of HOT lane use occurs in the AM peak period, and that is when the majority of northbound revenue is obtained and when HOT lane prices are typically highest.

Total Daily Crashes

Table 7-1 lists the Before and After crash statistics in the increasing direction on SR 167. It covers all crashes in the increasing direction from May 1, 2013, through what was processed in 2015 (which did not include the entire month of May).

Table 7-1: Northbound Crashes Before and After HOT Access Rule Changes

	2013	2014	2015
January		***25***	**29**
February		***25***	**24**
March		***23***	**26**
April		***30***	**28**
May	21	17	**16**
June	13	34	
July	16	19	
August	11	24	
September	***35***	**27**	
October	***13***	**29**	
November	***20***	**25**	
December	***17***	**30**	

The ***Before*** period crashes are shown in ***bold Italics.*** The **After** period crashes are shown in **plain bold** text.

Table 7-1 shows an increase in the total number of crashes that occurred in the eight full months after the 2014 facility change in comparison to the same eight months from the previous year (218 versus 188 crashes). However, that increase did not occur consistently during the eight-month period. That is, while the average number of crashes per month was up 16 percent, in three of the eight months the number of post-change crashes was lower than in the same months one year before the change.

If the months of May through July 2014 (also before the change in HOT lane rules) are included in the examination, then the monthly crash rate appears to have started increasing in January 2014, and the months included in the After portion of the HOT lane evaluation were just a continuation of that trend. The largest number of crashes in a month actually occurred in June 2014—before the access rule change. The number of post-change crashes in the corridor was also higher than the numbers in previous years (e.g., 2011 and 2012).

These factors suggest that the changes in the access rules are not significantly responsible for the increase in crashes observed northbound along the corridor. Additional years of After crash data would be required to state this outcome with any level of statistical certainty.

As discussed earlier in this report, both total vehicle volumes and AM peak period vehicle volumes in the corridor increased during the After period in comparison to the Before period. However, comparing the number of monthly crashes with observed traffic volumes in the corridor did not show a significant correlation (see Figure 7-1).

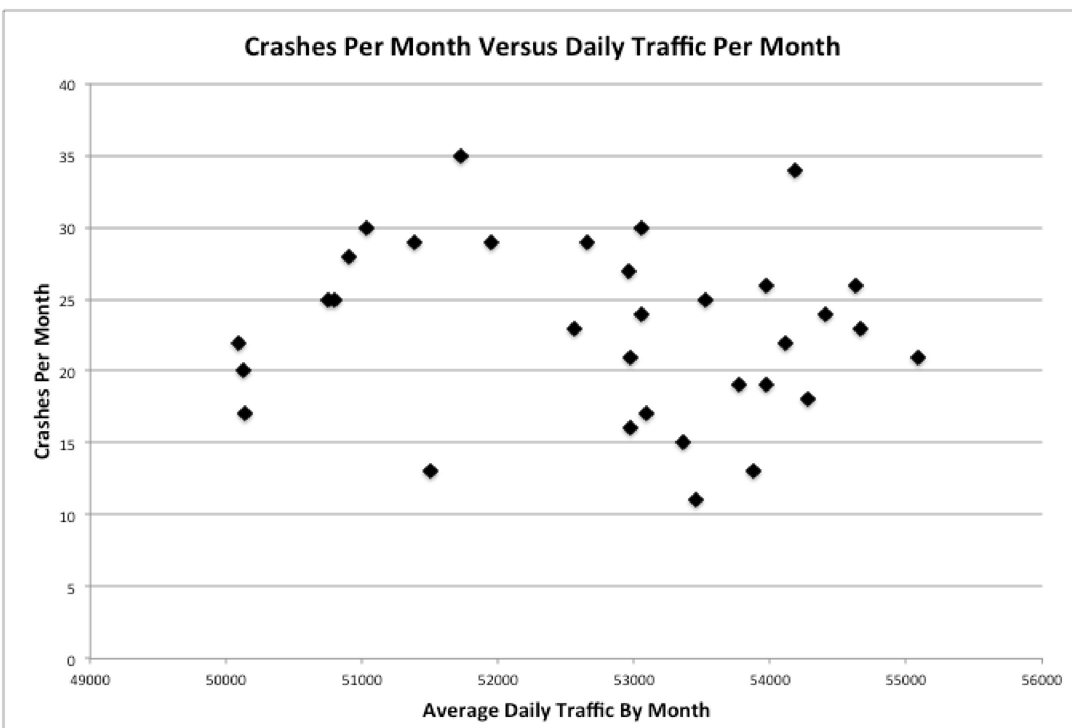


Figure 7-1: Comparison of Crashes Each Month with Average Monthly Weekday Volume

<u>Northbound AM Peak Period Crashes</u>

When we restricted the Before/After crash analysis to the AM commute period (5:00 AM through 9:59 AM), when the HOT lane was most heavily used in the northbound direction, then the increase in crashes was even larger than the increase for total crashes. The total number of AM peak period crashes increased by 22 percent in the eight-month After period in comparison to the same eight months one year before the HOT access rule change. However, as with daily crashes, three of the five months in the comparison actually exhibited a decline in vehicle crashes per month (see Table 7-2). In addition, the number of crashes observed each month of the After period was well within the bounds of the corridor's previous experience.

Table 7-2: Northbound AM Peak Period Crashes Before and After HOT Access Rule Changes

	2013	**2014**	**2015**
January		***11***	**11**
February		***9***	**8**
March		***10***	**12**
April		***13***	**10**
May	6	4	3
June	4	15	
July	4	9	
August	2	7	
September	***11***	**8**	
October	***4***	**13**	
November	***8***	**12**	
December	***2***	**9**	

The ***Before*** period crashes are shown in ***bold Italics.*** The **After** period crashes are shown in **plain bold** text.

The majority of the crash increases occurred in October through December. In comparison to earlier years (2011 and 2012), the Fall 2014 crash rates were not unusually high. Instead, the Fall 2013 crash rates were unusually low in comparison to 2011, 2012, or 2014 (2014 being after the change in access rules). In contrast, the Winter 2015 crash rates (After period) were very similar to the Winter 2014 crash rates (Before period). The After crash rates were slightly higher than those observed in the Winter of 2011 and Winter of 2012, but they were still within the range of crashes typically observed.

Even if the increase in crashes was not a statistically significant change in safety, the higher number of crashes in the peak period did contribute to the increase in northbound commute period travel times in the Fall of 2014 (After period) over those in the Before comparison months. Detailed analysis of the crash data in relation to the travel time data also showed that the timing of crashes played a large role in how much congestion they caused.

In October and November 2014, early in the After period, crashes often happened early in the peak period. The combination of the increased number of crashes and the early time they occurred helps explain why October 2014 experienced a large amount of congestion. Because of the crashes, congestion started early in the day, and the peak period volumes resulted in significant queuing that increased both the cost for using the HOT lane and travel times in the corridor. Four of the morning peak period crashes in October also occurred in the last 6 miles of the corridor, meaning that the back-up from those crashes could grow within the travel time computation. (When crashes occur at the southern end of the corridor, the queue forms south of where the travel time computation is performed.)

Conversely, while a large number of crashes occurred in the AM peak in June 2014, because those crashes typically occurred later in the commute period than the crashes in October and November of 2014, the June crashes had less impact on congestion levels and travel times during the heart of the peak period. This means that they had less of an impact on the price required to keep the HOT lane flowing freely.

SOUTHBOUND (DECREASING) DIRECTION

The afternoon commute period is the primary time when congestion forms southbound in the decreasing milepost direction of the corridor. There is no routine congestion southbound during the AM commute period. Consequently, the majority of HOT lane use occurs in the PM peak period, the majority of crashes occur then, and that is when prices are typically highest and the majority of southbound revenue is obtained.

Total Daily Crashes

Table 7-3 lists the total monthly Before and After crash statistics for southbound SR 167. It covers all crashes in the decreasing direction from May 1, 2013, through what was processed in 2015 (which did not include the entire month of May).

Table 7-3: Southbound Monthly Crashes *Before* and After HOT Lane Access Rule Changes

	2013	2014	2015
January		***14***	**30**
February		***21***	**16**
March		***19***	**21**
April		***22***	**37**
May	20	15	23
June	23	16	
July	17	28	
August	31	25	
September	***25***	**31**	
October	***17***	**30**	
November	***19***	**24**	
December	***17***	**18**	

The ***Before*** period crashes are shown in ***bold Italics.*** The **After** period crashes are shown in **plain bold** text.

As with the northbound direction of travel, there was an overall increase in the total number of crashes after the change in operating rules was implemented. Total crashes in the corridor were up 34 percent during the first eight months of the new operating rules in comparison to the same eight months in the Before period (September 2013 through April 2014). However, unlike the northbound direction, the After period number of southbound crashes was slightly larger than the number that occurred in the first five months of 2014. Also unlike the northbound direction, all but one of the nine months since the rule change occurred showed an increase in crashes in comparison to one year earlier.

Arguing against attributing the increase in crashes in the After period to the change in HOT access rules is the fact that traffic volumes increased throughout the corridor during the After period. In addition, the number of crashes observed in the After period was not unusual in comparison to historical monthly crash rates. In fact, the 2013-2014 Before period crashes were typically lower than monthly crash rates in 2011 and 2012.

PM Peak Period Crashes

If the southbound analysis is restricted to just the PM commute period (3:00 PM through 7:59 PM), then the increase in crashes observed after the new HOT lane access rules were implemented is particularly apparent in September and October of 2014, immediately after the rule change occurred (See Table 7-4). However, unlike the AM peak in the northbound direction, the November and December crash rates in the southbound direction in the PM peak were modest in comparison to the previous (2013) conditions. Also, unlike the northbound AM peak period, the monthly crash rate southbound in the first five months of 2015 was generally up in comparison to the previous year, while the AM crash rates were essentially stable in comparison to the previous year.

Overall, the number of crashes observed southbound was within the bounds of the corridor's performance in the first half of 2014 (except for September 2014, which experienced a marginally new high in terms of crashes per month).

As with the northbound AM peak period, there is no good correlation between monthly crash rates and either average daily traffic for the month or average peak period traffic for the month. Average monthly traffic volumes in the After period increased modestly from the traffic volumes found in the Before period for the same months of the year. Average southbound PM peak period volumes also increased modestly for each of the months in the Before/After comparison. Therefore, although it is possible that the modest increase in traffic volume helped cause additional congestion, which in turn increased the crash rate, the modest level of correlation between volume increases and crash increases, combined with the limited duration of this test, means that we cannot state that the increase in traffic volume caused the increase in crashes. Neither can the crash rate increase be directly associated with the change in HOT lane access rules.

Table 7-4: Southbound PM Peak Crashes *Before* and After HOT Lane Access Rule Changes

	2013	2014	2015
January		**8**	***12***
February		**8**	***9***
March		**8**	***7***
April		**12**	***17***
May	12	8	10
June	12	9	
July	5	13	
August	15	13	
September	***12***	**19**	
October	***7***	**16**	
November	***8***	**9**	
December	***7***	**7**	

The ***Before*** period crashes are shown in ***bold Italics.*** The **After** period crashes are shown in **plain bold** text.

LANE CHANGING CRASHES

One of the concerns of allowing continuous access to and from the HOT lane was that vehicles merging to/from the HOT lane at the driver's discretion would increase the number of merge-related crashes. That is, the change would increase the frequency with which slower moving vehicles darted into the path of faster moving vehicles in the HOT lane. This was countered by the argument that giving drivers more opportunity to choose locations to enter and exit the HOT lane would improve safety because the original limited access point rules could force drivers to merge/diverge when openings were less conducive to lane changes.

To examine this topic, crash data were examined for just those crashes associated with lane changing maneuvers involving either the left-most GP lane or the HOT lane. Again, the primary analysis was performed for the eight-month After period versus the same eight months in the previous year. For additional historical context, data were obtained for those same months for both 2011 and 2012. Lane change crashes involving vehicles in lane 1—the right most lane of travel—were NOT examined, as that lane is not directly affected by movements into and out of the HOT lane.

Like the previously discussed crash results, the lane change crash outcomes were inconclusive.

In the increasing (northbound) direction of travel, crashes involving a lane changing movement decreased from 23 crashes in the Before period to 18 crashes in the After period. Both of these eight-month statistics were larger than the 11 lane change crashes reported in 2012. However, in 2011, 20 lane change crashes were reported. Therefore, we cannot say that a trend is present, or that the new access rules increased or decreased the likelihood of a lane changing crash.

In the decreasing (southbound) direction, lane change crashes did increase from 10 in the eight months before the change in access rules to 19 in the eight months after the rule change. This mimics the general increase in southbound crashes discussed earlier. However, again, the After period crash statistics were very comparable to the number of lane change crashes that occurred in the corresponding months of 2011 (10 crashes) and 2012 (20 crashes).

The simple conclusion is that no statistically valid change in lane change involved crash rates was apparent in the data.

CRASH SEVERITY

When the crash analysis was restricted to the HOT lane and the GP lane next to that lane, there was no significant change in the severity of crashes that occurred during the Before and After period. While the After time period had slightly more crashes than the Before period, those crashes were not significantly different than in the Before period. Neither the northbound or southbound direction of travel experienced a fatal collision that was connected to the HOT lane during either period. There was one fatal collision in the corridor in March 2014 (before the HOT access rule change), but that crash occurred southbound, south of the HOT facility, and involved a drunk driver. The fraction of crashes that involved injuries was remarkably consistent between the Before and After periods.

Although in the northbound direction of travel crashes in the After period increased from 103 to 115, the fraction of crashes that involved injuries was unchanged at 33.0 percent. In the southbound direction, the number of crashes increased in the After period from 86 to 119. The fraction of crashes that involved injuries grew very slightly from 41.9 percent to 42.9 percent. This change was not statistically significant. Therefore, it can be concluded that the change in HOT lane access rules did not result in an increase in the severity of crashes occurring in the corridor.

CHAPTER 8: TRANSIT OPERATIONS

Two transit agencies, King County Metro and Sound Transit, submitted letters to FHWA in support of the access rule change. Both agencies expected the change to result in easier, safer access to HOT lanes, which in turn should improve the operational characteristics of transit routes operating in HOT lanes. Sound Transit is the only agency that operates buses within the SR 167 HOT lane, and Pierce Transit physically operates those buses under contract to Sound Transit.

Pierce Transit staff were asked about their experiences with the access rule change. Responses were obtained from the Safety and Training Office, from a number of operators who drive the route, and from a number of service supervisors who work in the corridor. The responses were all positive. Specific comments received are shown below, separated by the source of the response.

No direct changes in service reliability were associated with the change in access rules, but the two ST routes that use SR 167 both also use I-405 to Bellevue, which can experience very congested HOV lanes, and thus any improvements occurring on SR 167 could easily have been lost on I-405. Operators did comment that the improved ability to access the HOT lane helped keep them on schedule.

TRANSIT OPERATOR RESPONSES

From the Safety and Training Office

"I looked at the HOV lane on 167 and had the driver move into and out of them as if they were doing the 566 route. The driver had no problem going from the HOT lane and taking the exits or getting back into the HOT lane after merging back onto 167."

From Operators

"Yes, I can get on at Kent and have a smooth ride."

"Really like since SR 167 drivers are much more courteous and it really helps in keeping schedule."

"Really like it, especially since they got rid of the double lines so you can easily maneuver in and out if necessary."

"It is great. Every driver I speak to really likes having these HOT lanes. We are looking forward to them expanding."

From Service Supervision

"I like the ability for the coaches to enter and exit the HOT lanes on SR 167. We were getting complaints from the passengers if a driver could not make it over to the HOT lanes in time. And they would complain if the driver crossed the lanes. And they would complain if they didn't. So, I think the ability to get in and out is much better and it's faster. You might think that it is more dangerous with this ability but it is the same as I-5. Operators just need to be diligent and pay attention to what others are doing."

CONCLUSIONS

The transit agencies are pleased with the change in access rules. It is clear that both the operators and the supervisors are happy with the change in access. The fact that the change in HOT access rules has also removed one more topic for complaints is also a strong positive for the agencies.

It is clear from the transit agency perspective that the HOT lane access rule change is viewed as an improvement.

APPENDIX
ADDITIONAL GRAPHICS DESCRIBING CHANGES IN VOLUME FOR APRIL 2014 – AUGUST 2014 VERSUS APRIL 2015 – AUGUST 2015

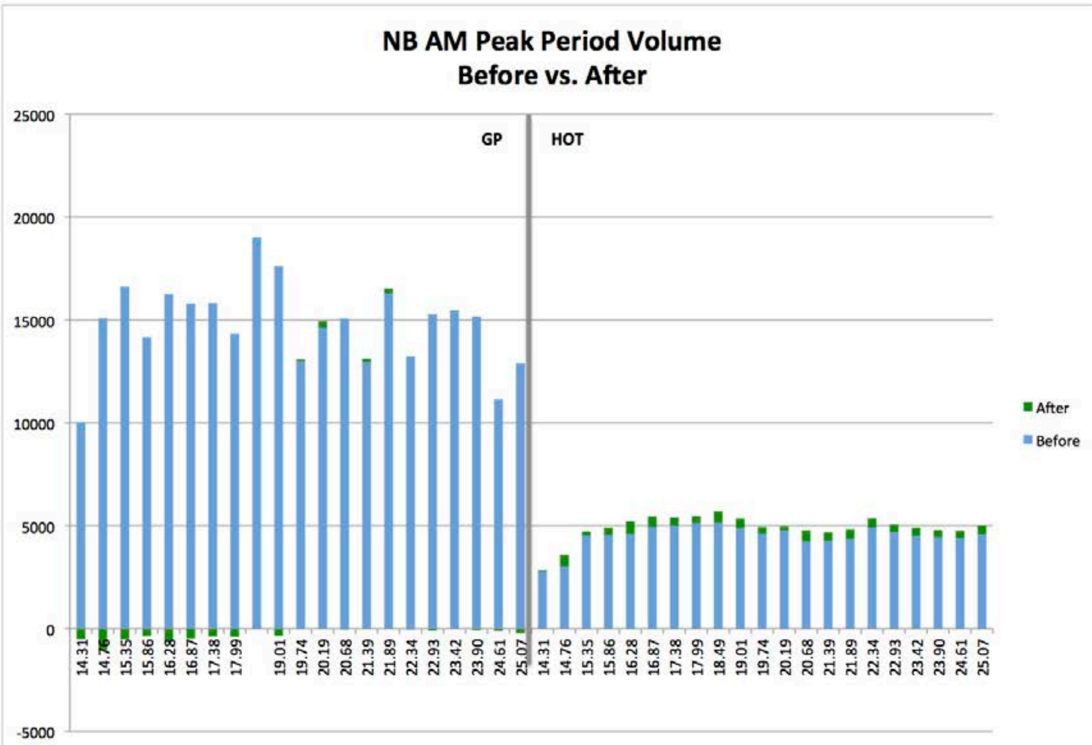


Figure A-1: Northbound AM Peak Period Volumes Before and After Access Rule Changes, April-August 2014 versus April-August 2015

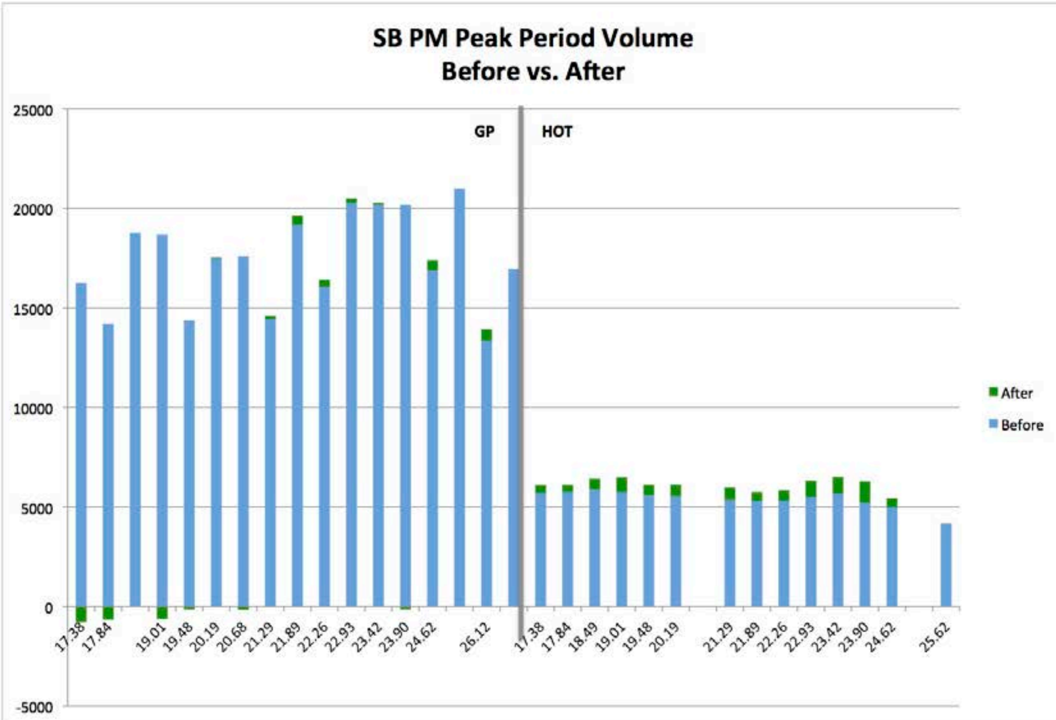


Figure A-2: Southbound PM Peak Period Volumes Before and After Access Rule Changes, April-August 2014 versus April-August 2015

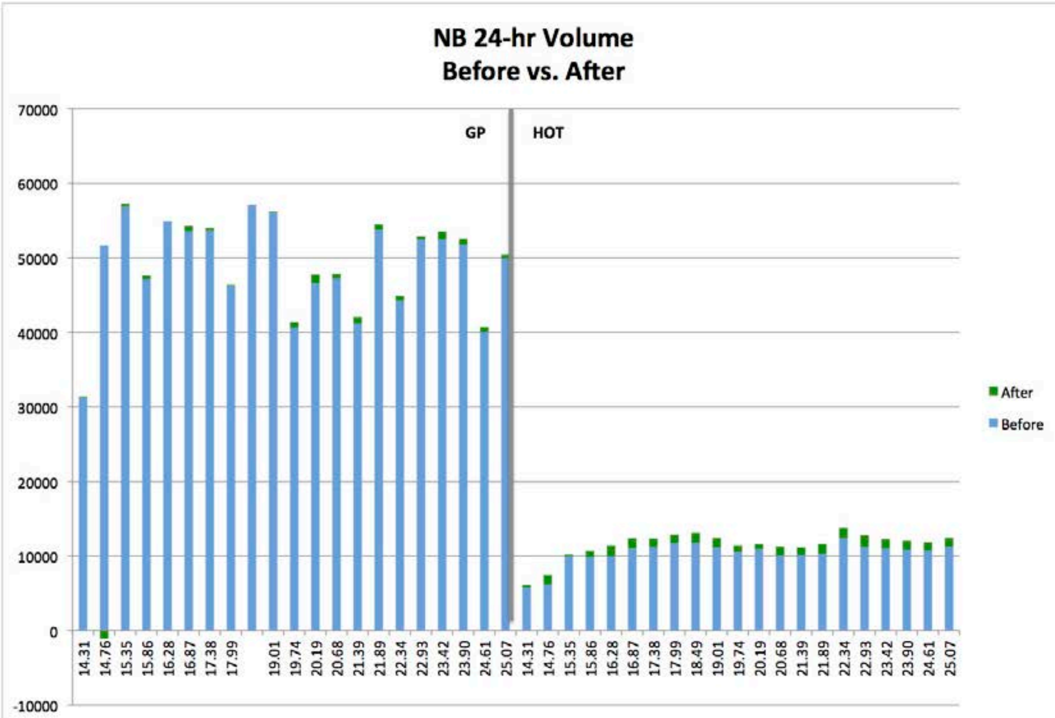


Figure A-3: Northbound 24-hour Volumes Before and After Access Rule Changes, April-August 2014 versus April-August 2015

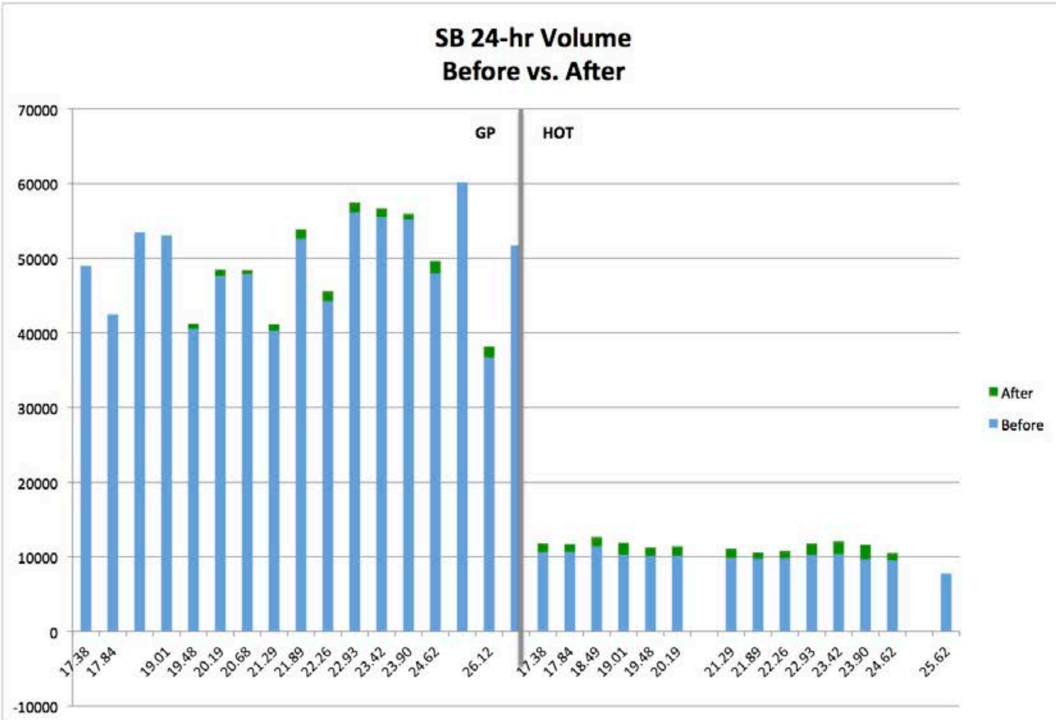


Figure A-4: Southbound 24-hour Volumes Before and After Access Rule Changes, April-August 2014 versus April-August 2015

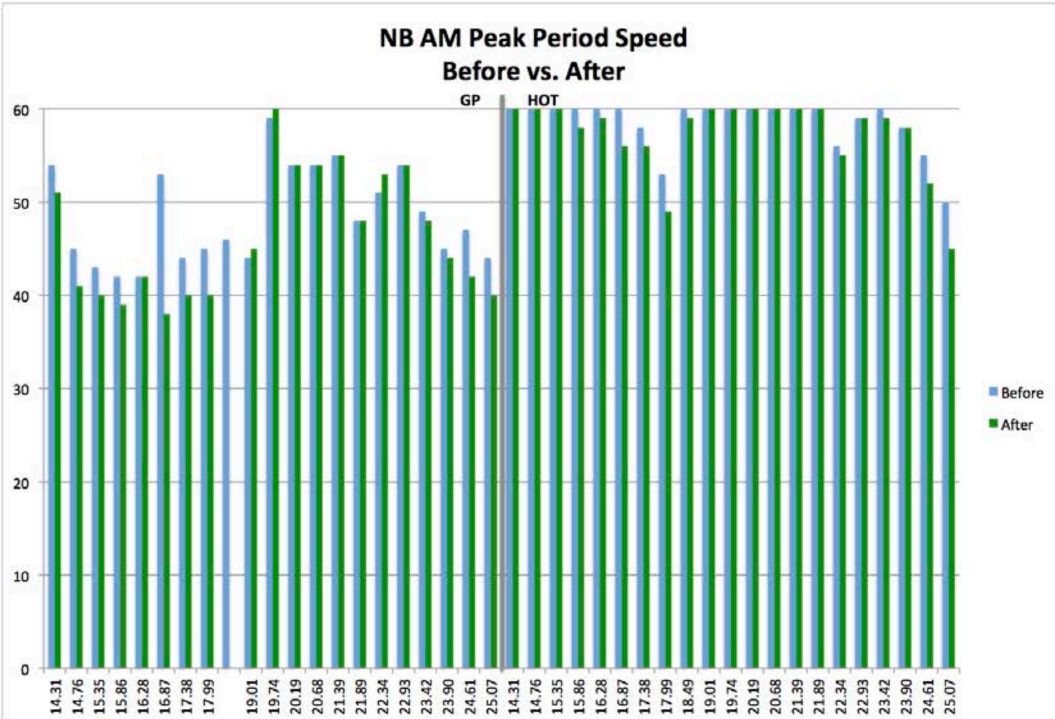


Figure A-5: Northbound AM Peak Period Speed Before and After Access Rule Changes, April-August 2014 versus April-August 2015

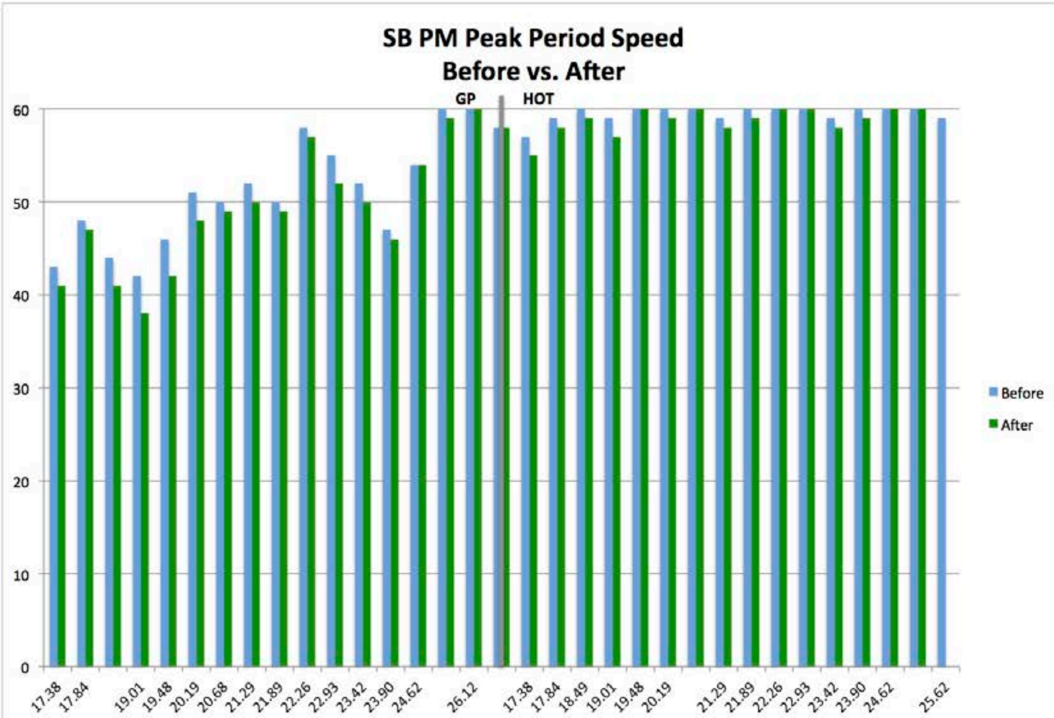


Figure A-6: Southbound PM Peak Period Speed Before and After Access Rule Changes, April-August 2014 versus April-August 2015

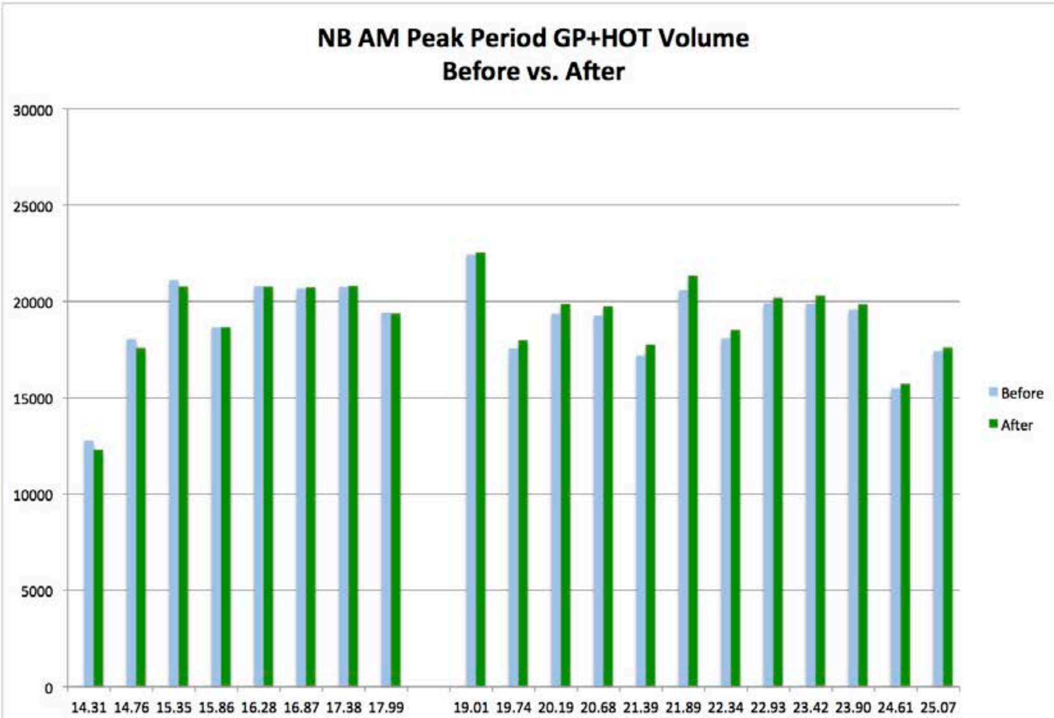


Figure A-7: Northbound AM Peak Period Combined Volume for General Purpose and HOT Lanes, Before and After Access Rule Changes: April-August 2014 versus April-August 2015

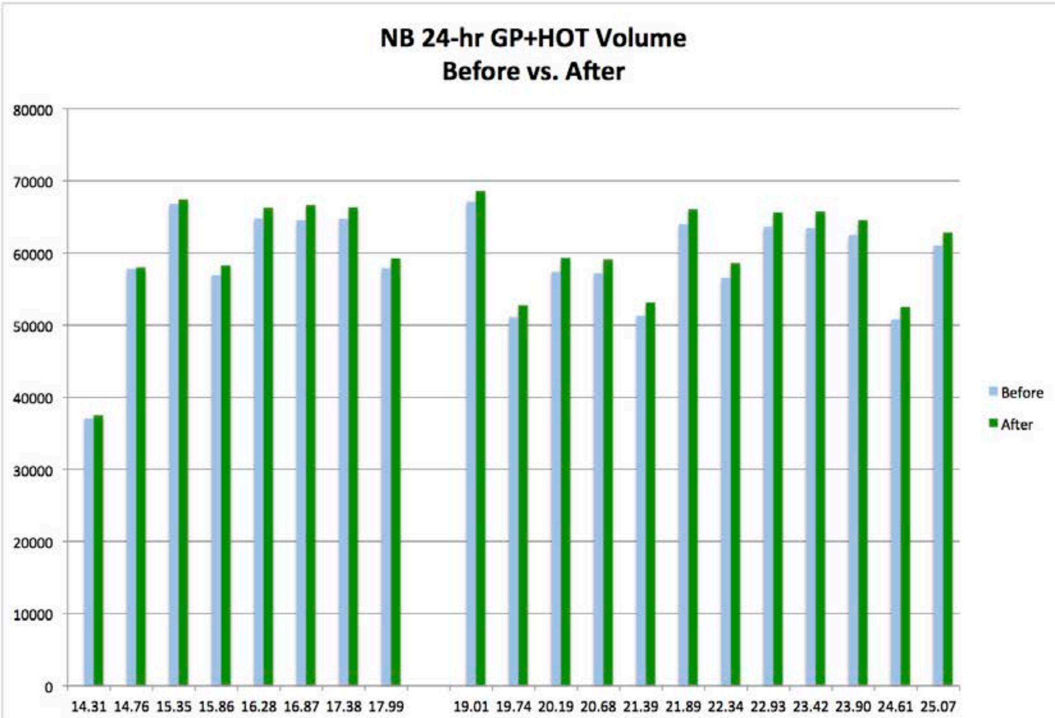


Figure A-8: Northbound Daily Combined General Purpose and HOT Lane Volume, Before and After Access Rule Changes: April-August 2014 versus April-August 2015

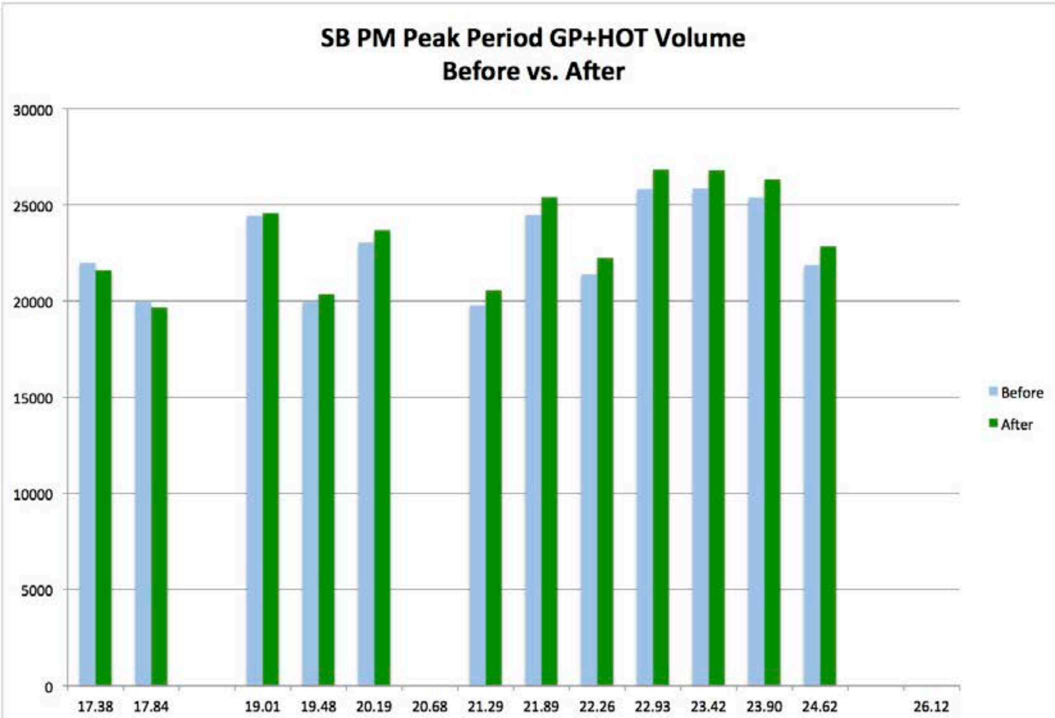


Figure A-9: Southbound AM Peak Period Combined Volume for General Purpose and HOT Lanes, Before and After Access Rule Changes: April-August 2014 versus April-August 2015

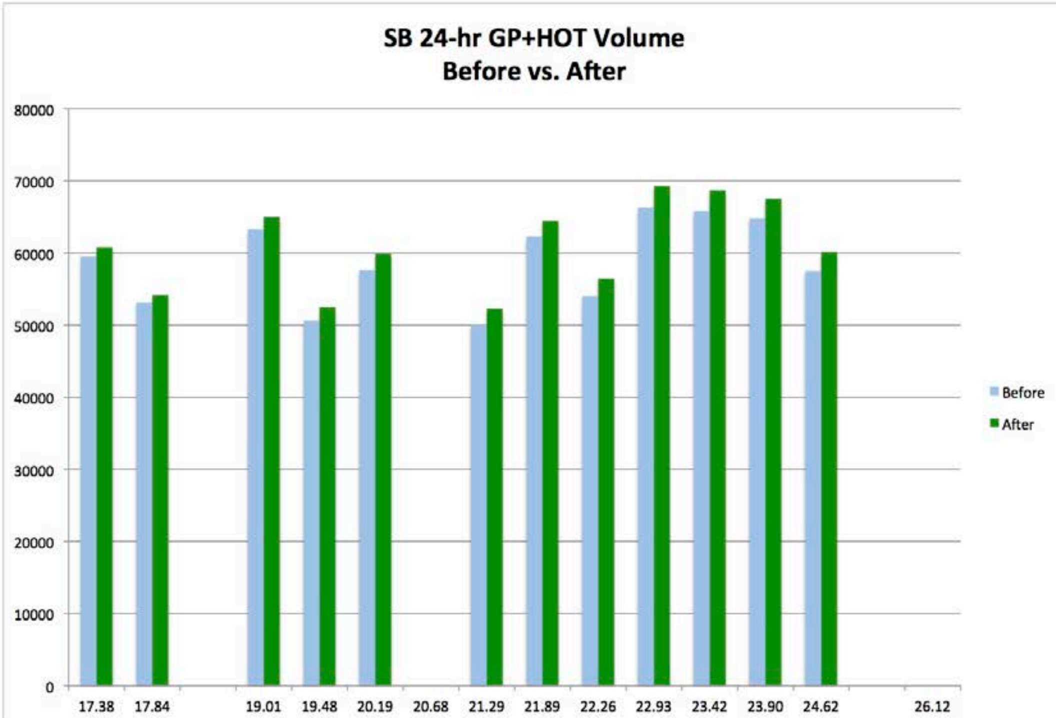


Figure A-10: Southbound Daily Combined General Purpose and HOT Lane Volume, Before and After Access Rule Changes: April-August 2014 versus April-August 2015