**Value of Time Comparisons in the Presence of Unexpected Delay**

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## Abstract

This study estimates Value of Time differences between people who arrived at their destination as planned and those that were delayed. The analysis is based on the I-394 MnPASS High Occupancy/Toll (HOT) lane project recently implemented in the Minneapolis/St. Paul region. Using a Stated Preference survey, the individuals are asked about a trip they have taken before, and asked if they would opt for the free route or pay and go on the HOT lanes. The analysis groups the travelers into subscribers and non-subscribers of the MnPASS (electronic toll collection transponder) system and further decomposes choices into categories based on trip time and experience (delayed or not). Trip times were divided into morning peak, afternoon peak, and off peak and trip experience was divided into delayed and not delayed, creating six categories. The findings suggest an increased willingness to pay among subscribers who were late to reduce travel time in the PM rush hour. As well, we find some evidence that individuals who were late during the AM peak have a lower VOT as compared to their on-time counterparts.



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## Introduction

Reliability is often defined in terms of the adherence of a systems operation to its expected behavior. Previous studies have identified costs of excess delay and the willingness of individuals to pay for a reduction in variability has been demonstrated both in the Stated Preference and Revealed Preference settings (Brownstone and Small 2005; Small 1982; Noland and Small 1998). This willingness to pay is related to the costs of scheduling, or the ability to meet time constraints at both the origin and destination without excessive unanticipated delay. While it is apparent that individuals would schedule activities and departure time according to past experience, once they have departed from their point of origin, their ability to meet scheduled arrival times is largely influenced by events out of their control (e.g. unanticipated congestion).

One advantage of recent implementations of value pricing project has been to give travelers the option to get out of unanticipated congestion by paying a premium. In recent times several High Occupancy/Toll (HOT) alternatives have been opened across the US including SR-91 and I-15 in California, I-10 and US 290 in Texas, and Minnesota's I-394 MnPASS lanes. This study is based on stated preference data collected from travelers on I-394, including both MnPASS and general lanes. The stated preference questions are based on actual travel experiences reported by the respondents.

HOT lanes, as implemented on I-394, offer travelers the ability to travel in vehicles carrying two or more people for free, while single drivers can access the lanes by paying a toll, thereby avoiding congestion. MnPASS uses a variable fee system that depends on traffic levels on the HOT lanes. While travelers can opt to use the I-394 HOT lanes to avoid both anticipated and unanticipated congestion, our study focuses on avoidance of unanticipated congestion, which is at the center of reliability considerations.

Researchers in transport have used several ways to measure and value travel time reliability including the standard deviation and/or variance of travel time (Black and Towriss 1993) as well



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as measures of range (difference between 80$^{th}$ and 50$^{th}$ percentile, 90$^{th}$ and 50$^{th}$ percentile (Brownstone and Small 2005; Tilahun and Levinson 2007). In all cases larger measures signify unreliability and frequent departures from the expected. For the individual traveler, the same information is compiled from actual experience of delays and early arrivals. It would thus be easier for the individual to parse the impact of 5 minute or 10 minute delays rather than a 1 or 2 minute increase in standard deviation. In this study individuals are asked to respond to SP questions that are based on their previous experience. We test whether or not individuals that were delayed on an actual trip would show a willingness to pay that is higher than individuals that arrived at their destination on time.

Consistent with previous studies (Small 1982; Tilahun and Levinson 2007), it is expected that the case of excess delay is especially penalized and travelers are expected to behave in such a way such that whenever they anticipate getting delayed, they would increase their willingness to pay to avoid such a situation. Once on the road, an individual is expected to react differently when anticipating delay in the context of paying for service. The premise for our analysis is that individuals that anticipate delays attach higher values for their time. For instance an individual that plans a 20 minute work trip, and finds out that the trip is going to take 30 minutes would show a higher willingness to pay for time savings on that day than when his trip would take the planned 20 minutes. The difference in the value of time reflects the individual cost of an unreliable service. The same hypothesis is extended for groups of people. It is expected that individuals that are delayed as a group would show a higher time value than individuals that expect to be either on time or early. Though other studies have shown early arrival to have a disutility, here it is lumped together with on-time arrival to simplify the number of categories that we are investigating and for ease of estimation, and because the trip is already underway in the context examined here.

One characteristic of the I-394 HOT lanes is that the system is entirely electronic and requires prior subscription for any SOV to use the facility. Decisions to pay and use the HOT lanes can thus only be made dynamically by those who have an active subscription. The initial access hurdle reduces the possibility that a traveler changes behavior the next time they anticipate



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similar traffic conditions. By using a stated preference survey, it is possible to solicit responses from both subscribers and non-subscribers and analyze in what ways their behavior and choice differs. The following section briefly discusses the survey and is followed by the analysis and results of the SP study.

**The Survey**

The data used for this study is part of a three phase pre- and post-MnPASS implementation study. We specifically focus on waves 2 and 3, which have been conducted after the opening of the MnPASS lanes. The mail and call survey assigned particular trips to respondents on which to record their experiences. After a few weeks, individuals were phoned to gather the information on their travel experience on the assigned trip, attitude, and a subset of them were asked stated preference questions. Complete survey questions used in these studies is provided in (NuStats 2006). The SP questions are reproduced in Appendix A.

For our purposes, we focus on those individuals that participated in the SP study. These individuals have provided information on their experiences on their assigned trip including times of departures, expected time of arrival, and actual time of arrival which they had recorded into a worksheet pre-mailed to the respondents. The SP questions were asked by setting up situations similar to the one that they have been in but by offering them an alternative that provides time savings if they were willing to pay a toll. Those that participated in the SP study are the ones that used drove alone on their reference trips.

Two types of SP questions were asked of the respondents. The first set (method A) has four questions that have randomly generated travel time savings and toll costs. The second set (method B) has a fixed travel time savings, while asking the respondents if they will pay one of eight possible tolls consecutively. The individuals are told to assume that in the future they are making the same trip as the one they had recorded, and further the trip is on the same day, at the same time, for the same purpose, and under the same time pressure as they were in the reference trip.



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The number of questions under method B varies from person to person because as a person switches preference to pay, it is assumed they would pay anything less than offered, or as they switch to reject a particular toll, it is assumed they would reject anything higher since the time savings doesn't change. In order to have a balanced dataset, all eight offers are included and offers they would have rejected or accepted are coded accordingly.

Travel time savings and toll values are randomly generated for both methods A and B. In all cases, the toll time is equal to the actual experienced time by the travelers, and the free option's travel time is calculated as the toll time plus the randomly generated travel time. The respondent thus has a total of 12 choices to make in which they can pay a toll and get the time savings or forego the time savings and travel on the free lanes.

In the original survey, there was a "don't know" choice. Out of 908 respondents, 179 had responded "don't know" on some of the questions. It is not clear if respondents were responding that they were indifferent or what their intention was. Therefore, the 179 people have been left out of the analysis reported here. Twenty nine additional people were excluded because they didn't provide sufficient information on their reference trip.

**Analysis**

The analysis looked at subscribers and nonsubscribers separately. The majority of the subscribers were sampled from the subscriber database, while nonsubscribers were randomly selected from households that live along the recently opened I-394 corridor. An additional 35 people were included from a Transit database, but they have reported driving alone as their main mode of travel and the mode used for the reference trip.

The data for each group (subscribers and non subscribers) is then divided into six categories based on the individuals' travel experience as reported on their assigned trip. Each category is a combination of departure time period (Morning peak (7-9:30AM), afternoon peak (4:00-6:00PM) and off peak time durations) and whether each individual arrived at their destination on time/Early or if they arrived later than they expected. The assumption here is that individuals



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that were actually delayed would show a significant increase in their willingness to pay to experience some time savings. The six categories and the number of people in each category is given in Table 1.

**Table 1.** Respondents in each Category

| Category | Subscribers | Non Subscribers |
|---|---|---|
| Off peak - On time/Early | 56 | 210 |
| Off peak – Late | 6 | 41 |
| Morning peak - On time/Early | 110 | 143 |
| Morning peak – Late | 22 | 39 |
| Afternoon peak - On time/Early | 14 | 39 |
| Afternoon peak – Late | 7 | 13 |
| Percentage Early/On time | 83.7% | 80.8% |
| Percentage Late | 16.3% | 19.2% |

As discussed earlier, each individual makes repeated choices of 12 questions. To account for the repeated choices, a random parameter logit model is used to account for subject to subject differences.

$$(Y_{ij}/b_i) \sim binomial\ (1, p_{ij})$$

$$logit\ (p_{ij}) = U_{ij} + \delta_i$$

$$\delta_i \sim N\ (0,\sigma^2)$$

$$U_{ij} = V_{ij} + \varepsilon_{ij}$$

The utility form that is considered here for each of the cases is as follows:

$$V = f\ (T,C,F,W,A)$$

For each of the categories then, the models are as follows:

Off Peak – Early/On time: $V = g_0 + a_1{*}T + a_2{*}C + a_3{*}F + g_4{*}W + g_5{*}A$

Off Peak – Late: $V = g_0 + b_1{*}T + b_2{*}C + b_3{*}F + g_4{*}W + g_5{*}A$



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Morning Peak – Early/On time: $V = g_0 + c_1*T + c_2*C + c_3*F + g_4*W + g_5*A$

Morning Peak – Late: $V = g_0 + d_1*T + d_2*C + d_3*F + g_4*W + g_5*A$

Afternoon Peak – Early/On time: $V = g_0 + e_1*T + e_2*C + e_3*F + g_4*W + g_5*A$

Afternoon Peak – Late: $V = g_0 + f_1*T + f_2*C + f_3*F + g_4*W + g_5*A$

Where:

$Y_{ij}$ - Choice for individual i on choice set j.

T - Time Savings

C - Cost (toll)

F - Reported flexibility on arrival time for reference trip (0= have to be at destination on time or within 10 minutes, 1=Flexible)

W - Work trip (0 =No, 1=Yes)

A - Method A (randomly generated tolls, times in SP) (0 =No, 1=Yes)

$\delta_i$ – Random effect for person i

$g_i$, $a_j$, $b_j$, $c_j$,$d_j$,$e_j$,$f_j$ where i=0,4,5 and j=1,2,3 – Model coefficients to be estimated

The same model is fit for each of the six categories allowing different coefficients for time, cost and arrival time flexibility. The hypothesis is that the willingness to pay for those individuals that were delayed is going to be higher than those that reached their destination either on time or early. The difference signifies the cost of delay that arises due to lateness from expected travel time. It is also expected that individuals would be less likely to pay for trips that have flexible arrival time. Table 2 has the estimated model for the subscribers and non-subscribers. Tables 3 and 4 give the VOT estimates for subscribers and non subscribers respectively.

The results indicate that among subscribers, trip flexibility increases the probability of opting not to pay to use the tolls for morning peak trips on which the traveler is Early/on time and in the afternoon peak when the traveler is late. In all other cases subscribers that had flexibility were not statistically different from those subscribers that had no flexibility. On the other hand, non-subscribers showed increased probability of using the free lane when they are taking an off peak



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trip on which they are early/on time, while they show a significantly high increase in likelihood of using the toll lanes for AM peak travel for which they are late. In all other situations, both for subscribers and non subscribers, a trip's flexibility either makes the free option more appealing or doesn't significantly affect choice of route.

**Table 2.** Stated Choice Model

| | | MnPASS Subscribers | | | | | Non MnPASS Subscribers | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Description | | Estimate | Error | t Value | Pr>\|t\| | Sig. | Estimate | Error | t Value | Pr>\|t\| | Sig. |
| Intercept | $g_0$ | 1.325 | 0.575 | 2.31 | 0.022 | ** | -3.566 | 0.416 | -8.57 | 0.000 | *** |
| Off Peak - Early/On time (a group) | $a_1$ | -0.256 | 0.035 | -7.30 | 0.000 | *** | -0.320 | 0.028 | -11.36 | 0.000 | *** |
| | $a_2$ | -1.466 | 0.120 | -12.27 | 0.000 | *** | -1.609 | 0.117 | -13.77 | 0.000 | *** |
| | $a_3$ | 0.360 | 0.746 | 0.48 | 0.630 | | -1.272 | 0.467 | -2.72 | 0.007 | *** |
| Off Peak -Late (b group) | $b_1$ | -0.420 | 0.154 | -2.73 | 0.007 | *** | -0.297 | 0.048 | -6.19 | 0.000 | *** |
| | $b_2$ | -1.669 | 0.410 | -4.07 | 0.000 | *** | -1.206 | 0.163 | -7.42 | 0.000 | *** |
| | $b_3$ | -0.264 | 1.917 | -0.14 | 0.890 | | 0.573 | 0.918 | 0.62 | 0.533 | |
| AM Peak - Early/On time ( C group) | $c_1$ | -0.331 | 0.030 | -11.01 | 0.000 | *** | -0.329 | 0.031 | -10.74 | 0.000 | *** |
| | $c_2$ | -1.558 | 0.103 | -15.14 | 0.000 | *** | -1.478 | 0.119 | -12.39 | 0.000 | *** |
| | $c_3$ | -1.193 | 0.553 | -2.16 | 0.032 | ** | -0.627 | 0.542 | -1.16 | 0.249 | |
| AM Peak -Late (d group) | $d_1$ | -0.282 | 0.062 | -4.54 | 0.000 | *** | -0.332 | 0.048 | -6.90 | 0.000 | *** |
| | $d_2$ | -1.776 | 0.225 | -7.91 | 0.000 | *** | -1.974 | 0.251 | -7.87 | 0.000 | *** |
| | $d_3$ | -0.245 | 1.205 | -0.20 | 0.839 | | 3.999 | 1.089 | 3.67 | 0.000 | *** |
| PM Peak - Early/On time (e group) | $e_1$ | -0.236 | 0.079 | -3.01 | 0.003 | *** | -0.256 | 0.051 | -5.06 | 0.000 | *** |
| | $e_2$ | -1.335 | 0.210 | -6.36 | 0.000 | *** | -1.093 | 0.174 | -6.27 | 0.000 | *** |
| | $e_3$ | 0.767 | 1.189 | 0.65 | 0.520 | | -0.728 | 0.939 | -0.77 | 0.439 | |
| PM Peak - Late (f group) | $f_1$ | -0.758 | 0.180 | -4.21 | 0.000 | *** | -0.531 | 0.095 | -5.60 | 0.000 | *** |
| | $f_2$ | -1.788 | 0.418 | -4.28 | 0.000 | *** | -1.684 | 0.321 | -5.25 | 0.000 | *** |
| | $f_3$ | -6.250 | 2.155 | -2.90 | 0.004 | *** | -0.410 | 1.492 | -0.27 | 0.784 | |
| Work Trip (1=Yes, 0=No) | $g_4$ | -0.514 | 0.512 | -1.00 | 0.317 | | -0.056 | 0.340 | -0.17 | 0.868 | |
| Method A (1=Yes, 0=No) | $g_5$ | -0.059 | 0.154 | -0.38 | 0.702 | | -0.472 | 0.151 | -3.12 | 0.002 | *** |
| Standard Deviation | $\sigma$ | 2.945 | 0.227 | 12.99 | 0.000 | *** | 3.054 | 0.197 | 15.52 | 0.000 | *** |
| Number of Respondents | | 215 | | | | | 485 | | | | |
| -2logliklihood (at Final Estimates) | | 1769 | | | | | 2397 | | | | |
| -2logliklihood (at all 0, $\sigma$=1 ) | | 3320 | | | | | 5392 | | | | |

*** p-val < 0.01 **p-val < 0.05 *p-val < 0.1



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Estimates of time and cost coefficients are negative in sign and consistent with decreasing utility with rising travel time and monetary costs. Value of time estimates for subscribers in each of the categories suggest differences in time values for afternoon early/on time ($10.62/hr) and those that were late ($25.42/hr) , but no significant differences are detected for the off peak and AM peak groups . The afternoon estimates are based on 168 and 84 responses from 14 and 7 individuals that were early/on time and delayed respectively. This puts the magnitude of delay penalty at $14.80/hr for this time period (CI ($5.91, $23.7)). For the same group, differences are not detected between those that were on time those that were delayed both in the off peak duration and the AM duration.

There are several possible implications of this model; one is that costs of unreliability are more severe for afternoon rush hour travelers than either morning rush hour travelers or off peak travelers particularly among subscribers. Our confidence is weighed down by the wide estimate and the fact that few individuals were in this situation. For both subscribers and non subscribers, VOT estimates are larger in this last category (PM travelers that are late) suggesting a consistency of preference among travelers.

The results show that there is no evidence to suggest that choices over work trips are any different from other trips. In addition while subscribers show no difference between survey question methods suggestion more reliable choices, non subscribers are more willing to pay under method B than they are under method A. Additional individual variables such as sex and income were found to be not significant in this model specification and were dropped. Appendix B shows income categorized by MnPASS subscription and trip experience for those that were used in this analysis.

Among non-subscribers, possible differences in VOT are detected between those that are early/on time ($13.63/hr) in the AM peak and those that are late in the same time period( $10.10/hr) (p-val=0.046). However the VOT magnitude for those that are late is less than the VOT for those that are early/on time. This seems counter intuitive; however, again it is possible that this is due to a self selection process where those that are late were so because they had lower values of time



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or lower penalties on lateness in the first place. The CI ($0.06, $6.44) illustrates that the differences between these two experiences are very close to one another.

**Table 3.** Value of Time (VOT) Estimates for Subscribers ($US/hour)

| Label | Estimate | SE | t-Stat | p-Val | Confidence Interval |
|---|---|---|---|---|---|
| Off peak – early/on time ($VOT_a$) | 10.47 | 1.241 | 8.44 | 0.000 | (8.03, 12.92) |
| Off peak – late ($VOT_b$) | 15.11 | 3.856 | 3.92 | 0.000 | (7.51, 22.71) |
| Morning - early/on time ($VOT_c$) | 12.73 | 0.955 | 13.33 | 0.000 | (10.84, 14.61) |
| Morning – late ($VOT_d$) | 9.54 | 1.811 | 5.27 | 0.000 | (5.97, 13.11) |
| Afternoon - early/on time ($VOT_e$) | 10.62 | 3.004 | 3.54 | 0.001 | (4.7, 16.55) |
| Afternoon – late ($VOT_f$) | 25.43 | 3.386 | 7.51 | 0.000 | (18.75, 32.1) |
| $VOT_a$ - $VOT_b$ | -4.63 | 3.999 | -1.16 | 0.248 | (-12.51, 3.25) |
| $VOT_c$ - $VOT_d$ | 3.19 | 1.952 | 1.63 | 0.104 | (-0.66, 7.04) |
| $VOT_e$ - $VOT_f$ | -14.80 | 4.513 | -3.28 | 0.001 | (-23.7, -5.91) |

**Table 4.** Value of Time (VOT) Estimates for Non Subscribers ($US/hour)

| Label | Estimate | SE | t-Stat | p-Val | Confidence Interval |
|---|---|---|---|---|---|
| Off peak – early/on time ($VOT_a$) | 11.94 | 0.971 | 12.290 | 0.000 | (10.03, 13.84) |
| Off peak – late ($VOT_b$) | 14.82 | 2.247 | 6.590 | 0.000 | (10.4, 19.23) |
| Morning - early/on time ($VOT_c$) | 13.36 | 1.169 | 11.430 | 0.000 | (11.06, 15.65) |
| Morning – late ($VOT_d$) | 10.10 | 1.331 | 7.590 | 0.000 | (7.49, 12.72) |
| Afternoon - early/on time ($VOT_e$) | 13.96 | 2.714 | 5.140 | 0.000 | (8.62, 19.29) |
| Afternoon – late ($VOT_f$) | 18.95 | 3.052 | 6.210 | 0.000 | (12.95, 24.94) |
| $VOT_a$ - $VOT_b$ | -2.88 | 2.317 | -1.240 | 0.215 | (-7.43, 1.67) |
| $VOT_c$ - $VOT_d$ | 3.25 | 1.624 | 2.000 | 0.046 | (0.06, 6.44) |
| $VOT_e$ - $VOT_f$ | -4.99 | 4.022 | -1.240 | 0.215 | (-12.89, 2.91) |

## Conclusion

This study examined differences in choice behavior for individuals that have had different travel experiences. The analysis is based on the I-394 MnPASS HOT lane project recently



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implemented in the Twin Cities. Using a Stated Preference survey, the individuals are asked about a trip they have taken before, and asked if they would opt for the free route or pay and go on the HOT lanes. The basic hypothesis, that individuals would be willing to exchange more money per time savings after experiencing an unexpected delay bears out in the afternoon peak for subscribers, but not the morning or off-peak cases, nor the afternoon peak for non-subscribers. The results for non-subscribers suggest that individuals who are late in the morning actually have lower values of time in the SP context as well. The findings suggest an increased willingness to pay among subscribers who were late to reduce travel time in the afternoon rush hour. As well, we find some evidence that individuals who were late during the morning peak have a lower VOT as compared to their on-time counterparts.

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**APPENDIX A:** Stated Preference Questions

Now assume you're making the same trip in the future that you recorded in your travel log. It's a trip on the same day, at the same time of day, for the same purpose, and you're under the same time pressures. You enter the freeway, I-394, and have the option of making this trip using MnPASS if you want to. RANDOMLY ASSIGN [$] AND [#] BELOW

**Method A**

SP1-2. If you were to use the general traffic lanes on I-394, your trip would take
TOLLTIME+[#]
and be free. If you used the MnPASS lane you would pay [$] and your trip would take TOLLTIME, saving [#] minutes. Now under these conditions, which would you choose to use:

The MnPASS lane, pay [$] and save [#] minutes 1
The general lane for free 2
DK 998

SP1-2. If you were to use the MnPASS lane on I-394, you would pay [$] and your trip would take TOLLTIME. If you were to use the general traffic lanes, your trip would take TOLLTIME+[#], [#] minutes longer than in the toll lane, but it would be free, Now under these conditions, which would you choose to use:

The MnPASS lane, pay [$] and save [#] minutes 1
The general lane for free 2
DK 998

**Method B**

SP3. Now imagine a different scenario. If you were to use the MnPASS lane on I-394, you would pay [$] and you would save [#] minutes. Under these conditions what would you do?

Use the MnPASS lane, pay [$] and save [#] minutes 1
Use the general lane for free 2
DK 998



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**Appendix B.** Income by Subscriber, and Trip Status

| Trip Status | | Income ($US '000s) | | | |
|---|---|---|---|---|---|
| | | < 50 | 50-100 | 100-125 | >125 |
| Non Subscribers | Off peak – early/on time | 37 | 86 | 25 | 52 |
| | Off peak – late | 10 | 17 | 5 | 6 |
| | Morning – early/on time | 15 | 50 | 26 | 47 |
| | Morning - late | 2 | 13 | 10 | 13 |
| | Afternoon – early/on time | 2 | 24 | 6 | 6 |
| | Afternoon – late | 1 | 3 | 1 | 6 |
| **Total – Non Subscribers** | | **67** | **193** | **73** | **136** |
| Subscribers | Off peak – early/on time | 3 | 13 | 6 | 27 |
| | Off peak – late | 2 | 1 | 1 | 1 |
| | Morning – early/on time | 4 | 21 | 13 | 59 |
| | Morning - late | 0 | 6 | 3 | 12 |
| | Afternoon – early/on time | 0 | 3 | 3 | 8 |
| | Afternoon – late | 0 | 0 | 0 | 7 |
| **Total – Subscribers** | | **9** | **44** | **25** | **114** |



Tilahun, Nebiyou and David Levinson (2009) Unexpected delay and the cost of lateness on I-394 high occupancy/toll lanes.
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**Appendix C.** Sex by Subscriber, and Trip Status

| | Trip Status | Male | Female |
|---|---|---|---|
| Non Subscribers | Off peak – early/on time | 85 | 125 |
| | Off peak – late | 16 | 25 |
| | Morning – early/on time | 52 | 91 |
| | Morning - late | 18 | 21 |
| | Afternoon – early/on time | 15 | 24 |
| | Afternoon – late | 7 | 6 |
| **Total – Non Subscribers** | | **193** | **292** |
| Subscribers | Off peak – early/on time | 24 | 32 |
| | Off peak – late | 2 | 4 |
| | Morning – early/on time | 44 | 66 |
| | Morning - late | 12 | 10 |
| | Afternoon – early/on time | 5 | 9 |
| | Afternoon – late | 4 | 3 |
| **Total – Subscribers** | | **91** | **124** |



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