
Study of the Effectiveness of Guide Signs with Purple Backgrounds

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EXECUTIVE SUMMARY

With the opening of the Westpark Tollway, the Harris County Toll Road Authority (HCTRA) began limited use of a new background color for tollway guide signs. These guide signs use a purple background with white letters. Purple is one of several colors in the Manual on Uniform Traffic Control Devices (MUTCD) that are “reserved” for a future use to be designated by the Federal Highway Administration (FHWA). HCTRA has recently been granted approval for a “Request to Experiment with Purple Guide Signs on Toll Roads”. The Texas Transportation Institute (TTI) has completed this research proposal to support that experimentation.

The first phase of the research was a mail survey concerning toll road sign design and colors was mailed to 1000 electronic toll tag customers of the Harris County Toll Road Authority (HCTRA). The survey received close to a 50% return rate. The survey sought to determine electronic tag users’ current understanding of forms of payment accepted on various toll roads; to determine preferences for sign designs for electronic tag-only roads; and, to assess whether exposure to signs with purple backgrounds on the Westpark Tollway has created an association between purple signs and the restriction of payment to electronic tag only. The results showed that drivers who frequently drove on the Westpark Tollway, and hence were exposed to purple guide signs, had come to associate the color purple with toll roads, and in particular electronic toll collection on those roads.

The second phase of the research was an on-road legibility and sign recognition study of the purple guide signs along the Westpark Tollway and two advanced guide signs installed specifically for this study. These signs were on southbound US 59 announcing the entrance to westbound Westpark Tollway and in the northbound lanes of Sam Houston Tollway marking the entrance to the eastbound lanes of the Westpark Tollway. Forty-eight participants drove an instrumented vehicle in open traffic and read traffic signs along a toll road with purple signs on one segment and green signs on another. Results showed no significant difference in legibility distance between signs with purple and green backgrounds. An analysis of recognition distances for advance guide signs marking ramps to the toll road also showed no difference between purple and green signs. These results support the implementation of this new color without any loss in legibility.

The third phase of the project was an analysis of the electronic toll tag violations before and after the test signs had been placed at the entrance ramps to Westpark on US 59 and Sam Houston Tollway. Analysis of EZ Tag violation rates at two locations on the Westpark Tollway before and after the introduction of two experimental guide signs indicates the original guide signs are associated with significantly fewer violations per 1,000 vehicles than either of the two experimental signs. The all purple experimental did perform better than the green with purple banner experimental relative to the original guide sign, but the absolute violation rates observed with the two signs were virtually identical. Guide signing recommendations based solely on the relationship of those signs to EZ Tag violations favor the original sign design which included a yellow banner across the bottom of the sign with EZ TAG ONLY message. Should other considerations support adoption of new signs despite the increased violation rates observed, there is little basis for choosing either of the tested experimental signs over the other.

The last phase of the project was a two-year material durability study. Standard test decks were constructed to mount the materials south facing at 45 degrees upward to accelerate the weathering. In this manner, 2 years of exposure is equivalent to 4 years vertical exposure. In order to assure the same atmospheric or pollution conditions as Houston, the test deck was located near the Hardy Toll Road in a HCTRA maintenance yard. The periodic evaluations of the test panels included photometric measurements of test panels installed in the Houston area. Measures of retroreflectivity and color showed no marked deterioration during the two-year test period. It should be noted, however, that none of the materials tested would meet the new color specifications proposed by the Federal Highway Administration in January 2008.

In conclusion, the overall project showed that :

- drivers are able to understand a unique category related to electronic payment based on exposure to purple signs
- drivers could read purple background signs as good as green background signs both during the day and at night
- changing the EZ TAG only banner from a black on yellow panel located at the bottom of the sign to a white on purple panel located at the top of the sign resulted in higher violation rates
- materials available in 2006 for creating purple signs appear to have durable color after two years of 45 degree southward facing exposure.

CHAPTER 1: SURVEY OF HARRIS COUNTY TOLL ROAD AUTHORITY EZ TAG PATRONS: TOLL SIGNING KNOWLEDGE AND PREFERENCES

INTRODUCTION

The Harris County Toll Road Authority (HCTRA) has introduced the use of a new color scheme for toll road guide signs. These signs, as illustrated in Figure 1, use a purple background with white letters. Purple is one of several colors in the Manual on Uniform Traffic Control Devices that are reserved for a future use to be designated by the Federal Highway Administration (FHWA). FHWA has approved a request by HCTRA to experiment with purple guide signs on toll roads. To date, the purple signs have been deployed only on guide signs for the Westpark Tollway, the one tollway currently operated by HCTRA for which an EZ TAG is the only form of toll payment accepted. EZ TAG is HCTRA's electronic toll collection system that allows motorists to pay tolls without stopping at tollbooths. Except on the Westpark, where it is the only option, motorists with the tags can use lanes reserved exclusively for them or designated mixed-use lanes that allow either cash or EZ TAG transactions.



Figure 1. Example of Installed Purple Guide Sign.

As part of an evaluation of HCTRA's use of purple guide signs, the Texas Transportation Institute (TTI) conducted a mail survey of HCTRA EZ TAG patrons. The primary goals of the survey were to:

- Determine EZ TAG users' current understanding of:
 - color coding of payment lanes at toll plazas
 - forms of payment accepted on various toll roads.
- Determine preferences for sign designs for EZ TAG only roads.
- Assess whether exposure to signs with purple backgrounds on the Westpark Tollway has created an association between purple signs and the restriction of payment by EZ TAG only

SURVEY METHODOLOGY

Survey Development

Survey items were developed in four general areas to realize the survey's goals. In addition to basic demographic information about respondents' age, gender and frequency of use of HCTRA tollways, questions were developed to ascertain EZ TAG patrons' knowledge and opinions about their:

- Familiarity with specific guide signs (with both the standard green and experimental purple backgrounds) and the forms of toll payment allowed based on sign color
- Expectations of appropriate toll lanes to use based on sign color
- Ratings of specific sign designs and the preferred use and meaning of purple signs

A draft of the survey was provided to HCTRA for review and suggestions on the draft were incorporated prior to implementation. Budget constraints limited the total survey sample size to 1,000. Several efforts were undertaken to maximize survey response rates; notably, targeting the mail out to the appropriate audience, providing a token payment (\$1.00) to survey recipients, and minimizing the time required to complete the survey. The final survey instrument, including color renditions of pertinent signing (see Appendix A) comprised an 8.5 x 11 inch 4 page booklet mailed to a 1,000-person sample on May 30, 2006. As noted in the introductory letter accompanying the survey, no more than 10 minutes was required to complete the survey. The Texas A&M University Institutional Review Board – Human Subjects in Research, reviewed and approved the survey and survey procedures in compliance with Texas A&M University System requirements.

Survey Sampling Plan

A stratified random sample of 1,000 individual EZ TAG patrons was drawn from two groups of tag holders derived from HCTRA's December 2005 patron transaction and account records (tag holders identified as businesses were excluded from the samples). Sixty-five percent of the sample consisted of patrons the transaction records indicate had driven on the Westpark Tollway at least once during December 2005. The remaining 35 percent was drawn from tag holders who did not drive on the Westpark in that month. Within both of these groups, Westpark "users" and "non-users," individuals were randomly sampled from five groups of ZIP codes as indicated in Table 1. The ZIP code groups correspond to the most frequent ZIP codes of Westpark users and non-users. The sample of EZ TAG users is based on the most frequently cited ZIP codes of EZ patrons and thus is not a direct measure of most frequent use of the tags by individuals. It is, however, likely that there is a high positive correlation between the two.

SURVEY RESULTS

Return Rates

Of the 1,000 surveys mailed out, 38 were returned due to incorrect or otherwise undeliverable addresses. Thus, the effective sample size was reduced to 962. Of these, 473 (49.2%) were returned sufficiently completed to be used in the analysis. The proportion of Westpark "users" and "non-users" completing the survey was nearly identical; 47.8 and 46.3 percent of users and non-users, respectively (unadjusted for bad addresses). These very respectable return rates suggest both a significant interest among EZ TAG holders in the subject matter of the survey and that the procedural efforts to maximize survey response rates were largely successful.

Table 1. Survey Sample.

| ZIP Code Group | No. of ZIP Codes in ZIP Code Group | % of EZ TAG users in Zip Code Group | No. individuals sampled from ZIP Code Groups |
|---------------------------|------------------------------------|-------------------------------------|--|
| Westpark Users | | | |
| 1 | 6 | Most frequent 25% | 163 |
| 2 | 14 | 2nd most frequent 25% | 163 |
| 3 | 35 | 3rd most frequent 25% | 163 |
| 4 | 68 | 4th most frequent 15% | 98 |
| 5 | 2207 | 5th most frequent 10% | 65 |
| All | 2330 | Total Sample1500.00% | 650 |
| Westpark Non-Users | | | |
| 1 | 13 | Most frequent 25% | 88 |
| 2 | 25 | 2nd most frequent 25% | 88 |
| 3 | 51 | 3rd most frequent 25% | 88 |
| 4 | 86 | 4th most frequent 15% | 53 |
| 5 | 4406 | 5th most frequent 10% | 35 |
| All | 4581 | Total Sample3000.00% | 350 |

Responses to all survey items are provided in tabular form in Appendix B. The sections below discuss the most important and revealing information derived from those responses.

Respondent Demographics and Tollway Use

Most of the substantive results presented compare responses to individual survey items among three groups of EZ TAG patrons based on their self-reported frequency of driving on the Westpark Tollway (survey item 5). This differs from the distinction between Westpark “users” and “non-users” employed for developing the survey sample. Item 5 of the survey asked respondents how often they drive on the Westpark Tollway. Five alternatives were provided:

- Never
- Once or twice a year
- Once or twice a month
- Once or twice a week
- 3 or more times a week

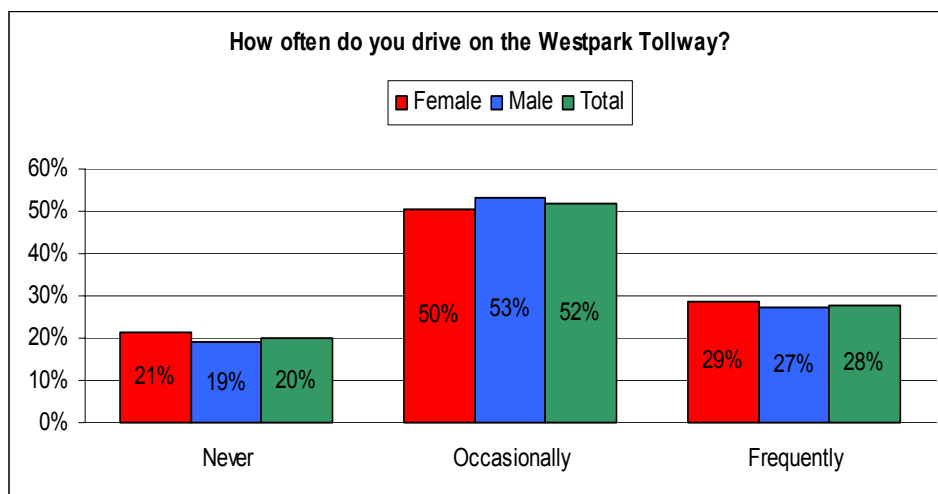


Figure 2. Frequency of Driving on Westpark Tollway by Gender.

For purposes of assessing frequency of use, respondents answering “once or twice a year” or “once or twice a month” were grouped together and categorized as driving on the Westpark “Occasionally.” Similarly, respondents indicating they drive on the Westpark either “once or twice a week,” or “3 or more times a week” were identified as “Frequent” Westpark drivers.

Overall, only 20% of survey respondents indicated that they never drive on the Westpark. A somewhat larger proportion of respondents were male (55.5%) than female (44.5%), however, the frequency of Westpark use was very similar for both genders as shown in Figure 2.

A broad range of ages are represented among survey respondents (Figure 3), with about 73% in the prime commuting ages of 30-59 years old. Within the age groups surveyed, the three youngest groups reported the most frequent Westpark use; more than 30 percent of each of these groups were characterized as driving on the Westpark frequently (see Figure 4). Westpark driving frequency decreases as a function of age among the three older respondent age groups.

Respondents were also asked how frequently they drive on two other HCTRA facilities, the Sam Houston and Hardy Tollways. The responses, shown in Figure 5 and Figure 6, respectively, suggest much more use of the Sam Houston Tollway than the Hardy by the survey sample.

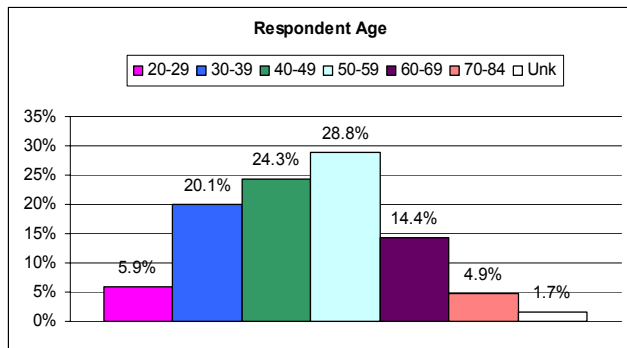


Figure 3. Ages of Survey Respondents.

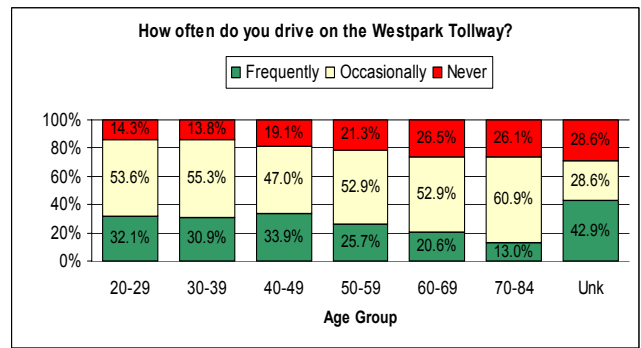


Figure 4. Frequency of Driving on Westpark Tollway within Age Groups.

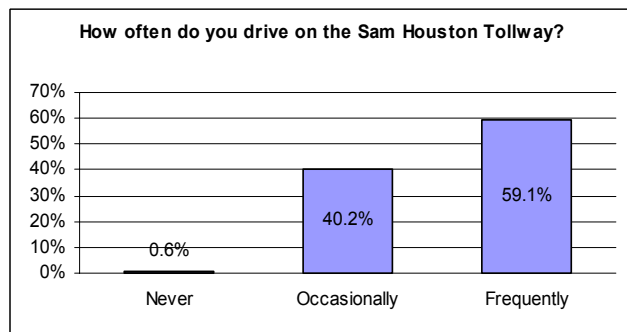


Figure 5. Frequency of Driving on Sam Houston.

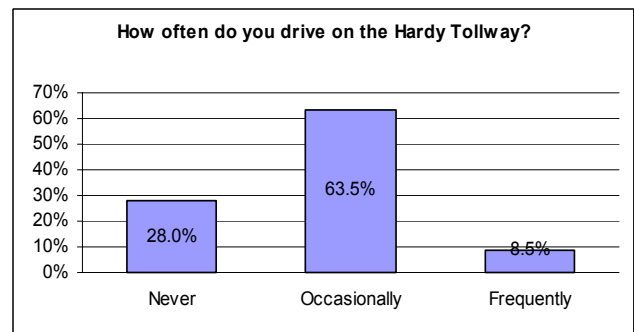


Figure 6. Frequency of Driving on Hardy.

Given that the data base from which all potential survey recipients were drawn consisted of HCTRA EZ TAG holders, it was somewhat surprising to find that only 87.2 percent of respondents replied in the affirmative when asked “Have you ever paid a toll with an EZ TAG in the Houston area?” (9.2% replied “No” and 3.6% were “Not sure.”). A plausible, though unconfirmed, explanation for this is that some respondents who actually filled out the questionnaire had not personally used the EZ TAG, while a spouse or other person in the household receiving the survey had used the tag.

Nearly 10 percent of all respondents indicated they have used an electronic toll tag similar to EZ TAG outside the state of Texas.

Familiarity with specific guide signs and the forms of toll payment allowed

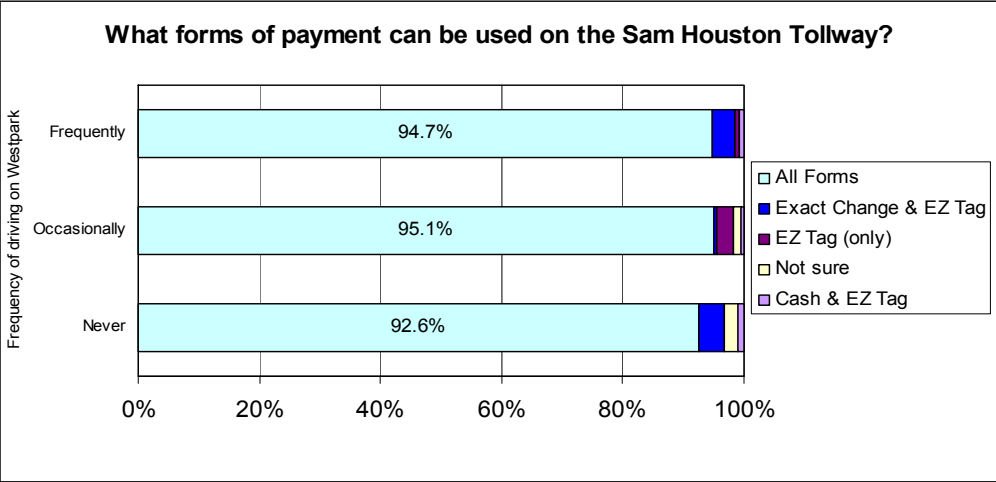
The survey queried respondents about all forms of toll payment acceptable on the Sam Houston, Hardy and Westpark Tollways. For each tollway, respondents were asked to indicate which of three forms of payment are acceptable; exact change, cash (full service), or EZ TAG. The combination of payments types result in seven possible responses (plus an eighth option of “not sure”):

- Exact Change (only)
- Cash (only)
- EZ TAG (only)
- Exact Change & Cash
- Exact Change & EZ TAG
- Cash & EZ TAG
- All Forms: Exact Change, Cash & EZ TAG
- Not sure

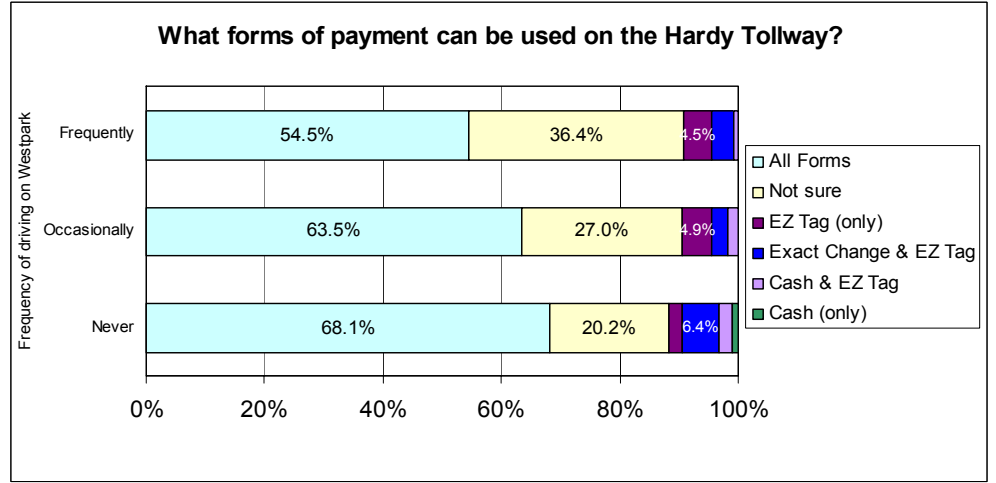
Figures 7¹ summarize responses as a function of self-reported frequency of driving on the Westpark Tollway.

Error! Reference source not found.A clearly illustrates the large majority (94.5% overall) of respondents who correctly indicated that all of the forms of payment are acceptable on the Sam Houston Tollway. Recall, from Figure 5, virtually 100 percent of survey respondents use the Sam Houston at least occasionally, with 59 percent driving on it frequently. Not surprisingly, very little difference in knowledge of acceptable toll payments was observed as a function of Westpark experience.

¹ In these and similar figures that follow, percentages smaller than 5 percent are included but the values are not labeled. See tables in Appendix B for exact values.



7A. Forms of Payment Allowed on the Sam Houston Tollway



7B. Forms of Payment Allowed on the Hardy Tollway

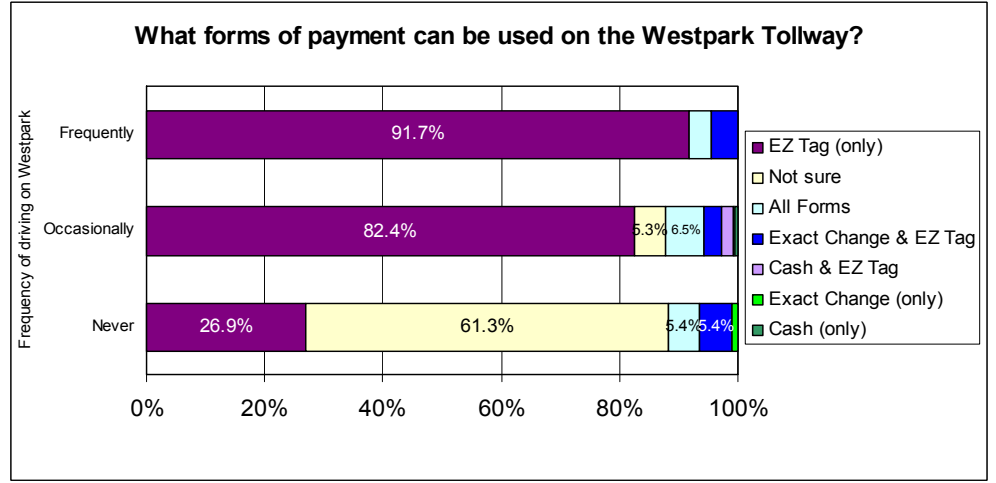


Figure 7A. Forms of Payment Allowed on the Westpark

Figure 7. Respondents' Knowledge of Forms of Payment

A smaller majority, 62 percent overall, correctly indicated that all forms of payment are also accepted on the Hardy Tollway, reasonably consistent with the 72 percent of respondents who report occasionally or frequently driving on that facility. Considerable uncertainty about the types of payment permitted on the Hardy, as reflected in the proportion of “not sure” responses is evident, particularly among those who drive frequently on the Westpark Tollway (see Figure 7B).

Knowledge of the only accepted payment on the Westpark Tollway is, clearly, the most relevant to the issue of purple signs. Figure illustrates that although a few individuals who report frequent use of the Westpark apparently believe that all forms of payment or exact change in addition to EZ TAG toll payment is permitted, more than 90 percent correctly understand that EZ TAGS are the only allowed toll payment mechanism. Among drivers who occasionally use the Westpark, more than 80 percent (82.4%) correctly identified EZ TAGS as the only toll payment allowed. Among those who never drive on the Westpark, only 27 percent correctly identified the only payment type allowed. More than 60 percent of non-Westpark drivers were not sure what forms of payment are accepted on this facility.

Asked to recall if they have seen the specific purple and green signs illustrated in Figure 10, overall, 34.6 percent responded affirmatively to the purple sign and 43 percent to the green sign. As indicated in Figure 9 and Figure 10, however, familiarity with these signs varied as a function of frequency of driving on the Westpark Tollway. Especially notable is the decrease in familiarity with the purple sign associated with decreasing self-reported driving on the Westpark. That nearly 12 percent of the respondents who claim they never drive on the Westpark report having seen the purple Fondren Road sign appears inconsistent since that sign is located on the Westpark. It is possible, however, that respondents observed this sign while a passenger in a vehicle on the Westpark.



Figure 8. Existing Purple and Green Signs.

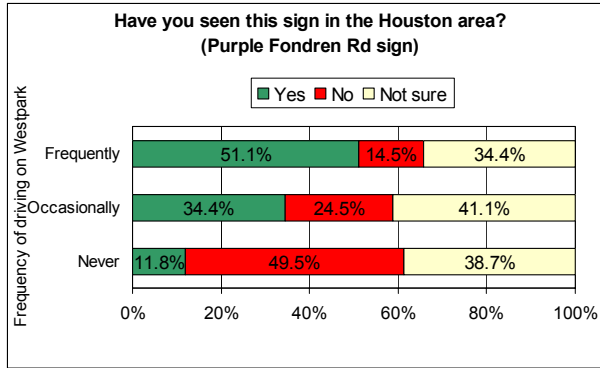


Figure 9. Familiarity With Existing Purple Sign.

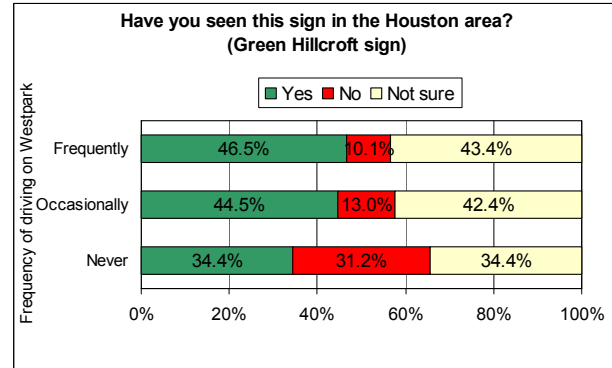


Figure 10. Familiarity with Existing Green Sign.

To obtain an estimate of the extent to which HCTRA EZ TAG patrons associate sign color with the type of toll payments permitted, respondents were asked to indicated all of the forms of payment allowed on a hypothetical new Houston area tollway based solely on their experience and the presence of each of the signs illustrated in Figure 11.

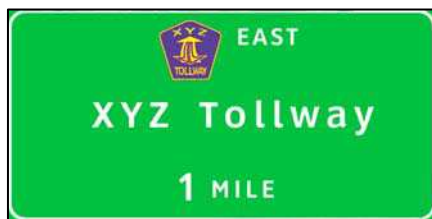


Figure 11. Green and Purple Guide Signs for Hypothetical New Tollway.

The association of green and purple sign backgrounds with toll payment is summarized in Figure 12 and Figure 13, respectively. Among all EZ TAG patrons, 83.2 percent associate a green tollway guide sign with all forms of toll payments; i.e., they would expect payment to be allowed by full-service service, exact change, or EZ TAG electronic payment. Differences as a function of frequency Westpark use are small, although 7.9 and 5.9 percent of frequent and occasional users of the Westpark reported an association of the green sign exclusively with EZ TAG payment.

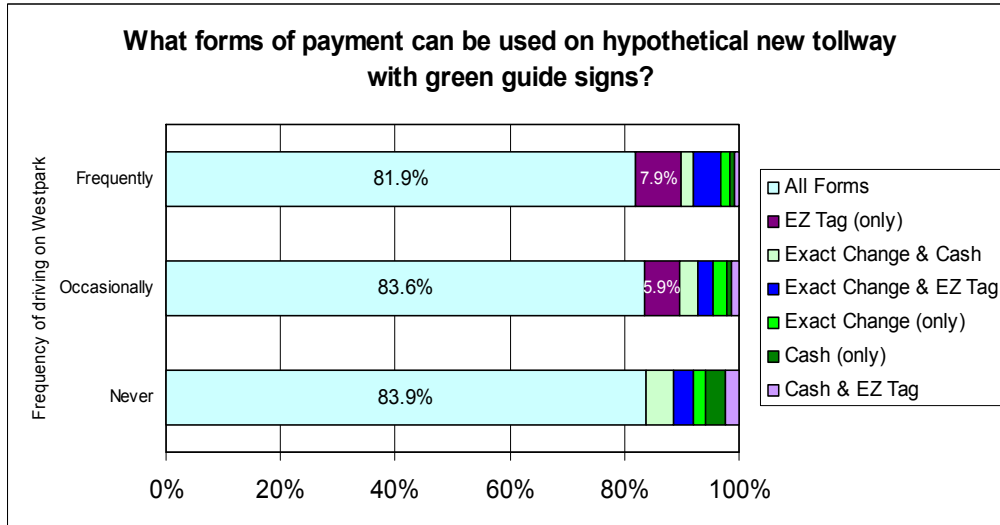


Figure 12. Forms of Toll Payment Associated with Green Tollway Guide Signs.

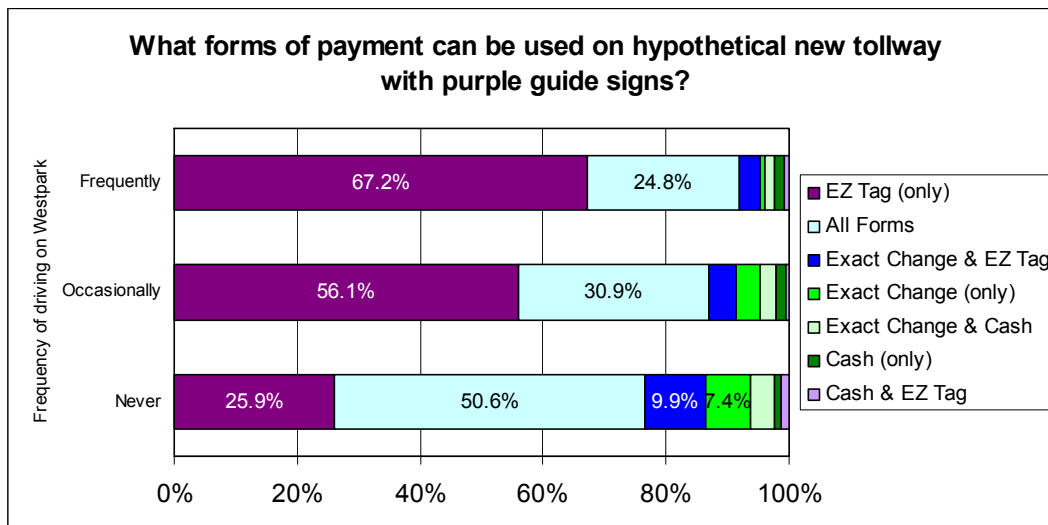


Figure 13. Forms of Toll Payment Associated with Purple Tollway Guide Signs.

Overall, purple guide signs are associated with EZ TAG-only toll payment by 53.7 percent of EZ TAG holders, while 32.8 percent indicate that all forms of payment would be acceptable on tollways designated with purple signs. As shown in Figure 13, these responses vary considerably with Westpark use; the association between a purple guide sign and exclusive EZ TAG payment increases with frequency of Westpark use. Only about a quarter of respondents who never drive on the Westpark associate purple with EZ TAG-only compared to two thirds of the frequent Westpark drivers. Conversely, a quarter of frequent Westpark drivers

associate purple signs with acceptance of all forms of toll payment while about half of those who never use Westpark do so. Also note that among Westpark non-users, 10 percent indicate an association between purple signs and toll payment by either EZ TAG or exact change and an additional 7.4 percent associate purple with exact change only.

Expectations of toll lanes to use based on sign color

Survey respondents were asked to indicate, using the photograph shown in Figure 14, all of the color-coded toll plaza lanes drivers could use on Houston tollways under three conditions:

- Exact change is used to pay toll
- Assuming the toll is \$1.00, a dollar bill is used to pay the toll
- An EZ TAG is used to pay the toll

Responses for each scenario are provided in Figure 15 -Figure 14 as a function of frequency of driving on the Westpark Tollway.



Figure 14. Intentionally Blurred Photo for Assessing Knowledge of Toll Lane Color Coding.

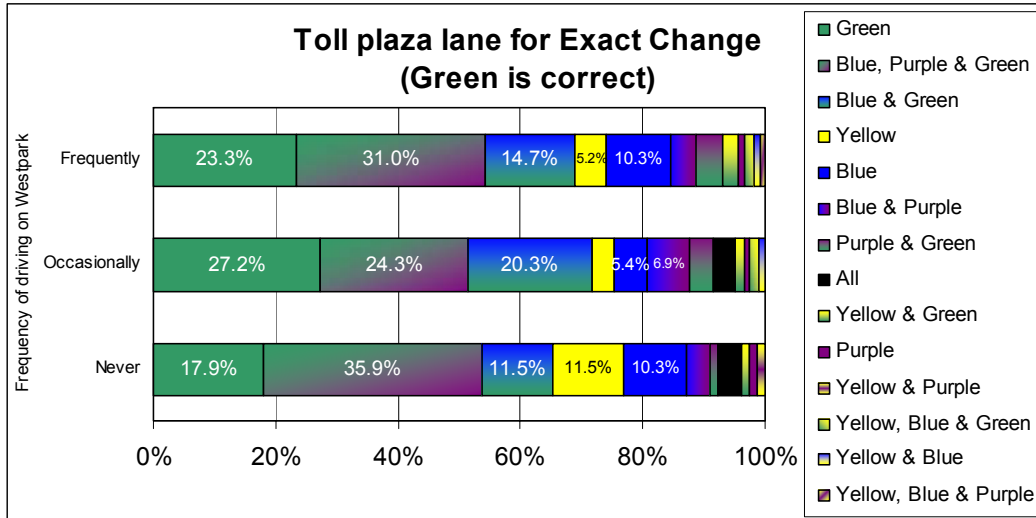


Figure 15. Knowledge of Toll Lane Color Coding – Exact Change.

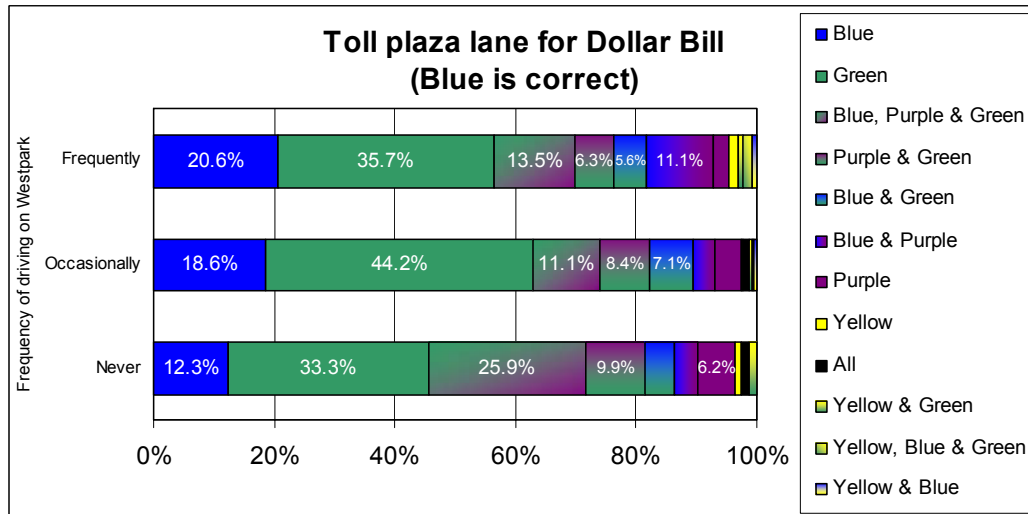


Figure 16. Knowledge of Toll Lane Color Coding – Dollar Bill.

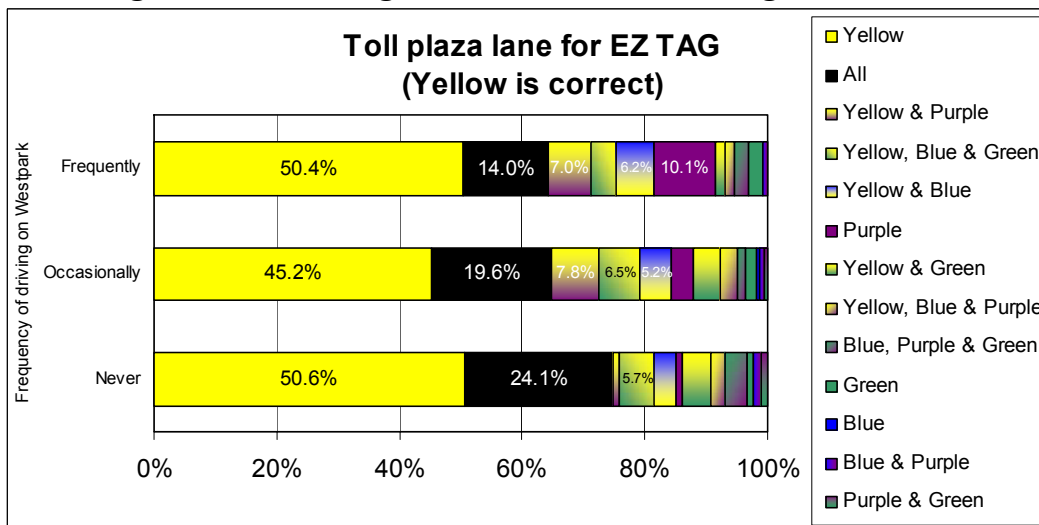


Figure 17. Knowledge of Toll Lane Color Coding – EZ TAG.

Overall, without regard to their frequency of driving on the Westpark Tollway, 24 percent of respondents correctly identified all of the lanes drivers could use to pay tolls with exact change and only 18 percent correctly identified all lanes for which a dollar bill was acceptable. In both cases, drivers who reported they never drive on the Westpark were the least likely to correctly identify all appropriate toll lanes. Differences between frequent and occasional Westpark users are small. A much greater proportion of all respondents, 48 percent, correctly identified all toll lanes for which an EZ TAG could be used. Differences as a function of Westpark use were small. Virtually the same proportion of frequent Westpark users and those who never drive on the Westpark correctly identified the EZ TAG lanes. Experience on the Westpark is reflected in the incorrect responses shown in Figure 17. Erroneously identifying all lanes as appropriate for EZ TAG use decreased as experience on the Westpark increased: 24.1, 19.6 and 14 percent for non-users, occasional and frequent Westpark users, respectively. In addition, a small increase was observed in selecting the purple lane for EZ TAG use among more frequent Westpark users: from 1.1 percent for non-users to 3.5 and 10.1 percent for occasional and frequent Westpark drivers, respectively.

Ratings of specific sign designs and the preferred use and meaning of purple signs

HCTRA EZ TAG patrons were asked to rate each of six specific signs for a hypothetical planned tollway in the Houston area that would be an EZ TAG-only facility; that is, like the Westpark, this new tollway would require users to have an EZ TAG. Neither cash nor exact change would be accepted for toll payment. Respondents were instructed to rate the signs based on how well they thought drivers, including out of area drivers unfamiliar with Houston area roadways, would be able to understand the sign at highway speeds. Ratings were made on a scale from 1 – 10 in which ‘1’ is a “very bad” sign for conveying the intended message, ‘5’ is an “OK or average” sign, and ‘10’ is “very good” sign.

Figure 18 illustrates each of the six signs and the mean rating for each sign by all respondents without regard to experience driving on the Westpark Tollway.

The all green (a) and all purple (b) signs with purple tollway shields received the lowest ratings. Frequency of Westpark use did not substantially affect the ratings, which on average

ranged only between 2.2 and 2.6. Adding an “EZ TAG ONLY” banner across the top of the signs (Signs c, d and f) increased the ratings significantly, especially for the green background signs (c and d), but also for the all purple sign (f). Again, Westpark experience appears to have had little influence on the mean ratings for Signs c, d and f. Although each of these signs received slightly higher average ratings from frequent Westpark drivers than occasional users, who in turn, rated the signs higher than non-users, the maximum difference was less than one rating point (0.86).

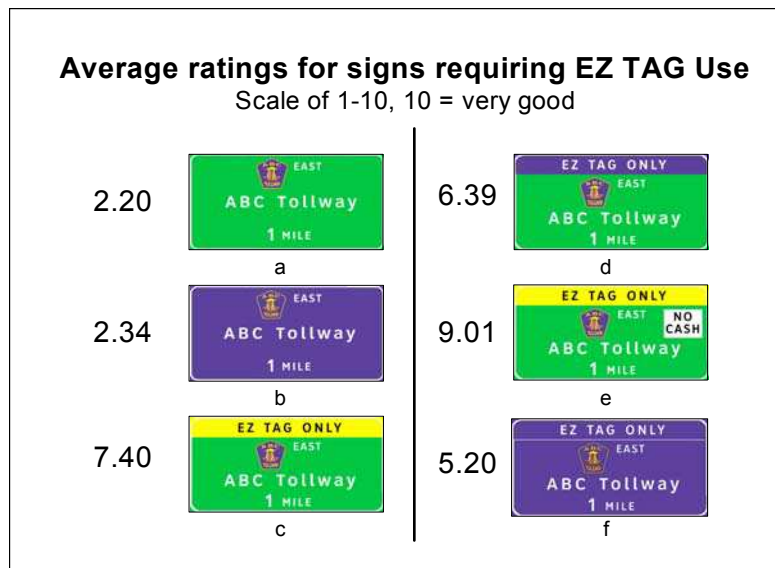


Figure 18. Mean Sign Ratings for Signs Requiring EZ TAG Use – All Respondents.

The highest average ratings were assigned to Sign e, both overall (9.01) and within each of the three Westpark experience groups, ranging from 8.76 to 9.07. Ratings for this sign also exhibited the least variability in ratings of all of the signs among respondents who reported any Westpark driving experience. Unfortunately, this green sign with yellow EZ TAG ONLY banner, is the only sign presented on which a “NO CASH” placard was also included. Although technically redundant with “EZ TAG ONLY,” this addition does add information, especially for drivers who are unfamiliar with EZ TAGs. Including “NO CASH” clearly increased the ratings for Sign e when compared to Sign c. It is likely, but untested, that the addition of a “NO CASH” placard to Signs d and f would also have resulted in higher ratings. It is unlikely, however, that ratings for Signs d and f would have exceeded those for Sign e, especially in light of the numerous comments added by respondents that suggest some perceived problems with the visibility and conspicuity of the purple sign elements, especially at night.

Comparison of the two all purple signs (Signs b and f), as shown in Figure 19, suggests a reluctance among current EZ TAG patrons to rely exclusively on sign color to convey the message that only EZ TAG-equipped vehicles can use a particular tollway. This appears to be true even among those who report the most experience on the Westpark Tollway and who have been exposed most to purple signs. As already noted, the addition of the “EZ TAG ONLY” banner to an all purple sign substantially increased respondent ratings. The aforementioned respondent comments regarding potential visibility problems associated with purple signs combined with the previously reported (see Figure 19) relatively high recognition that “yellow” on toll plaza lane assignment signs is associated with EZ TAG use, suggest a purple sign with a yellow ‘EZ TAG ONLY” banner may receive high ratings from HCTRA customers. Those ratings, and the perceived effectiveness of the signs, would likely be further enhanced by inclusion of a “NO CASH” placard.

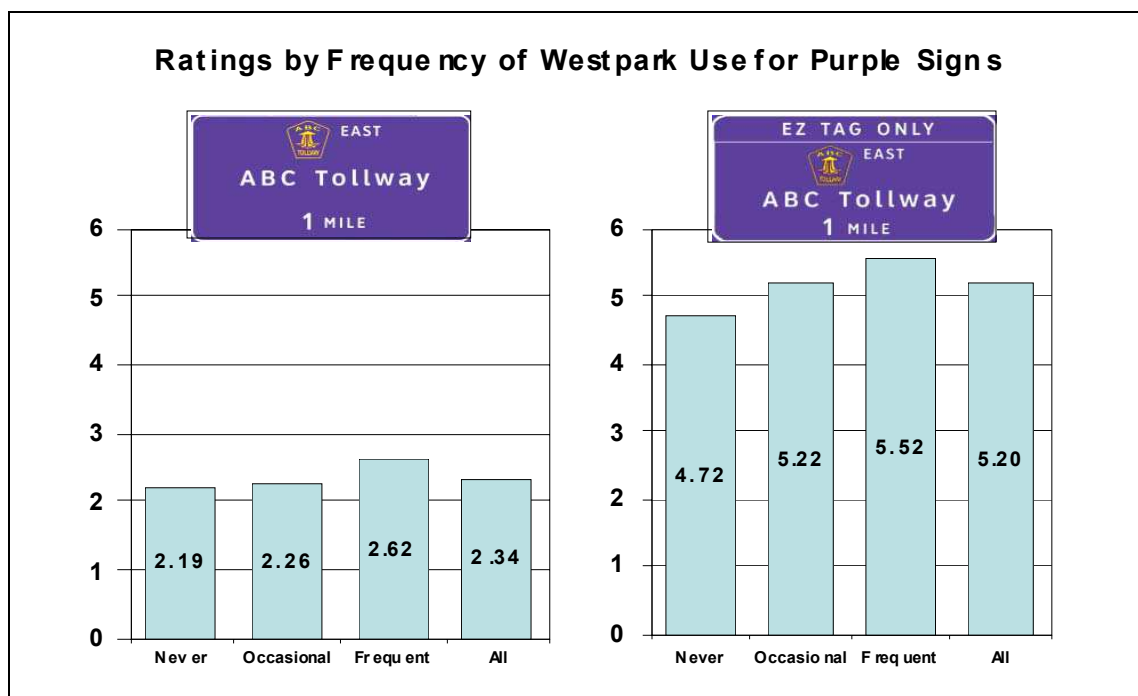


Figure 19. Comparison of All-Purple Signs.

Requested to imagine they were driving outside of Texas and saw purple signs on a toll road, survey participants were asked to identify all forms of payment that would be allowed.

Overall, more than half responded that EZ TAGS payment alone would be permitted. This association between a purple guide sign and “EZ Tag Only” increases with the frequency of Westpark use as shown in Figure 20.

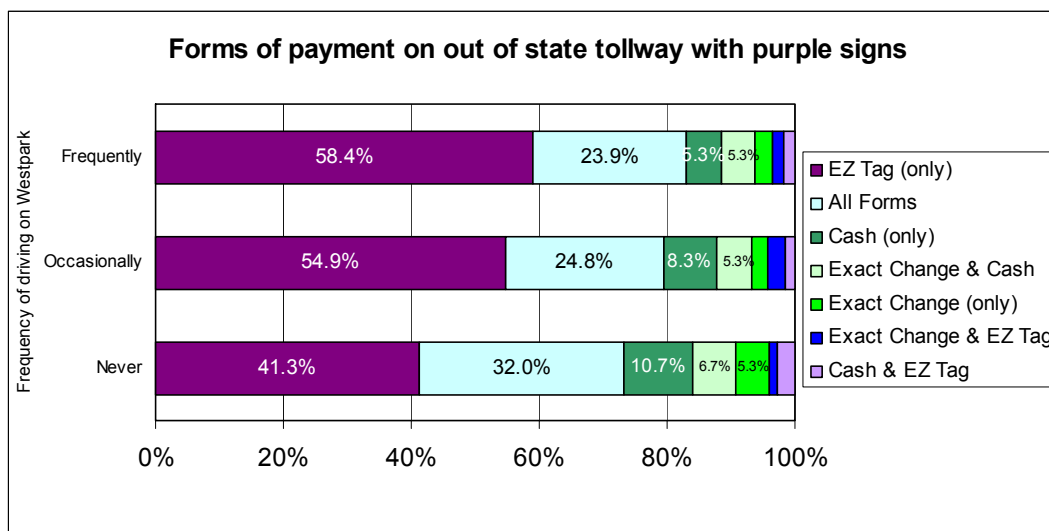


Figure 20. Perceived Meaning of Purple Signs on Toll Roads Outside of Texas.

The final survey item asked respondents directly, “If news signs that have purple backgrounds are created to direct drivers to enter tollways, how do you think these purple signs should be used?” Response alternatives, from which only one choice was allowed, were:

- For all toll roads
- For toll roads where only vehicles with toll tags are allowed
- There’s nothing wrong with the signs now; we don’t need new ones.

Responses, summarized in Figure 21, indicate that overall about a third of EZ TAG patrons do not see a need for new signs. This response, however, appears directly related to the frequency of Westpark Tollway use, and by extension, to familiarity with existing purple signs. Only 25 percent of frequent Westpark users indicated no new signs are needed compared to nearly half of the respondents who never drive on the Westpark.

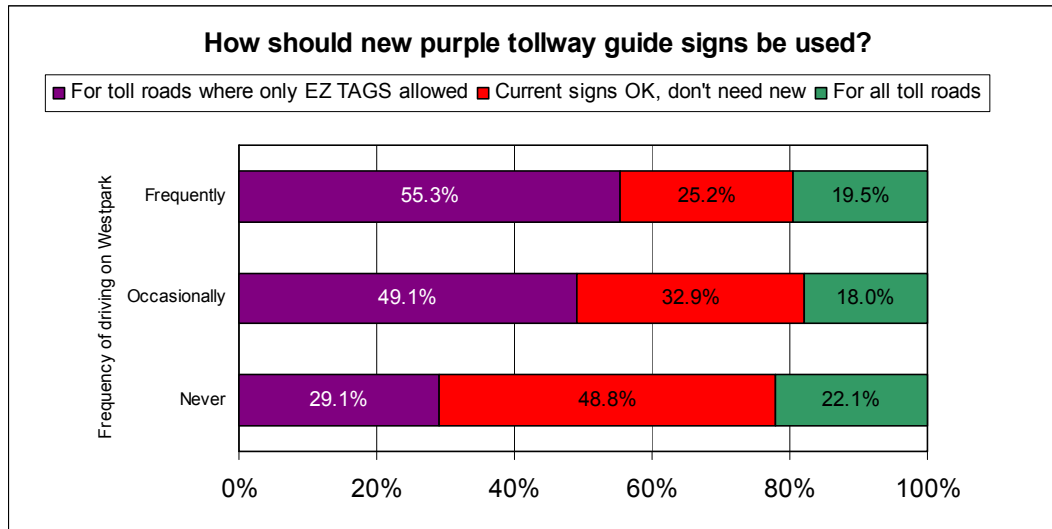


Figure 21. Opinions on the Appropriate Use of Tollway Signs with Purple Backgrounds.

Less than 20 percent of all respondents think purple signs should be used for all toll roads and the extent of experience on the Westpark does not influence this opinion.

A little less than half (46.9%) of all survey respondents indicated that they believe purple signs should be used for toll roads where only vehicles with toll tags are allowed. This response does appear to be influenced by familiarity with purple signs; more than 55 percent of frequent Westpark users compared to less than 30 percent of respondents who never drive on the Westpark indicated that purple signs should be used for EZ TAG-only toll roads.

SUMMARY AND CONCLUSIONS

A mail survey of approximately 1,000 users of HCTRA's electronic toll payment system (EZ TAG) was conducted as part of an evaluation of HCTRA's experimental use of purple guide signs. Among multiple goals, the survey was intended to:

- Assess current EZ TAG patrons' knowledge about the forms of payment accepted on Houston area toll roads
- Evaluate their understanding of the use of color coding on signs at toll plazas
- Estimate the extent to which exposure to purple signs on the Westpark Tollway has created an association between purple signs and the restriction of payment by EZ TAG only.

- Determine preferences for specific sign designs intended to convey that that a toll road is restricted exclusively to EZ TAG toll payment.

The results of the survey suggest that HCTRA EZ TAG holders are generally very knowledgeable about the forms of payment permitted on the Sam Houston and Westpark Tollways, less so with regard to the Hardy Tollway. Frequency of driving on the Westpark is a strong determinant of the knowledge that only EZ TAG toll payment is allowed on that facility.

Less than a quarter of all respondents were able to correctly identify the toll plaza lanes that would accept Exact Change or lanes that would accept a Dollar Bill based on lane sign color alone, whereas nearly half correctly identified that yellow-signed lanes indicated payment by EZ TAG.

Survey results support the idea that exposure to purple signs has led drivers to associate that color with electronic payment even with no public information campaign. While strongest among those who report driving on the Westpark frequently, the association is evident, albeit to a lesser extent, even among drivers who said they never drive on the Westpark.

Overall, EZ TAG patrons prefer existing or only slightly modified sign designs to convey that a toll road is restricted exclusively to EZ TAG toll payment, i.e., a green sign with a yellow EZ TAG ONLY banner. The addition of a “NO CASH” placard to the sign increased the favorable rating it received.

An all purple sign did not fare well as a means for conveying that a toll road is restricted exclusively to EZ TAG toll payment, even among respondents who drive on the Westpark frequently. The addition of a purple “EZ TAG ONLY” banner did increase its rating. While untested, it is reasonable to hypothesize that a purple sign with a yellow “EZ TAG ONLY” banner would be rated still higher.

CHAPTER 2: ON-ROAD EVALUATION OF PURPLE AND GREEN TOLLWAY GUIDE SIGNS

As toll facilities become more widespread, it may be beneficial for driver understanding to uniquely identify toll roads by color coding or the use of special sign designs or logos. Unique colors provide advance notice, at a far greater distance than the words on the sign can be read, of signing related to tollways. For connector ramp applications, this advance notification may result in earlier lane changes to access the ramp. While on the facility, the color can help remind drivers that they are on a toll road. Both the Texas and the Federal MUTCD make few direct recommendations for signing practices on toll facilities. In theory, all signing standards apply to toll roads that are open to travel by the general public. In practice, many toll authorities have been using purple on signs for several years, particularly for electronic toll collection lanes.

With the opening of the Westpark Tollway, the Harris County Toll Road Authority (HCTRA) began limited use of a new background color for tollway guide signs. These guide signs use a purple background with white letters. Purple is one of several colors in the Manual on Uniform Traffic Control Devices (MUTCD) that are “reserved” for a future use to be designated by the Federal Highway Administration (FHWA). HCTRA has been granted approval for a “Request to Experiment with Purple Guide Signs on Toll Roads”.

The Texas Transportation Institute performed an evaluation of the legibility and recognition of freeway guide signs during daytime and nighttime driving in the Houston TX area during March 2007. The purpose of the study was to compare the legibility of words (white letters) on green backgrounds to those on purple backgrounds. In addition, the recognition distance of two designs of advance guide signs for connecting ramps to the Westpark Tollway were assessed. The designs compared were a green guide sign with a purple banner across the top and a guide sign with a full purple background.

EXPERIMENTAL DESIGN

Driving Course Development

Driving Layouts

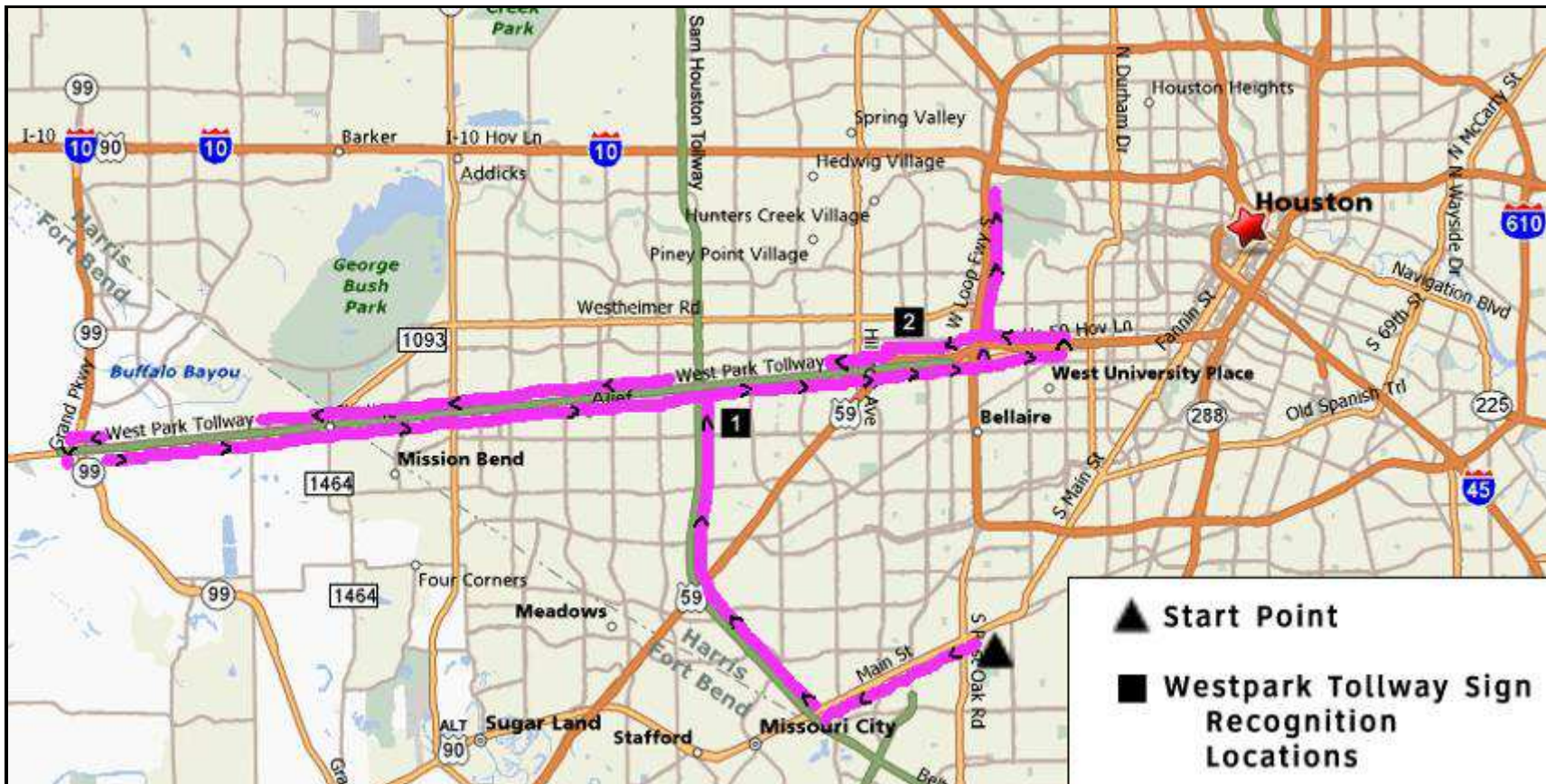
Two different routes, A and B were developed for the study in order to counterbalance the sequence of the two recognition questions for the US 59 and Sam Houston Tollway connector ramp approaches. These routes can be seen in Figure 22 and Figure 23. Both routes began and ended at the Houston TTI office located near the I-10 / I-610 West Loop interchange. For Route B, a researcher drove the instrumented vehicle with the participant as a passenger to a starting location near the southwest portion of the Sam Houston toll road before beginning the study. Participants in Groups A and B would drive Routes A and B respectively. The driving routes were developed to achieve a mix of sign colors, sizes, and legends. Because the experiment had to be designed around existing signs, the traffic volumes and geometric designs of the sign approaches could not be perfectly matched. Photographs of most of the target signs accompany the procedure scripts found in the Appendices C and D.

One feature of the Westpark Tollway proved to be a particular advantage to the experimental design. This roadway crosses through two counties and two different toll road authorities. In Harris County, the guide signs along Westpark Tollway have a purple background. At the western end of the roadway, in Fort Bend County, the signs have a green background. The driving routes took advantage of this by extending the full length of the Westpark Tollway and exposing drivers to signs of the same size, in similar mounting positions, along a road with similar geometrics and traffic volumes. The only difference in these signs was their background color. It should be noted that the street names in Fort Bend County may have been slightly less familiar to drivers. Several of the cross streets in the Harris County portion extend far into other sections of Houston and are familiar to drivers from other parts of the metropolitan area.



1. Participant drives right out of the TTI parking lot and enters the 610 South freeway
2. Exit to 59 South
3. Enter Westpark Tollway
4. Exit on 99 Grand Parkway, stay in left lane, take U turn and reenter Westpark Tollway East
5. Exit to Sam Houston South
6. Exit W. Airport Blvd, U-turn to get back on Sam Houston North
7. Enter Westpark Tollway East
8. Exit to Westpark Dr
9. Left onto 610 frontage and head back to TTI office

Figure 22. Group A Driving Route (Yellow Route).



1. Researcher enters 610 S and exits S Post Oak
2. At Hwy 90, turn left onto 90's frontage road into shopping area to switch drivers
3. Subject exits shopping center on 90's frontage, and does a u-turn to head on 90 in the Southwest direction
4. Exit to Beltway 8 North, then enter the Sam Houston Tollway North through a tollbooth
5. Enter Westpark Tollway East
6. Exit on Westpark Dr to the right
7. Left on Wesleyan
8. Left onto the 59W frontage and enter the freeway
9. Enter Westpark Tollway
10. Exit on 99 Grand Parkway, stay in left lane, take U turn and reenter Westpark Tollway East
11. Exit to Westpark Dr
12. Left onto 610 frontage and head back to TTI office

Figure 23. Group B Driving Route (Pink Route).

Data Collection

A specially instrumented Toyota Highlander (mid-size SUV) was used as the experimental car. The vehicle is equipped with a high resolution GPS system which allows accurate location information within 1 meter. The vehicle's systems also record throttle, brake, and steering position continuously while driving. Cameras in the vehicle recorded the participant's face as well as forward and rear views of the traffic environment.

For the legibility tasks, the experimenter indicated the location of an upcoming sign (e.g. "read the second line on the next overhead sign") and pressed a response button when the participant correctly read the word. The response button marked the GPS location of the vehicle in the data file which was later matched to the GPS location of the sign. The distance between the two points could then be determined. This distance was the legibility distance. For the recognition task, the participant was asked to indicate the earliest moment when they recognized that any upcoming sign told them of the impending exit for the Westpark Tollway.



Figure 24. Texas Transportation Institute's Instrumented Vehicle.

The experimenter was seated in the rear passenger seat and another TTI staff member was seated in the front passenger seat to act as an additional safety observer and to provide navigational directions to the participant. All questions and cues for legibility responses were initiated by the rear-seat experimenter.

Research Participants

Fifty one participants were recruited from the Houston area by word of mouth and distributed flyers. Forty-eight drivers, consisting of 23 women and 25 men completed the driving experiment (3 were dismissed due to rain at the time of testing). The drivers had an average age of 41. Each participant was paid \$50. The participants broadly represented the Houston area and its suburbs, and 62.5% of them reporting paying a toll in the Houston area with an EZ Tag before.

Two sets of pre-drive questions were asked to determine the participants' previous exposure to the Houston area tollways.

At the time of the study, HCTRA had begun installing purple background signs for EZ Tag lanes at some toll plazas along the Sam Houston Tollway that makes an outer loop around the city. Because of this, researchers wanted to know if the participants ever drove along those stretches and would have already been exposed to purple signs, and may established a connection in their mind between the color purple and the use of EZ Tag. While referring to the specific locations on a map, the following two questions in Table 2 were asked:

Table 2. Number of Participants who Drive by Purple Signs in Houston that do not Correspond to the Westpark Tollway.

| | Do you drive on the Sam Houston Tollway South between I-10 and 59? | Do you drive on the Sam Houston Tollway on the northwest side of town between 290 and 45? |
|------------------------------|---|--|
| Never | 8 | 6 |
| Once or twice a year | 12 | 16 |
| Once or twice a month | 19 | 11 |
| Once or twice a week | 4 | 8 |
| 3 or more a week | 5 | 7 |

The next pre-drive questions the participants would be asked could be found on the mail-out survey from year 1, and would also be asked after the participants completed the experimental drive. The questions and the participant responses can be found in Table 3.

Table 3. Number of Participant Responses to Tollway Payment Options Pre Questions.

| What forms of payment can be used on... | | | |
|---|--------------------------|-----------------------|--------------------|
| | the Sam Houston Tollway? | the Westpark Tollway? | the Hardy Tollway? |
| Exact Change | 47 | 8 | 29 |
| Cash (full service) | 47 | 7 | 29 |
| EZ Tag | 47 | 42 | 34 |
| Not sure/blank | 1 | 5 | 14 |

As previously mentioned subjects were divided into 2 groups, A and B. Within those groups, the subjects were also evenly distributed between 3 times during the day, 9 am, 11, am, 1 pm and 7 pm. These times were chosen to avoid the high traffic times in the west Houston area. The 7 pm time slot occurred after dark. In total 12 participants were tested after dark and 36 during daylight hours.

PROCEDURE

Before beginning the experiment, each participant was asked to read and sign a consent form acknowledging their rights as a research participant. The researchers also conducted a Snellen visual acuity and color blind test for each participant to assure that all drivers would pass the vision portion of a Texas driver's license exam.

After completing all of the pre-drive tests and questions mentioned previously, the researcher read the following experimental instructions to the participants: (note: these instructions were also briefly revisited once each participant was seated and situated in the driver's seat of the experimental vehicle)

- *"You will be driving on several Houston freeways including tollways and I will be asking you some questions about the signs you pass. The vehicle you will be driving has an EZ Tag tollpass so you will be able to get on those roadways. Please follow all traffic rules, regulations and signs and pay close attention to the speed limits."*

- *“Unless I tell you differently, it is safe to assume that the questions I ask are about the overhead signs placed above the roadway. Sometimes I will ask you to let me know when you see a certain sign, sometimes I will ask you to read a portion of a sign, and other times I might ask what color the sign is. When reading the signs, please do not answer until you are close enough to the sign that you are sure what it says.”*
- For Group A: *“When we leave the parking lot, you will be driving, and we’ll turn right out of the lot and take the first entrance ramp we can to get onto 610 South.”*
- For Group B: *“When we leave the parking lot, I will drive us to a southern location on Hwy 90 near the Sam Houston Tollway, and then we will switch positions and you will drive.”*
- *“When you get into the car, you will be able adjust the mirrors, seat, and air conditioning for what is comfortable for you. I will ask that you do not wear your sunglasses for this drive. Also, please mute or turn off your cell phone for the study. There will be two people riding in the car with you helping you navigate, so you do not have to remember any directions at this point.”*
- *“I will be providing you with additional directions once we are on the road. Any questions?”*

Once the participant had their questions answered to their satisfaction, the participant and the two researchers headed outside to the experimental vehicle.

Experimental Session

Before leaving the TTI parking lot, a TTI researcher took the following steps to prepare the experimental vehicle for testing:

- Turn vehicle on,
- Turn on GPS power and place GPS antenna on roof of vehicle over the driver’s seat,
- Turn on camera power,
- Turn on Dewetron computer, and open software, and
- Open the appropriate data file variables and name the file for the upcoming subject run.

The researchers would wait until the participant was on the roadway and approaching the first sign stimuli before starting data collection.

As previously mentioned, participants in Group A would begin by driving the experimental vehicle immediately from the TTI parking garage, while Group B would begin by riding in the passenger seat as a TTI researcher drove the vehicle to the start point at Hwy 90 and S Post Oak.

Both the Group A and B scripts for the experimental drive can be found in Appendix C, but a sample segment of the script is shown below.

Q1. As the subject is entering 59

“As soon as you recognize a Westpark Tollway sign, say ‘Westpark’”

- Instruct subject to enter **Westpark Tollway**

Q2. After they respond

“How did you know it was a Westpark Tollway sign?”

Q3. After the last Westpark exit sign

“What color was the top banner sign on the right you just drove under?”
(purple)

Q4. Once on Westpark---

“What does the top line of the next sign on the right say?” (Fondren)

There were 5 basic types of questions that the participants were asked during the drive.

1. The recognition questions as in Q1 above asked the subject when they recognized a Westpark Tollway sign. They would hear this question two times, each time they approached the Westpark entrance (once from US59, once from Sam Houston Tollway).
2. The “how did you know” questions, like Q2 always followed the recognition questions.
3. The “what color” questions, like Q3, were asked periodically during the study for purple, blue, green, and brown signs.
4. The legibility questions as in Q4, would designate a portion of the sign for the participant to read.

5. “Do you expect to go thru a tollbooth on this road?” and “Why?”, were asked twice, both times the participant entered the Westpark Tollway.

Along the drive as the participant answered the backseat researcher’s questions, the researcher wrote their answers down, as well as used a trigger to time stamp the GPS locations of when the correct responses were given when required to read particular signs. Because the GPS locations of the signs had previously been recorded, this would allow the researchers to determine legibility and recognition distances when analyzing data.

Both Group A and B were asked 40 questions along their particular route before returning back to the TTI office.

RESULTS

Two different issues were considered relating to the relative utility of using purple guide signs in place of green guide signs. The first issue considered was the relative conspicuity of a purple sign versus a green sign marking the entrance to the Westpark Tollway from an adjoining roadway. The second issue examined in this study was the relative legibility of white text on purple signs versus green signs. Both of these issues were examined under day and night lighting conditions.

Recognition of Westpark Tollway Advance Guide Signs

First, a comparison between the two similar Westpark Tollway Advance Guide Signs will be presented. Figure 25 shows the two target signs. The sign on the left (green with purple banner) is found in the southbound lanes of U59 just east of the ramp to the Westpark Tollway. The sign on the right, (full purple) is found on the northbound lanes of the Sam Houston Tollway just south of the ramp to Westpark Tollway



Figure 25. Advance Guide Target Signs for Recognition Task.

Mean recognition distances for the two candidate Westpark Tollway signs are presented below in Table 4 below.

Table 4. Mean Recognition Distance for Westpark Tollway Advance Guide Signs.

| Guide Sign Background Color | n | Mean Recognition Distance (ft) | 50th percentile (ft) | 85th percentile (ft) |
|------------------------------------|----------|---------------------------------------|-----------------------------|-----------------------------|
| Purple | 48 | 1897 | 1478 | 1099 |
| Green | 48 | 1553 | 1589 | 1175 |

Table 4 above shows that the sign viewed from the Sam Houston Tollway (entirely purple) was seen an average of 344 feet further than the sign viewed from State Highway 59 (green with purple banner).

The Cumulative Distribution Function of the Daytime Recognition Distances (displayed below in Figure 26) gives more insight into the nature of the data. The observations were similar between signs for the 50% of participants with the shortest recognition distances. The results were very different for the 50% of participants able to spot the target sign at long distances.

When statistically analyzing the data it was found that the assumption of constant variance was violated, so the recognition distance data was log-transformed in all further analyses, and two outlying points were discarded. After this transformation, it was found that there was no significant difference in terms of recognition distance as a function of the color of the sign ($F(1, 46) = 0.48, p = 0.49$), the route ($F(1, 46) = 0.02, p = 0.89$), or the time of day ($F(1, 46) = 2.34, p = 0.13$). The lack of a statistically significant difference can be principally attributed

to the large standard deviation of the recognition distances, especially those collected for the purple sign.

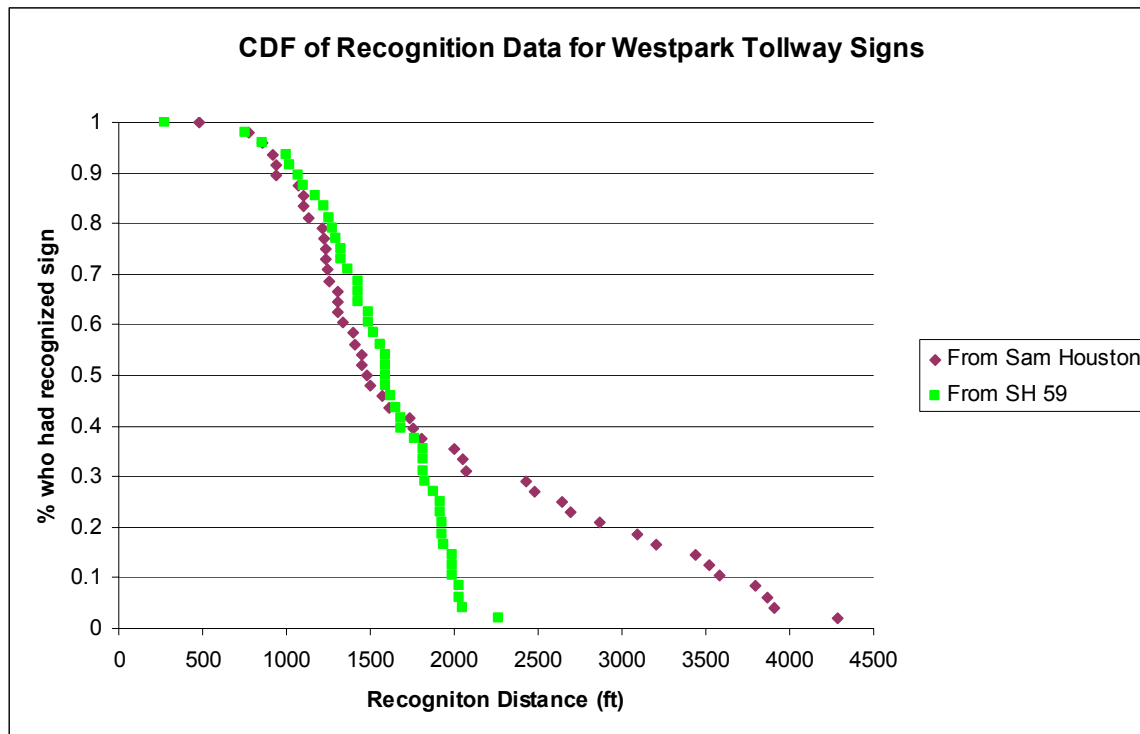


Figure 26. Cumulative Distribution Function of Recognition Distance for both Westpark Tollway Signs.

A particular concern regarding the visibility of purple signs at night has been raised, so the data were further categorized into daytime and nighttime. The night data shows a similar trend as found in the complete data set. Table 5 examines the same two signs, but compares day and night recognition distances. The data show that the all-purple sign produced a longer average recognition distance than the green sign with purple banner during both daytime and nighttime conditions.

Table 5. Mean Recognition Distance for Westpark Tollway Advance Guide Signs, Night Data Only.

| Guide Sign Background Color | n (day) | Mean Day Recognition Distance (ft) | n (night) | Mean Night Recognition Distance (ft) |
|--------------------------------|------------|--|--------------|--|
| Purple | 36 | 2009 | 12 | 1559 |
| Green | 36 | 1626 | 12 | 1333 |

Similar results were found when the data was broken down into 3 age groups. This is presented below in Table 6.

Table 6. Mean Recognition Distance for Westpark Tollway Advance Guide Signs, presented by Age Group.

| Age Group | Guide Sign Background Color | n | Mean Recognition Distance (ft) | Std. Dev. |
|------------------|------------------------------------|----------|---------------------------------------|------------------|
| Younger (<30yrs) | Purple | 8 | 1842 | 1137 |
| | Green | 8 | 1510 | 430 |
| Middle (30-55) | Purple | 25 | 2290 | 1110 |
| | Green | 25 | 1687 | 381 |
| Older (>55yrs) | Purple | 15 | 2190 | 1078 |
| | Green | 15 | 1627 | 263 |

Legibility Results

The experimenter asked the driver to read particular words on the target signs. These varied by letter size and word length in an attempt to get a variety of legibility data. Word length and letter size were balanced across the green and purple target signs as shown in the scripts in Appendix C and in Table 7. Along the route, seven purple signs and seven green signs were viewed and a single word from each sign was read. The signs were divided into groups based on the target words' letter height for further comparison. Mean legibility distances and standard deviations for 7 green guide signs and 7 purple guide signs are presented below in Table 7.

For the purpose of this initial analysis, signs were grouped into categories based on their color and by the size of the characters that the participants were asked to read. The signs discussed here were broken down into 2 color categories, Green signs and Purple signs (both with white legends.) The signs were also broken down into 3 categories based on the target word letter height of either 10 in., 12 in. or 16 in.

Table 7. Mean Legibility Distance for 7 Green and 7 Purple Signs.

| Sign Background Color | Target Legend | Letter Height (in) | Mean Legibility Distance (ft) | St. Dev |
|--------------------------------------|----------------------|-------------------------------|--|----------------|
| Green | Mason Rd. | 16 | 913 | 285 |
| | Peek Rd. | 16 | 815 | 257 |
| | Barker Cypress Rd. | 16 | 1071 | 350 |
| | Grand Mission Blvd. | 16 | 816 | 275 |
| | SOUTH | 12 | 953 | 267 |
| | EXIT 1 MILE | 10 | 1022 | 344 |
| | EXIT ½ MILE | 10 | 771 | 246 |
| Sign Background Color | Legend | Letter Height (in) | Mean Legibility Distance (ft) | St. Dev |
| Purple | Fondren | 16 | 1075 | 359 |
| | Downtown | 16 | 870 | 235 |
| | Eldridge Pkwy | 16 | 1107 | 377 |
| | Westpark Dr. | 16 | 1107 | 318 |
| | SOUTH | 12 | 900 | 265 |
| | EXIT 1 MILE | 10 | 1061 | 310 |
| | EXIT ½ MILE | 10 | 771 | 264 |

In Table 8, the same 7 signs discussed above are re-examined with the data separated based on the time of day at which the data was collected. As expected, data collected at night resulted in shorter legibility distances than data collected during daylight hours.

Table 8. Day/ Night Breakdown for 7 Green and 7 Purple Signs.

| Sign Background Color | Legend | Letter Height (in) | Mean Day Legibility Distance (ft) | Mean Night Legibility Distance (ft) |
|--------------------------------------|----------------------------|-------------------------------|--|--|
| Green | Mason Rd. | 16 | 981 | 707 |
| | Peek Rd. | 16 | 886 | 602 |
| | Barker Cypress Rd. | 16 | 1135 | 886 |
| | Grand Mission Blvd. | 16 | 893 | 588 |
| | AVERAGE for 16 in. letters | | 974 | 696 |
| | SOUTH | 12 | 1029 | 735 |
| | EXIT 1 MILE | 10 | 1074 | 865 |
| Purple | EXIT ½ MILE | 10 | 818 | 631 |
| | Fondren | 16 | 1156 | 836 |
| | Downtown | 16 | 942 | 660 |
| | Eldridge Pkwy | 16 | 1165 | 934 |
| | Westpark Dr. | 16 | 1186 | 848 |
| | AVERAGE for 16 in. letters | | 1112 | 819 |
| | SOUTH | 12 | 999 | 610 |
| Purple | EXIT 1 MILE | 10 | 1126 | 872 |
| | EXIT ½ MILE | 10 | 825 | 611 |

The data were analyzed using a split-plot design with “Participant” as a whole-plot and each treatment combination as a split-plot. When this analysis was done over all 14 signs, Letter Height ($F(3, 42) = 6.76, p < 0.01$), Time (day/night) ($F(1, 42) = 9.78, p < 0.01$), and Visual Acuity ($F(1, 42) = 4.56, p = 0.04$) proved to have a significant effect on legibility distance. Additionally, the two-way interaction of Color x Letter Height showed a marginally significant effect ($F(1, 42) = 2.36, p = 0.1$). Closer examination through a Tukey’s multiple comparison test revealed that this Color x Letter Height interaction is a result of the Purple signs with the 16 in. legends being read significantly further away than the Green signs with the 16 in. legends.

The main effect of color was not significant ($F(1, 42) = 1.26, p = 0.26$), this is the same result as was seen in the recognition portion of the experiment.

Direct comparisons were possible for signs with both the 10 in. and 12 in. legends because an identical word of this size was read on both a green and a purple sign. No direct comparison was possible for the four signs with the 16" legends because no cross street name occurred on both purple and green signs, so data from these were aggregated and then compared. Figure 27 below compares the mean daytime legibility distances for the 10 in., 12 in., and 16 in. legends. The purple 10 in. "Exit 1 Mile" sign received the largest mean daytime legibility distance (1126 feet).

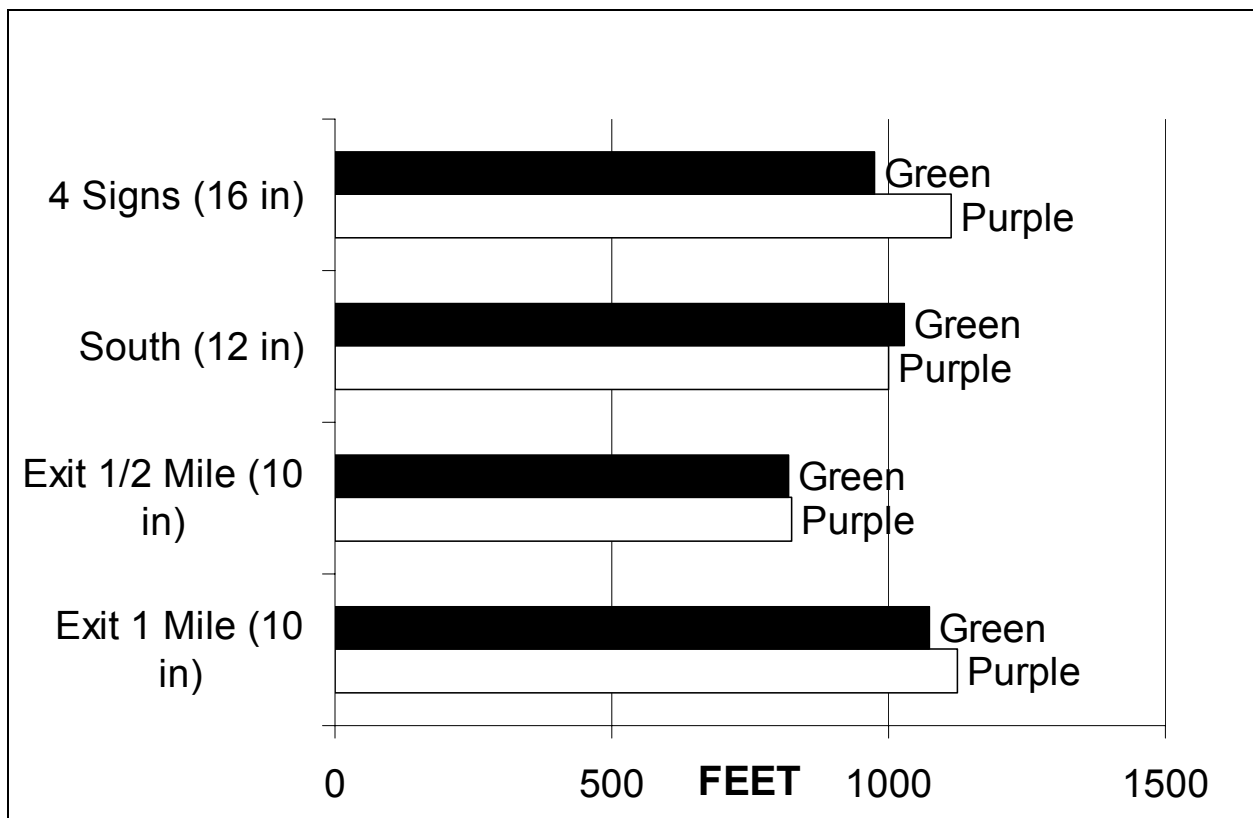


Figure 27. Mean daytime legibility distances (in feet) for 10", 12", and 16" legends.

Figure 28 below displays the mean nighttime legibility distances. Again, the purple "Exit 1 Mile" sign received the largest mean legibility distance.

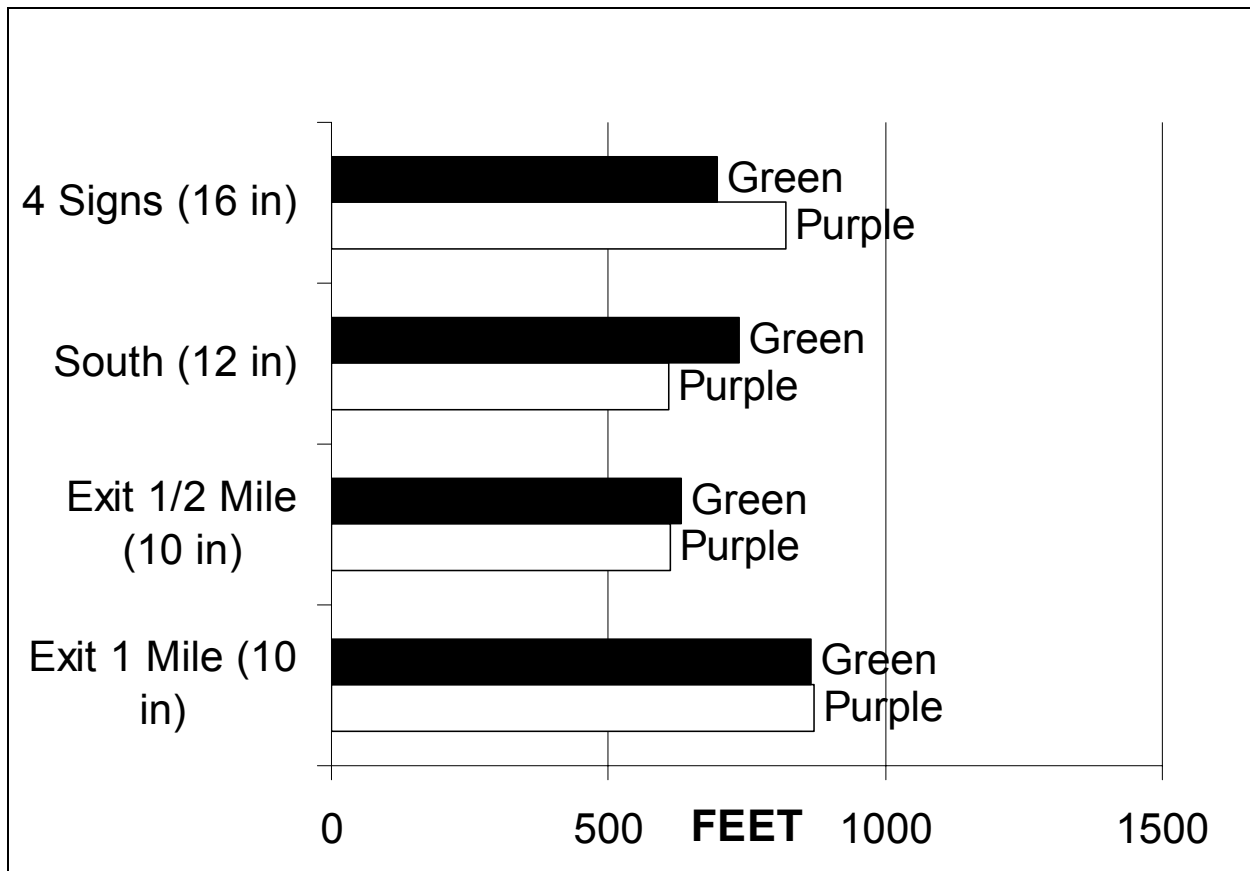


Figure 28. Mean nighttime legibility distances (in feet) for 10”, 12”, and 16” legends

SUMMARY AND CONCLUSIONS

The study reported here is one of the largest on-road traffic sign legibility studies ever conducted. The idiosyncrasies of the Westpark Tollway passing through two different jurisdictions presented a “natural” experiment allowing direct comparison of purple and green guide signs along a single roadway.

The sign legibility results show that there is no difference between purple and green background signs with regards to legibility distance. The recognition results suggest that there may be an advantage to purple signs in terms of drivers recognizing an advance sign for a connector ramp to a tollway.

Overall, the purple and green signs performed similarly in terms of both long distance recognition and legend legibility.

For the recognition task, based on the distribution of the data, it appears there may be some positive effect of using the purple signs in terms of long-range identification. While no statistically significant difference was found between the recognition distances of the two signs, the purple sign was recognized at over 2400 feet in 12 trials. No trials resulted in the green sign being recognized at this distance.

Potentially as drivers become aware of the meaning and usage of purple on freeway road signs they will be more likely to spot them early when looking for electronic tolling lanes. Chapter 1 reported that frequent users of the Westpark Tollway who had been exposed to the experimental purple guide signs along the road for over a year had indeed come to consider the color purple to be indicative of ETC payment and could generalize this knowledge to new situations.

While the only significant difference found in terms of sign color indicated that the some purple signs were actually legible at further distances than some green signs, (in the case of 16" letters,) in general it is unclear whether the purple signs perform much differently than the green signs at all. Based on the finding that the directly comparable legends ("Exit 1 Mile," "Exit ½ Mile," "South") produced very similar legibility distances, the difference found between the green signs with 16" letters and the purple signs with 16" letters is interesting. This effect is possibly related to the some of the participants' familiarity of the target words. Due to the nature of roadways in the area, the purple signs with the 16" letters tended to be located closer to the center of the city. These signs, and the roads they referred to are likely to be somewhat more familiar to the average Houston driver than the green signs (and the roads they referred to) which are located slightly further out of the central metropolitan area. While the test course offered a valuable corridor on which to test purple and green signs, it was not possible to exert careful experimental control over the legends on the signs.

A novel color like purple affords the added benefits of conspicuity and categorization to the average driver. Now traffic engineers can be confident that adding purple signs to the design palette will not lead to drivers being unable to read their signs.

The last discussion point concerns the legibility distances obtained from this on-road study at freeway speeds compared to previous work conducted on closed-course and surface streets. In general, participants read the signs at relatively long distances with legibility indices ranging from 50 to 80 feet of legibility per inch of letter height. Clearly this was based on their

familiarity with road signs in general, and in some cases their knowledge of the selected road names. However, the task in this experiment did closely simulate the actual way-finding task of a driver searching for a specific street name, exit distance, or cardinal direction on a guide sign. Also, in comparison to the closed-course studies cited earlier, participants in this on-road study likely approached the sign reading task differently. Participants in a closed-course environment are under no pressure to maintain a high level of situational awareness. However, participants in this study, driving in traffic on Houston freeways, may have responded quickly in order to remove the mental task of required reading from the overall driving task.

Conversely, participants in closed-course studies lose the ability to apply context clues when trying to recognize words. When drivers are trying to read a specific word on a real guide sign, they can refer to their prior knowledge to help them determine that, for example, “because the target word is in the top corner, it’s likely to be a cardinal direction.” While this tactic does not necessarily help them read the actual word, it would seem to make them more confident in their eye-sight if what they could barely make out corresponds with their expectation. In the closed course experiments cited, no context was presented. Data from this study demonstrate the continued need to conduct research under both the controlled conditions of a test course and the real-world conditions of the open road.

CHAPTER 3: EZ TAG VIOLATIONS BEFORE AND AFTER NEW GUIDE SIGNS

Task 3 of the project evaluated the relationship between the installation of newly designed experimental guide signs at approaches to the Westpark Tollway and EZ Tag violations. Since its opening in May 2004, use of the Westpark Tollway has been restricted to vehicles correctly displaying valid EZ Tags. Detected electronically, the tags function to identify EZ Tag account holders, enabling the toll system to debit user accounts to pay the required tolls. Because EZ Tags are required and provide the only means for toll collection on the Westpark, it is important that guide signing provides information sufficient to deter unintentional violation of the EZ Tag requirement.

Figure 29 (Sign A) illustrates the general design of guide signs on approaches to the Westpark prior to December 2006. New guide signs, replacing Sign A, were installed at the approaches to the Westpark Tollway from US 59 and Beltway 8/Sam Houston Tollway on December 5 and December 4, 2006, respectively. These signs, illustrated in Figure 30 and Figure 31, comprise the experimental sign designs used in the evaluation.



Figure 29. Sign A: Guide Sign Design at Entrance Ramps to Westpark Tollway from Opening until Installation of Experimental Signs in December 2006.



Figure 30. Sign B: Experimental sign design at US 59 Westpark Tollway entrance. Installed 12/5/06.

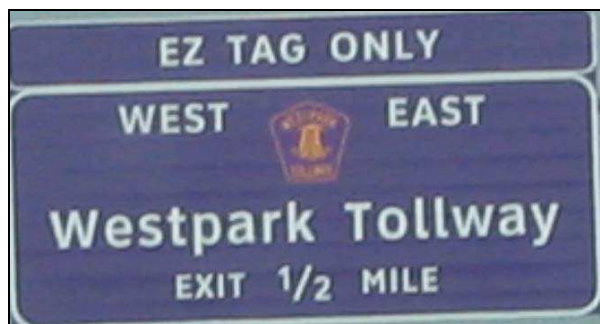


Figure 31. Sign C: Experimental sign design at Beltway 8 Westpark Tollway entrance. Installed 12/4/06.

TRANSPONDER DATA SAMPLED

HCTRA provided traffic volume and EZ Tag violation data from two Westpark Tollway gantry sensor locations for the period from June 1, 2006 through June 30, 2007. The electronically captured data include daily counts of all vehicles with Texas license plates and daily EZ Tag violation counts associated with those vehicles. All vehicles entering the Westpark Tollway westbound from US 59 near Hillcroft (location code MLP1W) and eastbound from the Sam Houston Tollway/Beltway 8 (location code B8X) are included. Thus, the complete data set provides more than six months of traffic and violation data both before and after installation of the experimental signs at these two locations.

Table 9 indicates the mean daily counts of vehicles, EZ Tag violations and violations per 1,000 vehicles and mean percent of vehicles in violation² for the 187 days immediately preceding installation of the guide signs and 208 days following sign installation at the US 59 site and for 186 days before and 209 days after installation at the Beltway 8 site.

Table 9. Summary of Daily Traffic Volume and EZ Tag Violations at Two Westpark Tollway Entry Locations Before and After Experimental Sign Installation: All Data.

| | US 59 Entrance (Location MLP1W) | | Beltway 8 Entrance (Location B8X) | |
|--------------------------|--|--|--|--|
| Daily Average | Before Installation 6/1/06-12/4/06 | After Installation 12/5/06-6/30/07 | Before Installation 6/1/06-12/3/06 | After Installation 12/4/06-6/30/07 |
| Traffic Volume | 20,446.4 | 21,780.0 | 5,138.4 | 5,943.5 |
| EZ Tag Violations | 1,397.8 | 1,885.3 | 486.5 | 497.9 |
| Violations/1000 Vehicles | 70.8 | 88.9 | 96.7 | 84.7 |
| Percent Violations | 7.1% | 8.9% | 9.7% | 8.5% |

² “Violations/1,000 vehicles” and “Percent violations” are functionally identical. They are simply expressed in different units. Daily percent violations are calculated as total number of daily violations/total daily traffic volume times 100.

The average number of daily violations detected increased at both of the sample locations during the period after installation of the new signs. However, at the Beltway 8 site, mean daily violations decreased relative to traffic volume, as indicated by violations per 1,000 vehicles and the percent of vehicles in violation, in the latter case, from 9.7 percent before to 8.5 percent after installation of the new guide signs. Conversely, the higher volume US 59 site experienced an increase in average daily violations from 7.1 to 8.9 percent following experimental sign installation.

Graphical representations of the complete data set obtained from HCTRA are provided beginning on page 4. The dashed vertical line in each figure indicates the installation date of the experimental signs. In all figures, data to the left of the sign installation line were collected when the guide signs at the approach to all Westpark entrance ramps were designed with white letters on a green background and a yellow banner with “EZ TAG ONLY” in black letters at the bottom of the sign, i.e., sign A illustrated in Figure 29. Data to the right of the installation line originate from the period after the guide signs at the approach to Westpark entrance ramps at the US 59 and Beltway 8 data sites were replaced with the experimental signs B and C, respectively, as depicted in Figure 30 and Figure 31. As apparent in the sign illustrations, the pertinent changes in guide signs at the US 59 site consist of moving the “EZ TAG ONLY” banner to the top of the sign and changing it’s color from yellow to purple. Experimental signs at the Beltway 8 site also include the purple banner at the top of the sign and, in addition, a purple background on the main signboard.

Several features of the traffic volume (Figure 32 and Figure 33), frequency of violations (Figure 40 and Figure 41), and violation rates (Figure 36 and Figure 37) are important to the statistical evaluations discussed below and shed light on the rationale for the final analysis that uses a truncated data set.

- The large downward spikes in traffic volume that result in the saw tooth pattern of traffic volume at both the US 59 (Figure 32) and Beltway 8 (Figure 33) sites are, with few exceptions, attributable to the large and predictable reduction in traffic volume on weekends and holidays.
- The absolute number of EZ tag violations (Figure 40 and Figure 41) also exhibit the saw tooth pattern seen in traffic volumes, again attributable primarily to a reduction in the frequency of violations on weekends and holiday periods relative to normal weekdays. Two other features of the frequency of tag violations are discernible in Figure 40 and Figure 41, and especially, in Figure 36 and Figure 37 that normalize violations relative to traffic volume.
- Figure 36 and Figure 37 illustrate the daily EZ Tag violation rate, that is, the number of daily EZ Tag violations per 1,000 vehicles.

- Two anomalies in the violation rate data are apparent in the US 59 data (Figure 7). First, in the period before the change in guide signs, there are two violation rate plateaus. The first extends from the beginning of data collection (June 1, 2006) through September 3, 2006, approximately three months before the change in signs. The second plateau, exhibiting a small but consistent drop in the rate of violations begins September 4, 2006. Both of these periods exhibit relatively stable violation rates (taking in to account the characteristic saw tooth pattern resulting from weekday/weekend variability).
- The second inconsistency in the US 59 data is evident in the sudden elevated violation rates through much of the final month of data following the change in guide signs, beginning on June 2, 2007. With very few exceptions, the post sign-change violation rates are very stable prior to June 2.
- A somewhat similar, but much more pronounced, incongruity is evident in the before sign-change violation rates observed at the Beltway 8 site. After the initial two weeks of data, there is a dramatic upward spike in violation rates, followed very shortly thereafter by a significant drop and then a gradual decline in violations until early October 2006. During the last two months before sign-change (beginning on October 2) violation rates appear very stable – much like the last three months before the sign change at the US 59 site.

Although some plausible explanations were explored, discussions held with HCTRA engineering and toll operations managers prior to finalizing the statistical analysis of the violation rate data were not fully successful in establishing a viable explanation for the apparent anomalies indicated. Despite our inability to fully understand the cause of the anomalous data, a second, truncated data set was developed that removed the questionable data from the before and after sign-change periods. This revised data set includes data from September 4, 2006 through June 1, 2007 for the US 59 site and from October 2, 2006 through June 29, 2007 for the Beltway 8 site. The most obvious difference between the original data set summarized in Table 1 and the revised (truncated) data set, summarized in Table 10, is that in the latter, violation rates at both sites appear to increase after introduction of the experimental signs when compared to the pre-change period.

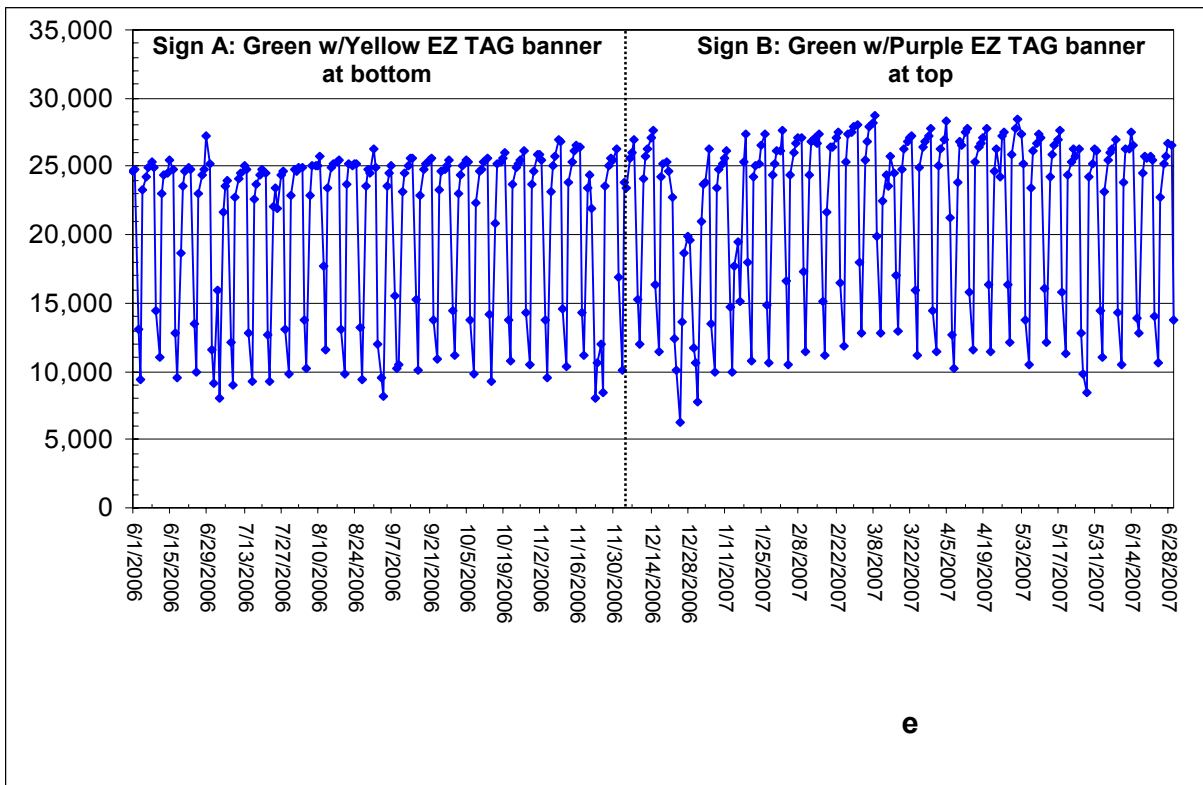


Figure 32. Traffic Volume at US 59 Entrance 6/1/06 – 6/30/07.

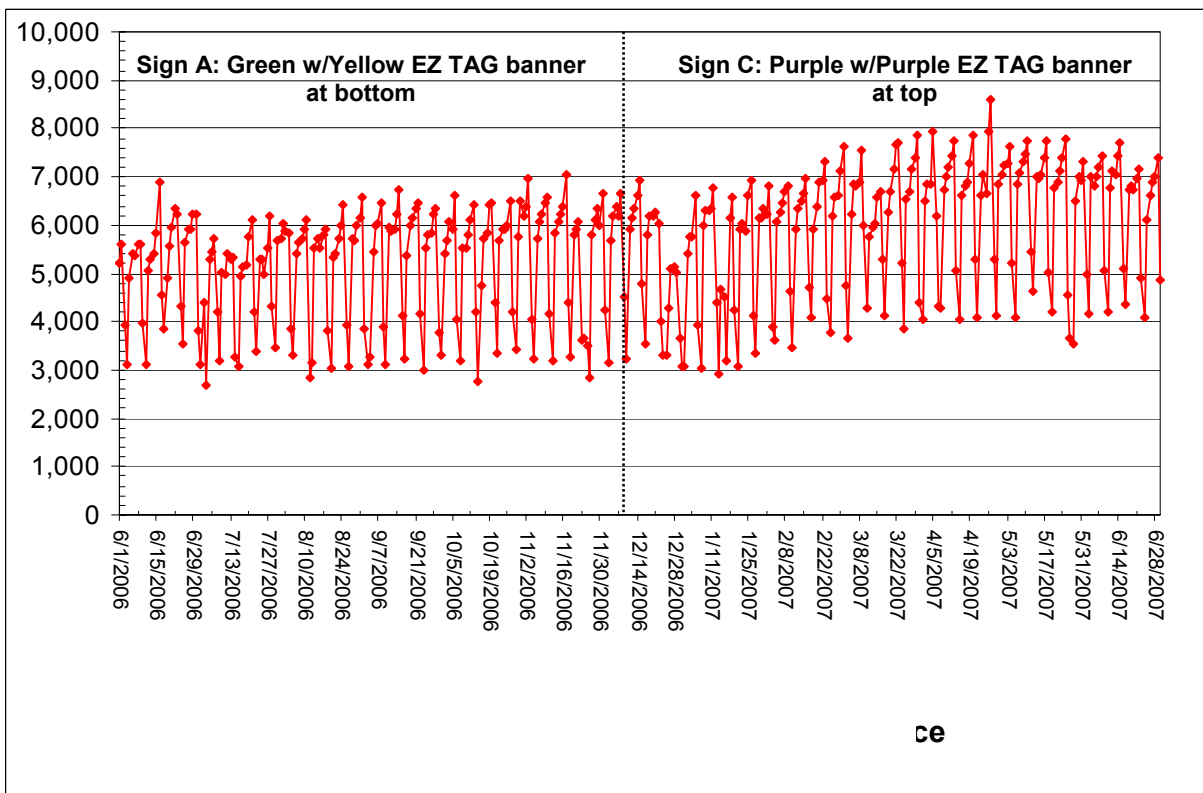


Figure 33. Traffic Volume at Beltway 8 Entrance 6/1/06-6/30/07.

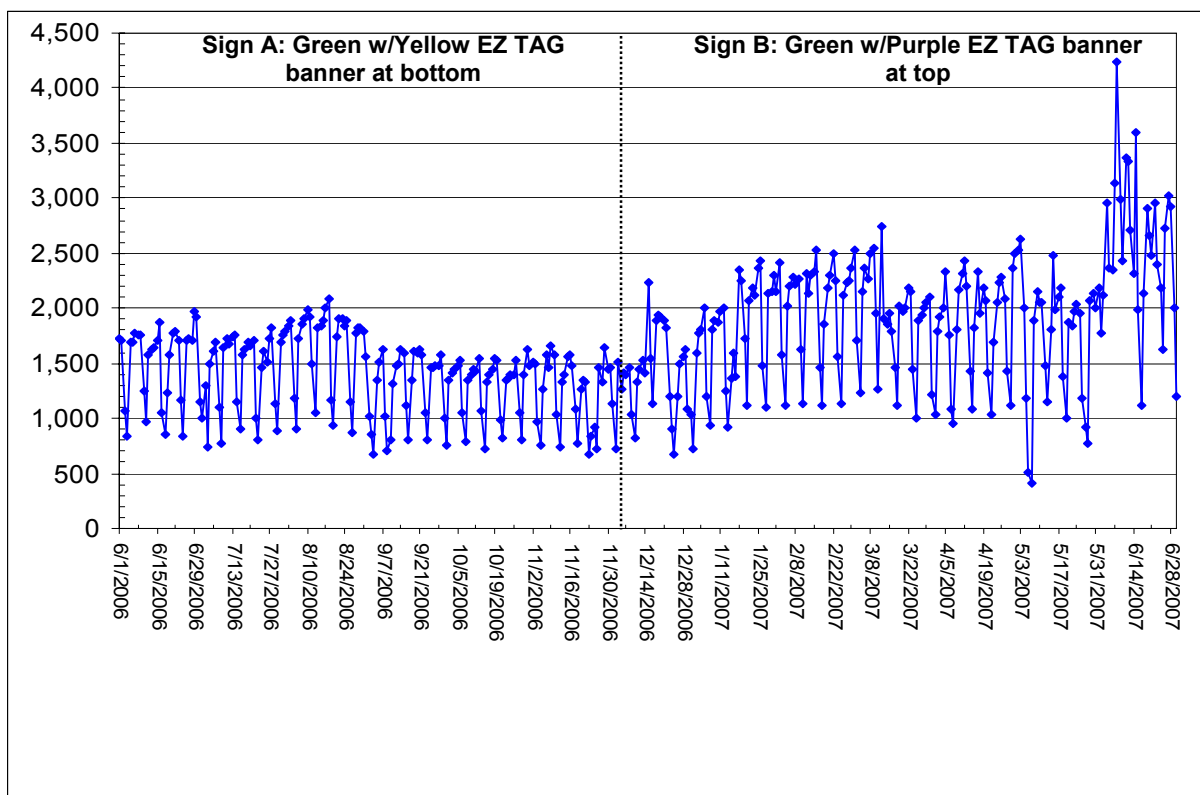


Figure 34. EZ TAG Violations at US 59 Entrance 6/1/06-6/30/07.

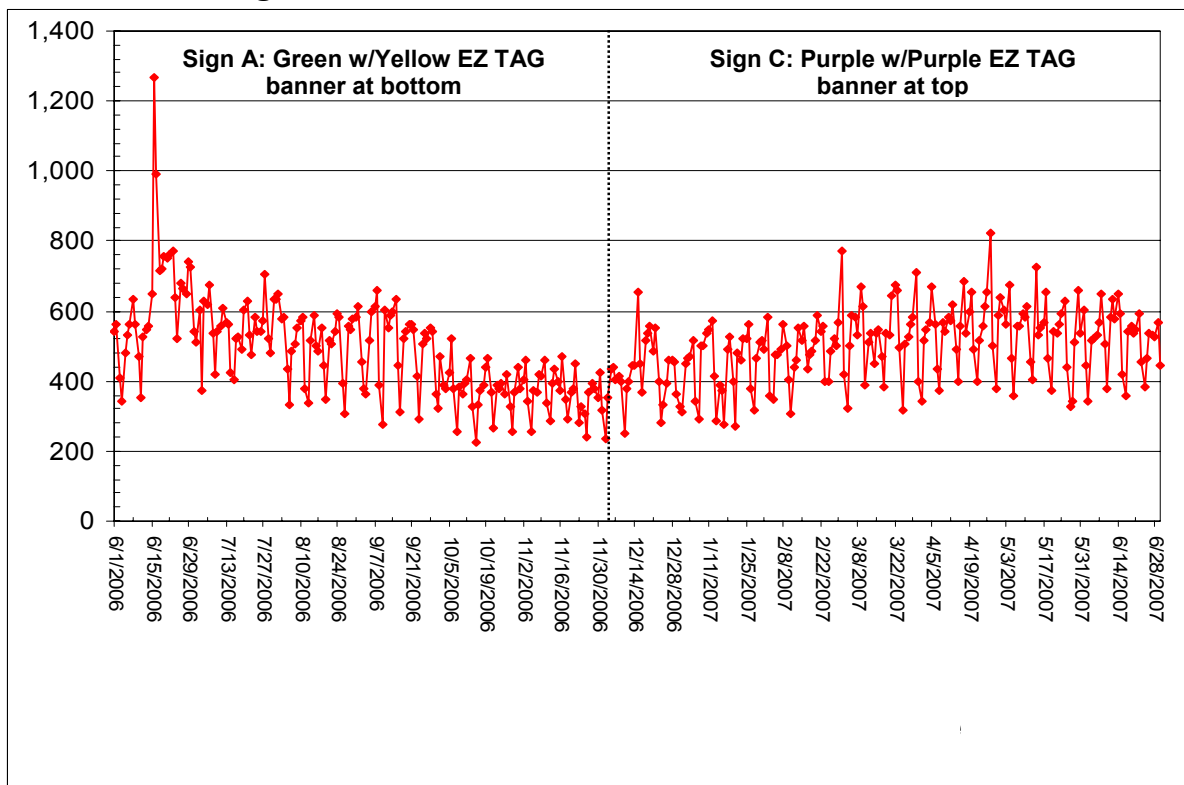


Figure 35. EZ TAG Violations at Beltway 8 Entrance 6/1/06 – 6/30/07.

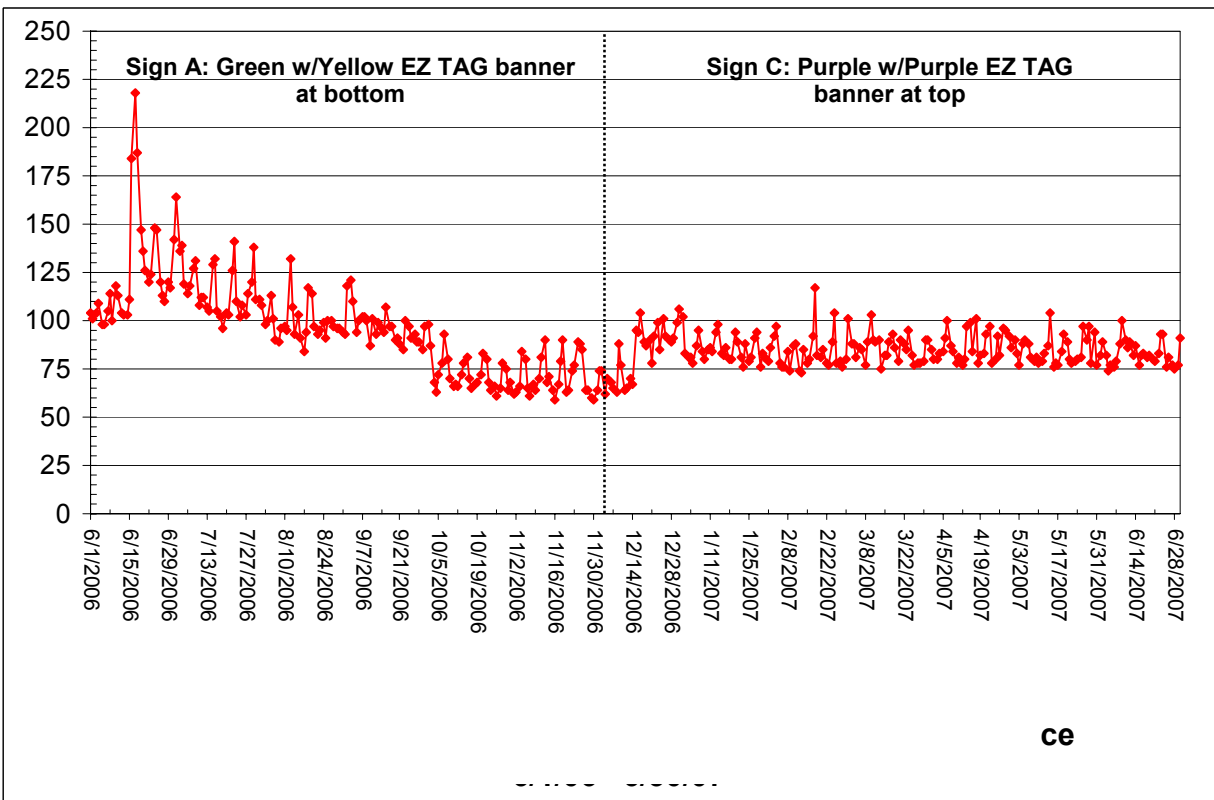


Figure 36. EZ TAG Violations /1000 Vehicles Beltway 8 Entrance 6/1/06-6/30/07.

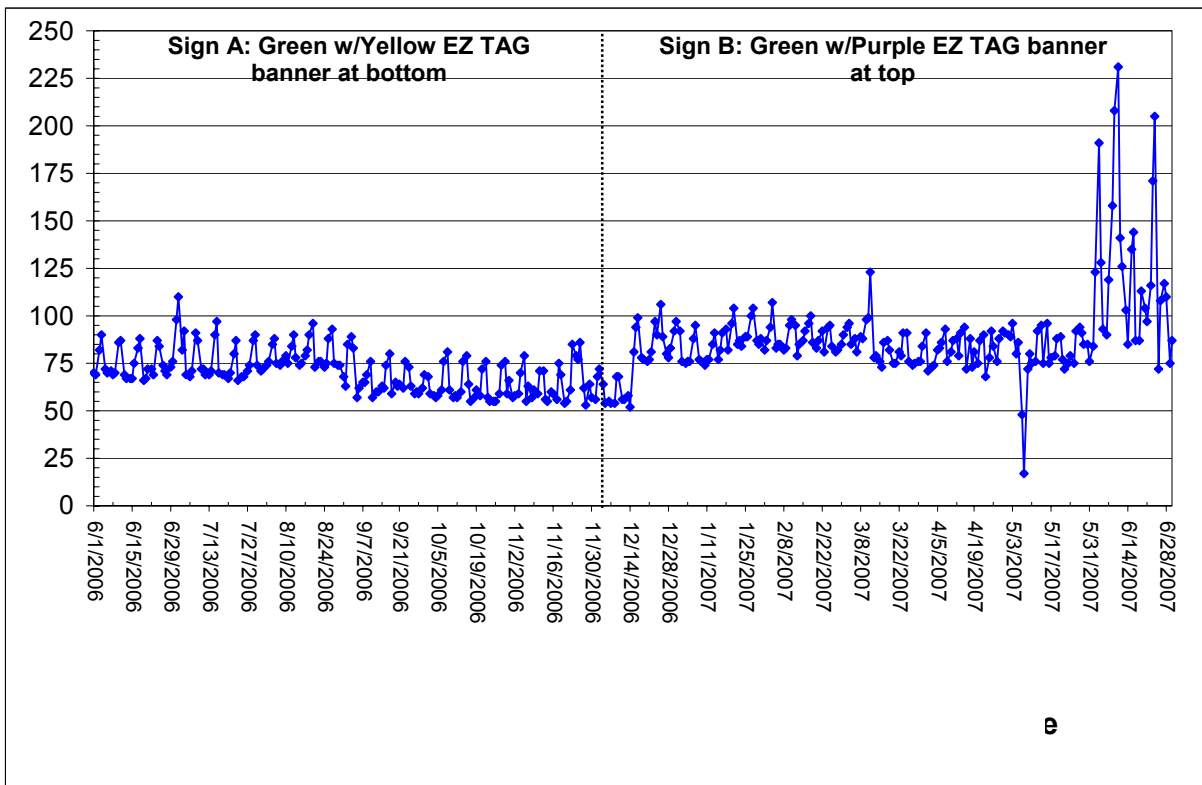


Figure 37. EZ TAG Violations /1000 Vehicles US 59 Entrance 6/1/06-6/30/07.

Table 10. Summary of daily traffic volume and EZ Tag violations at two Westpark Tollway entry locations before and after experimental sign installation: Truncated Data.

| Daily Average | US 59 Entrance (Location MLP1W) | | Beltway 8 Entrance (Location B8X) | |
|--------------------------|--|---|---|--|
| | Before Installation 9/4/06-12/4/06 | After Installation 12/5/06-6/1/07 | Before Installation 10/2/06-12/3/06 | After Installation 12/4/06-6/29/07 |
| Traffic Volume | 20,607.0 | 21,802.5 | 5305.1 | 5948.7 |
| EZ Tag Violations | 1,276.5 | 1,777.3 | 370.8 | 498.1 |
| Violations/1000 Vehicles | 64.2 | 83.0 | 71.5 | 84.7 |
| Percent Violations | 6.4% | 8.3% | 7.2% | 8.5% |

Figure 44 and Figure 45 depict violation rates at the US 59 and Beltway 8 sites using the truncated data set. Although fewer data points are used, especially in the pre sign-change period, the violation rate data are markedly less volatile than in the full data set and appear to remove or reduce the unexplained trends apparent in the complete data set.

DATA ANALYSIS

Identical statistical analyses³ of the violation rate data (violations/1,000 vehicles) derived from both the original complete data set provided by HCTRA and the truncated data set were conducted. The analyses addressed three research questions with respect to the rate of EZ Tag violations:

1. Overall, are the new, experimental signs (signs B and C) different from the original sign (sign A)?
2. Compared to the original sign, did either sign B or C perform better, i.e., result in a lower violation rate?
3. Is there a difference in the relationship between sign design and violation rates for signs B and C?

T-tests were conducted to compare the mean violation rates before and after installation of the experimental guide signs. However, since the data are temporally correlated, ordinary estimates of variance that assume independent data do not apply. To obtain appropriate estimates of the standard error of the mean with temporal correlation, a time series model must first be fit separately to the before and after sign-change data at each test site.

Several models were considered for the initial analysis of the complete data set. Ultimately, an Autoregression and Moving Average (ARMA) model was fit to the data. ARMA models consist of two parts, an autoregressive (AR) part and a moving average (MA) part. The models are referred to as ARMA(p,q) models where p is the order of the autoregressive part and q is the order of the moving average part. In this case, the models are ARMA(1,1). The same model used for analysis of the

³ The authors gratefully acknowledge Nathaniel Litton and Dr. Cliff Spiegelman of the TTI Stat Help Desk for their assistance in the analyses.

complete data set was fit to the truncated data. Basing inferences regarding sign effects on the truncated data may be more appropriate due to the previously noted unexplained trends observed in the complete data set.

Table 11 provides the mean violation rates calculated from the two data sets and the associated standard deviations of the means obtained from the ARMA time series models. These data provide the basis for the t-tests used to assess the influence of sign design on EZ Tag violation rates.

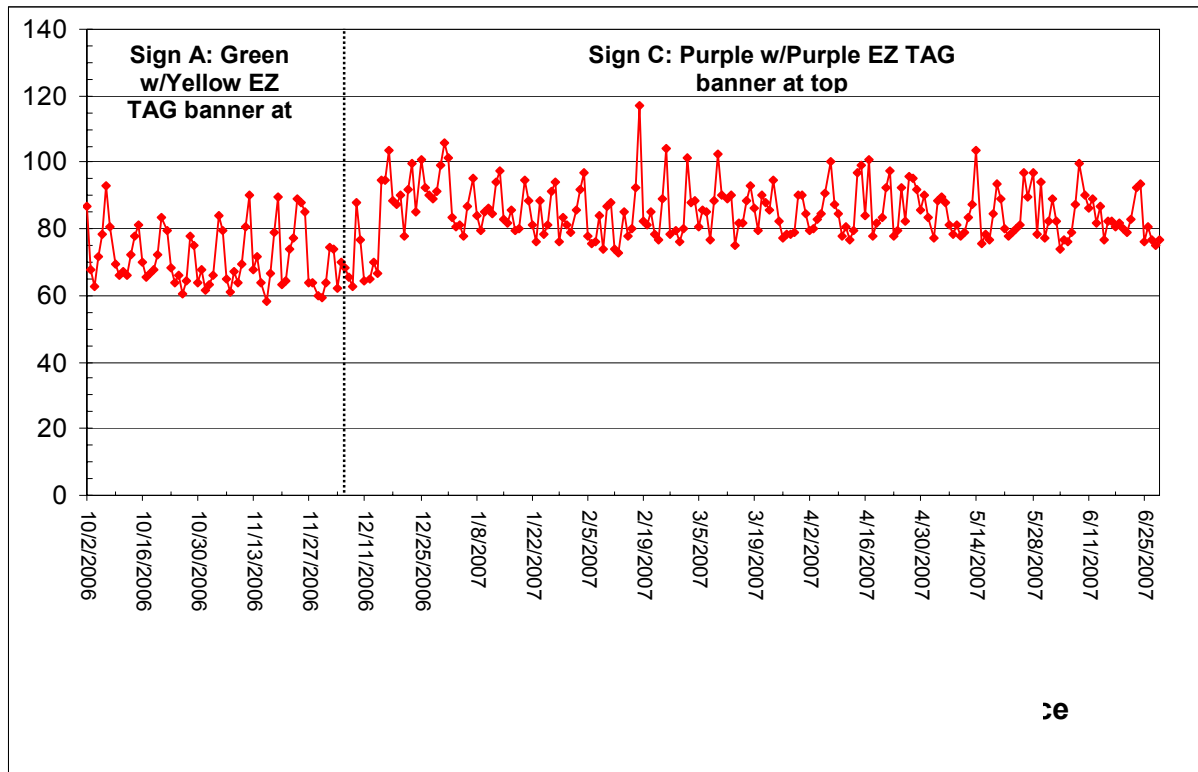


Figure 38. EZ TAG Violations /1000 Vehicles Beltway 8 Entrance 10/2/06-6/29/07.

Table 11. Summary of Daily Average EZ Tag Violation Rates at Two Westpark Tollway Entry Locations Before and After Experimental Sign Installation. All Data and Truncated Data.

| | EZ Tag Violation Rate (Violations/1,000 Vehicles) | | | |
|---|---|--------------------|--------------------|--------------------|
| | Complete data set | | Truncated data set | |
| | Mean | Standard Deviation | Mean | Standard Deviation |
| Sign A: US 59 entrance before sign change | 70.8 | 1.33 | 64.2 | 1.09 |
| Sign B: US 59 entrance after sign change | 88.9 | 3.20 | 83.0 | 1.60 |
| Sign A: Beltway 8 entrance before sign change | 96.7 | 5.61 | 71.5 | 1.64 |
| Sign C: Beltway 8 entrance after sign change | 84.7 | 0.84 | 84.7 | 0.85 |

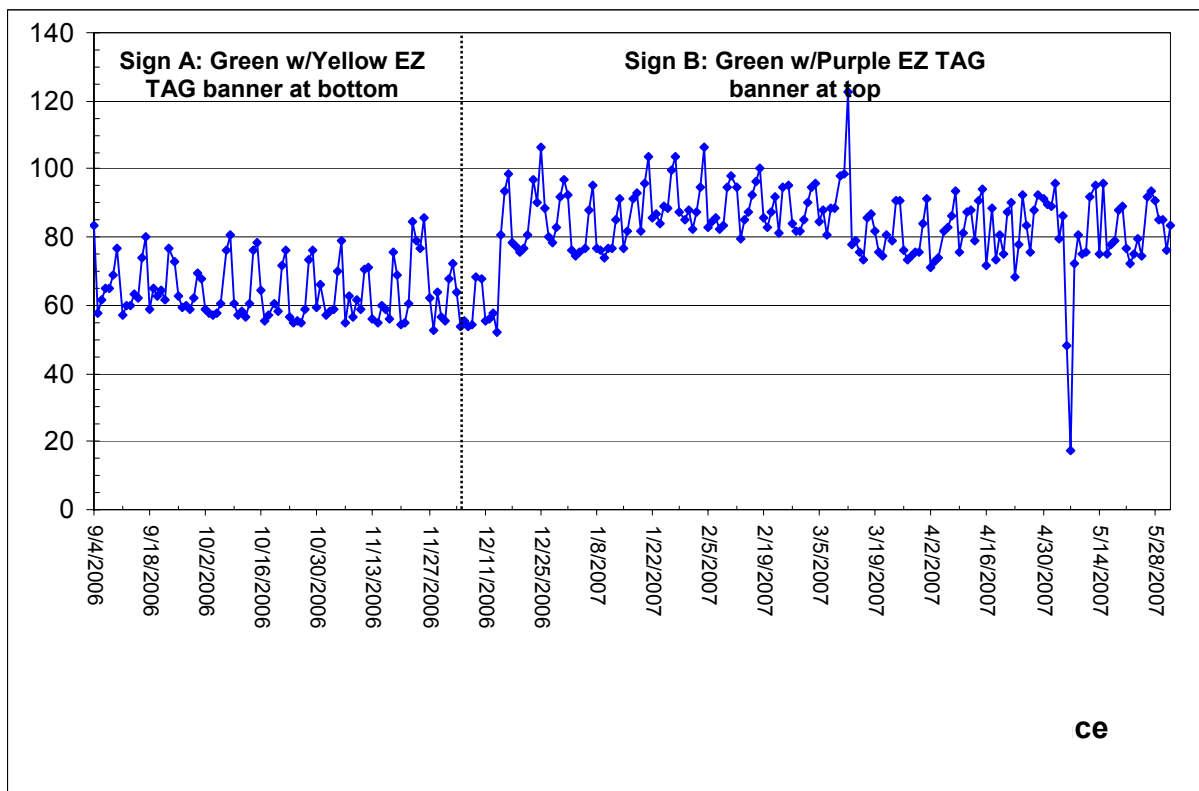


Figure 39. EZ TAG Violations /1000 Vehicles US 59 Entrance 9/4/06-6/1/07.

Table 12 and Table 13 show the results of all t-tests for the complete and truncated data sets, respectively. Rejection of the null hypothesis is accepted for all statistical tests at an alpha level of 0.05. That is, differences between means are considered statistically significant if $\alpha < 0.05$.

When all data are evaluated (including the unexplained, but apparently anomalous violation rates early in the 'before' period and late in the 'after' period) only the second null hypothesis, testing question 2, is rejected at an alpha level of 0.05, suggesting that one of the experimental signs is better than the other relative to the original sign. In this case, the difference C - A at Beltway 8 is significantly less than B - A at US 59. Sign C performs better than sign B since it resulted not merely in a smaller increase in violation rate relative to sign A than did sign B, but a numerically smaller EZ Tag violation rate than Sign A. Note, however, the failure to reject the null hypotheses that test questions 1 and 3 suggests that, overall, there is no difference between the performance of the experimental signs taken together and the original guide sign; and there is no difference in the absolute performance of experimental signs B and C.

Table 12. Hypotheses Tested and Analysis Results Complete Data Set.

| Research Question | Null Hypothesis | t | α |
|---|---|--------|----------|
| 1. Overall, are experimental signs B & C different from the original sign A? | $\mu_{A_{US\ 59}} + \mu_{A_{Beltway\ 8}} = \mu_{B_{US\ 59}} + \mu_{C_{Beltway\ 8}}$ | -0.925 | > .05 |
| 2. Compared to A, did either B or C perform better? | $\mu_{B_{US\ 59}} - \mu_{A_{US\ 59}} = \mu_{C_{Beltway\ 8}} - \mu_{A_{Beltway\ 8}}$ | 4.524 | < .05 |
| 3. Is there a difference in the relationship between sign design and violation rates for signs B & C? | $\mu_{B_{US\ 59}} = \mu_{C_{Beltway\ 8}}$ | 1.252 | > .05 |

The apparent superiority of the all purple sign C suggested by analysis of the complete data set may be a result of the previously discussed very high violation rates observed early in the 'before sign-change' period at Beltway 8 and late in the 'after sign-change' period at US 59. Analysis of the truncated data set supports this possibility.

Table 13. Hypotheses Tested and Analysis Results Truncated Data Set.

| Research Question | Null Hypothesis | t | α |
|---|---|---------|----------|
| 1. Overall, are experimental signs B & C different from the original sign A? | $\mu_{A_{US\ 59}} + \mu_{A_{Beltway\ 8}} = \mu_{B_{US\ 59}} + \mu_{C_{Beltway\ 8}}$ | -11.939 | < .05 |
| 2. Compared to A, did either B or C perform better? | $\mu_{B_{US\ 59}} - \mu_{A_{US\ 59}} = \mu_{C_{Beltway\ 8}} - \mu_{A_{Beltway\ 8}}$ | 2.074 | < .05 |
| 3. Is there a difference in the relationship between sign design and violation rates for signs B & C? | $\mu_{B_{US\ 59}} = \mu_{C_{Beltway\ 8}}$ | -0.925 | > .05 |

Unlike the complete data set, the truncated data set removes much of the unexplained trend that could not be handled with the current analysis tools. Repeating the same analysis applied to the complete data set yields different results that lead to different, and we believe more supportable, overall conclusions about the efficacy of the experimental signs to reduce EZ Tag violations.

In this analysis, as indicated in

Table 13, the null hypotheses testing both the first and second research questions are rejected at an alpha level of 0.05. Rejection of the first hypothesis leads to the conclusion that the experimental signs taken as a whole are indeed different from the old signs; in terms of violation rates, they perform more poorly than the original signs. Fewer violations per 1,000 vehicles are observed with the original sign A. Consistent with analysis of the complete data set, rejection of the second hypothesis again suggests that one of the experimental signs performs better than the other relative to the original sign. Also consistent with the initial analysis, the difference C - A at Beltway 8 is significantly less than B - A at US 59. Therefore, sign C performs better than sign B, relative to sign A. Importantly in this case,

however, both of the experimental signs are associated with higher tag violation rates than is the original green sign with yellow “EZ TAG ONLY” banner at the bottom of the sign.

It must be noted that the experimental signs differ from the original guide sign in both color and the position of the “EZ TAG ONLY” banner. This confounding of sign color and banner location may have had an influence on the performance of the experimental signs relative to the original sign separate and distinct from sign color alone. Observed violation rates in the truncated data set indicate that the experimental signs are associated with higher violation rates. The proportion of that rate increase attributable to sign color and banner placement separately or in interaction is not discernable from the present analysis. None-the-less, the weight of the evidence suggests that neither of the experimental signs as designed and installed for this study offer an improvement in terms of the rate of EZ Tag violations over the original guide signs.

SUMMARY AND CONCLUSIONS

Analysis of EZ Tag violation rates at two locations on the Westpark Tollway before and after the introduction of two experimental guide signs (Figure 30 and Figure 31) indicates the original guide signs (Figure 29) are associated with significantly fewer violations per 1,000 vehicles than either of the two experimental signs.

The all purple experimental sign C (Figure 31) did perform better than the green w/purple banner experimental sign B (Figure 30) relative to the original guide sign, but the absolute violation rates observed with the two signs were virtually identical. Guide signing recommendations based solely on the relationship of those signs to EZ Tag violations favor the original sign design. Should other considerations support adoption of new signs despite the increased violation rates observed, there is little basis for choosing either of the tested experimental signs over the other.

CHAPTER 4: DURABILITY TESTING

MATERIAL PREPARATION

Three different white retroreflective sheeting materials were tested (3M 3990 VIP, 3M DG3, and Avery 7500). The base materials were paired with the imaging systems which might reasonably be used to produce a finished sign. The 3M materials were paired with 3M ink, 3M EC film and ATSM EC film. The Avery material was paired with Avery ink and ATSM EC film (Avery does not offer its own purple EC film). The 3M EC films are acrylic and the ATSM film is cast vinyl. Flat sheets of retroreflective sheeting with various imaging systems were ordered through Interstate Signs. An example of a sheet about to be cut into smaller samples is shown in Figure 40.

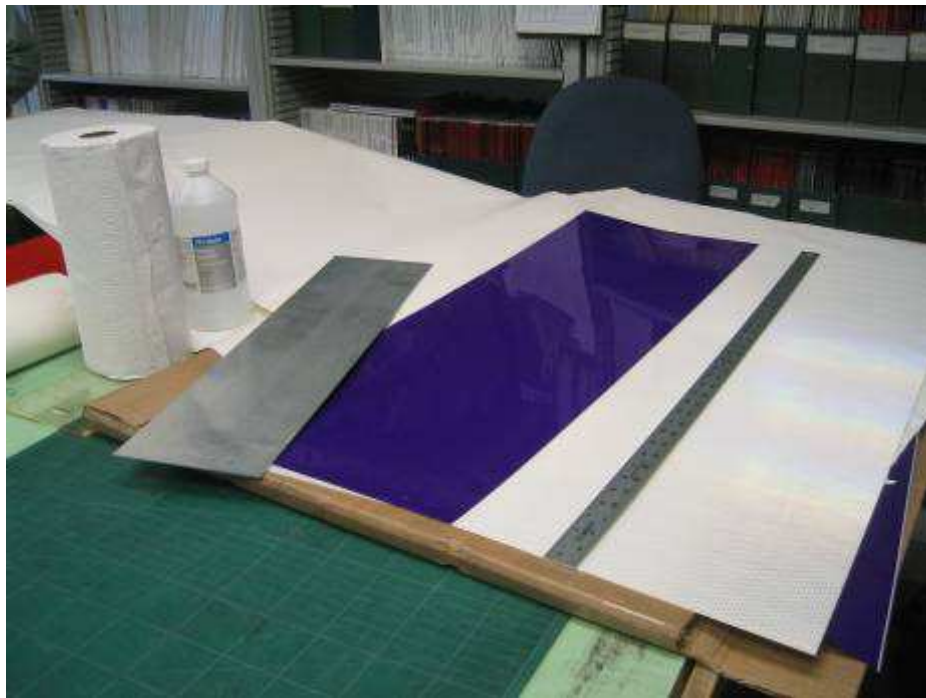


Figure 40. Flat Sheet From Which Weathering Samples were Cut.

From the center of each of these larger sheets, twelve small pieces were cut (3" x 6") that contained a 3" x 3" piece of purple and a section of white base sheeting of the same size. These are shown in Figure 41. This assured that each weathering panel received identical materials. Each smaller piece was applied to an aluminum panel (6" x 18") which had been wiped clean with isopropyl alcohol and allowed to air dry (see Figure 42). Twelve identical panels were created, each with 8 samples as shown in Figure 43.



Figure 41. Individual Pieces of Material Cut to be Put on Panels.



Figure 42. Application of Individual Samples to Weathering Panel.

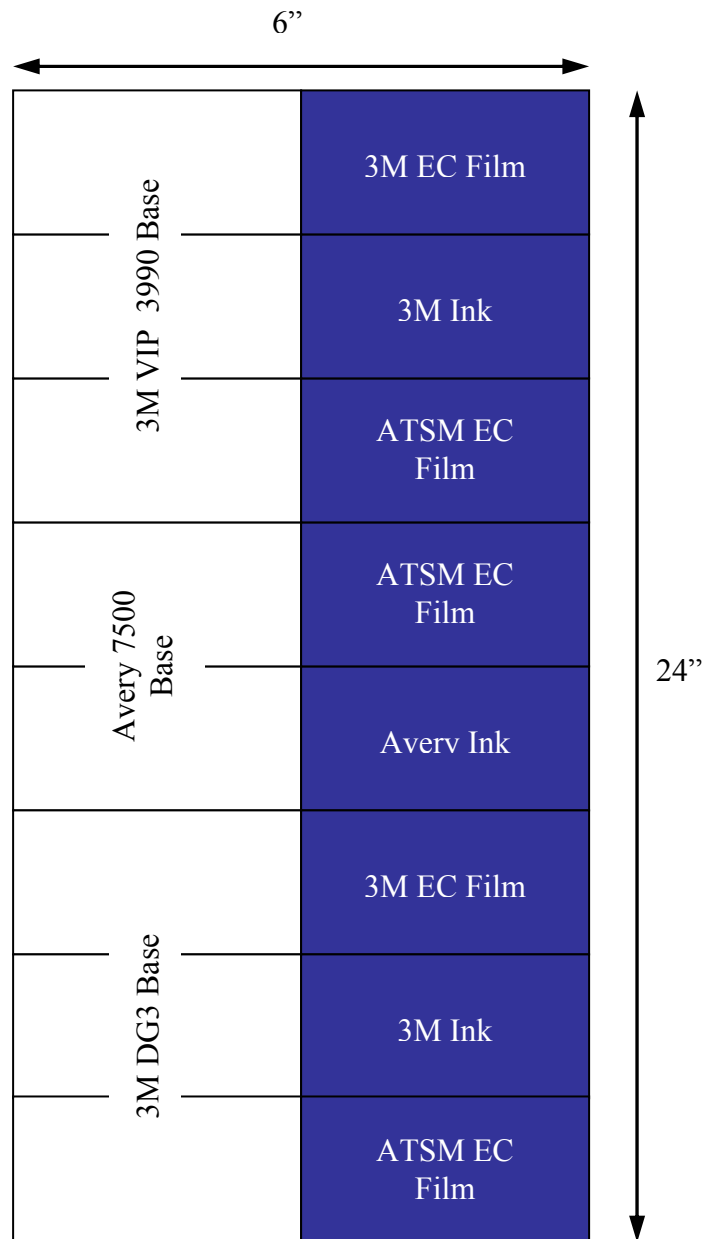


Figure 43. Layout of Completed Weathering Panel.

Before the samples were placed outdoors, retroreflectivity and color measurements were obtained. Retroreflectivity was measured at 0.2 ° observation angle and -4° entrance angle using a Delta RetroSign handheld unit as shown in Figure 44. Color measurements were taken using a BYK Gardner handheld spectrophotometer with a D65 10 ° illuminant as shown in Figure 45. Both of these measurement procedures follow TxDOT Materials Lab specifications.

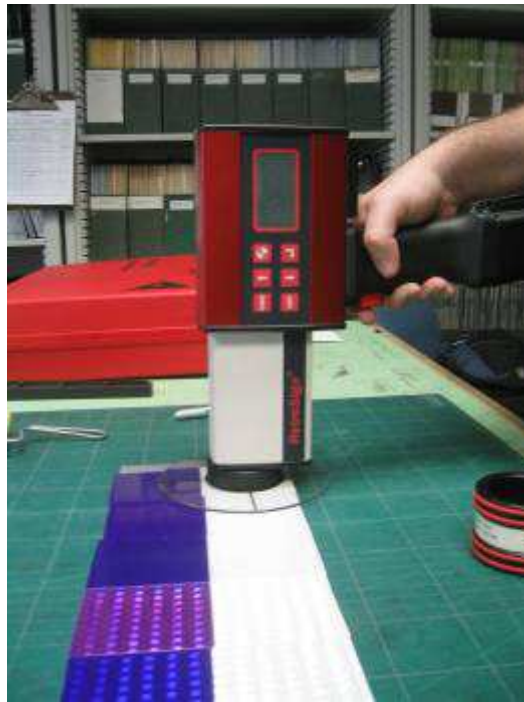


Figure 44. Retroreflective Measurements using Retrosign.



Figure 45. Color measurements Taken with BYK Gardner Instrument.

The weathering rack was installed at HCTRA's maintenance yard on Henry Road in north Houston on March 2, 2006. The rack was designed to present the panels at 45 ° to the sky (see Figure 46). The rack is positioned in the yard to be south-facing and panels are screwed to the wooden frame as

shown in Figure 47. One panel is being removed every three months by TTI staff. This allows visual inspection of all panels in various states of exposure. Panel #1 is being stored in a dark drawer to serve as an unexposed control panel. Panel #5 (12 month exposure) was inadvertently left on the weathering rack, so the 12 month exposure data is missing from the data set.

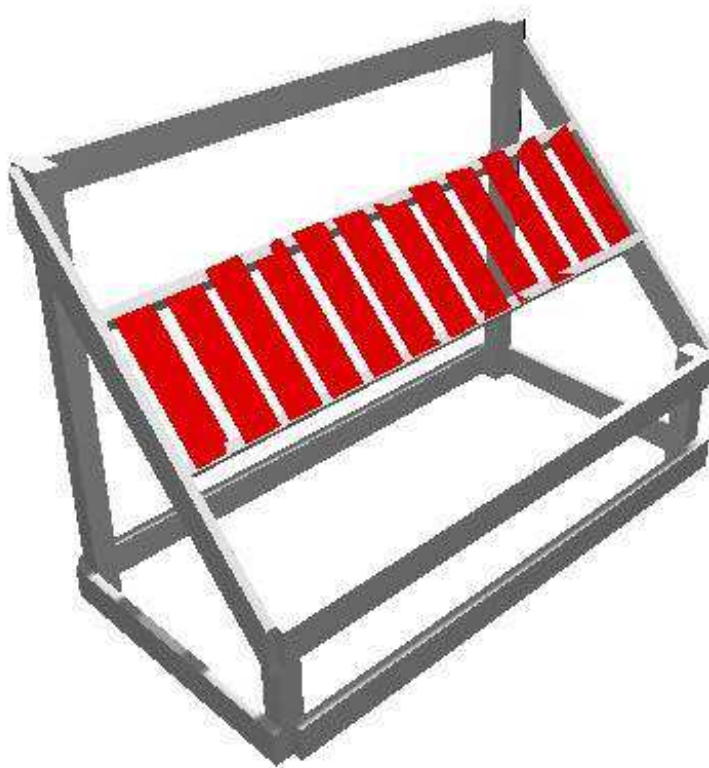


Figure 46. Drawing of Weathering Rack.



Figure 47. Installation of Panels on Weathering Rack.

Panels were removed at three month intervals and subsequently stored in a dark drawer. The instrument readings for all the exposed panels were obtained at the same time (i.e. at 18 months). Each panel was wiped with a damp paper towel to remove any surface dirt before being read.

RESULTS

Retroreflectivity

The results of the retroreflectivity measurements are shown in Table 14. The slight fluctuations in values for the unexposed panel illustrate the natural variability in sheeting material and imprecision of handheld units. The readings for the purple portions of the samples are shown graphically in Figure 48. These illustrate that the ink samples are losing some opacity, producing increasingly higher retroreflectivity values. But even at 18 months exposure, the contrast ratio between the purple inks and the white background was more than adequate for nighttime legibility. As shown in the next section, the daytime color measurements for the purple samples held steady with just a slight shift in the inked materials.

Table 14. Retroreflectivity Measurements for White and Purple Samples.

| Panel 1 - Unexposed Control – Initial Readings to 24 months | | Reflectivity Readings | | | | | |
|--|--------------|-----------------------|-----------------------------|---------|-----------------------------|-----------------------------|------------------------------|
| | | White | | Purple | | | |
| White | Purple | Initial | Unexposed @ 24 months | Initial | Unexposed @ 24 months | White Percent Changed | Purple Percent Changed |
| 3M VIP | 3M EC Film | 516 | 470 | 8 | 9 | -9% | 13% |
| 3M VIP | 3M Ink | 524 | 484 | 14 | 13 | -8% | -7% |
| 3M VIP | ATSM EC Film | 571 | 523 | 8 | 9 | -8% | 13% |
| Avery | Avery Ink | 772 | 717 | 54 | 50 | -7% | -7% |
| Avery | ATSM Film | 795 | 748 | 10 | 11 | -6% | 10% |
| 3M DG3 | 3M EC Film | 975 | 974 | 18 | 18 | 0% | 0% |
| 3M DG3 | 3M Ink | 1001 | 956 | 34 | 35 | -4% | 3% |
| 3M DG3 | ATSM EC Film | 992 | 1010 | 13 | 15 | 2% | 15% |

| Panel 2 - 3 months exposure | | Reflectivity Readings | | | | | |
|-----------------------------|--------------|-----------------------|----------|---------|----------|-----------------------------|------------------------------|
| | | White | | Purple | | | |
| White | Purple | Initial | 3 months | Initial | 3 months | White Percent Changed | Purple Percent Changed |
| 3M VIP | 3M EC Film | 582 | 553 | 9 | 12 | -5% | 33% |
| 3M VIP | 3M Ink | 527 | 534 | 13 | 15 | 1% | 15% |
| 3M VIP | ATSM EC Film | 554 | 567 | 7 | 10 | 2% | 43% |
| Avery | Avery Ink | 753 | 750 | 52 | 49 | 0% | -6% |
| Avery | ATSM Film | 662 | 639 | 9 | 11 | -3% | 22% |
| 3M DG3 | 3M EC Film | 1017 | 969 | 17 | 18 | -5% | 6% |
| 3M DG3 | 3M Ink | 1003 | 962 | 33 | 34 | -4% | 3% |
| 3M DG3 | ATSM EC Film | 958 | 898 | 13 | 14 | -6% | 8% |

| Panel 3 - 6 months exposure | | Reflectivity Readings | | | | | |
|-----------------------------|--------------|-----------------------|----------|---------|----------|-----------------------------|------------------------------|
| | | White | | Purple | | | |
| White | Purple | Initial | 6 months | Initial | 6 months | White Percent Changed | Purple Percent Changed |
| 3M VIP | 3M EC Film | 536 | 557 | 9 | 11 | 4% | 22% |
| 3M VIP | 3M Ink | 535 | 541 | 15 | 19 | 1% | 27% |
| 3M VIP | ATSM EC Film | 549 | 579 | 8 | 11 | 5% | 38% |
| Avery | Avery Ink | 856 | 912 | 64 | 57 | 7% | -11% |
| Avery | ATSM Film | 854 | 837 | 10 | 12 | -2% | 20% |
| 3M DG3 | 3M EC Film | 936 | 891 | 17 | 18 | -5% | 6% |
| 3M DG3 | 3M Ink | 1037 | 998 | 34 | 36 | -4% | 6% |
| 3M DG3 | ATSM EC Film | 989 | 955 | 15 | 18 | -3% | 20% |

| Panel 4 - 9 months exposure | | Reflectivity Readings | | | | | |
|-----------------------------|--------------|-----------------------|----------|---------|----------|-----------------------------|------------------------------|
| | | White | | Purple | | | |
| White | Purple | Initial | 9 months | Initial | 9 months | White Percent Changed | Purple Percent Changed |
| 3M VIP | 3M EC Film | 587 | 588 | 8 | 11 | 0% | -38% |
| 3M VIP | 3M Ink | 538 | 555 | 15 | 19 | -3% | -27% |
| 3M VIP | ATSM EC Film | 537 | 537 | 8 | 11 | 0% | -38% |
| Avery | Avery Ink | 874 | 881 | 67 | 58 | -1% | 13% |
| Avery | ATSM Film | 721 | 683 | 9 | 12 | 5% | -33% |
| 3M DG3 | 3M EC Film | 1014 | 960 | 16 | 19 | 5% | -19% |
| 3M DG3 | 3M Ink | 980 | 948 | 34 | 39 | 3% | -15% |
| 3M DG3 | ATSM EC Film | 1000 | 992 | 14 | 19 | 1% | -36% |

| Panel 5 - 12 months exposure | | Reflectivity Readings | | | | | |
|------------------------------|--------------|-----------------------|-----------|---------|-----------|-----------------------------|------------------------------|
| | | White | | Purple | | | |
| White | Purple | Initial | 12 months | Initial | 12 months | White Percent Changed | Purple Percent Changed |
| 3M VIP | 3M EC Film | 568 | 543 | 9 | 11 | -4% | 22% |
| 3M VIP | 3M Ink | 520 | 543 | 16 | 21 | 4% | 31% |
| 3M VIP | ATSM EC Film | 519 | 547 | 8 | 10 | 5% | 25% |
| Avery | Avery Ink | 897 | 663 | 66 | 54 | -26% | -18% |
| Avery | ATSM Film | 713 | 753 | 8 | 11 | 6% | 38% |
| 3M DG3 | 3M EC Film | 1030 | 883 | 17 | 19 | -14% | 12% |
| 3M DG3 | 3M Ink | 958 | 880 | 31 | 35 | -8% | 13% |
| 3M DG3 | ATSM EC Film | 1029 | 946 | 15 | 18 | -8% | 20% |

| Panel 6 - 15 months exposure | | Reflectivity Readings | | | | | |
|------------------------------|--------------|-----------------------|-----------|---------|-----------|-----------------------------|------------------------------|
| | | White | | Purple | | | |
| White | Purple | Initial | 15 months | Initial | 15 months | White Percent Changed | Purple Percent Changed |
| 3M VIP | 3M EC Film | 558 | 562 | 8 | 10 | 1% | 25% |
| 3M VIP | 3M Ink | 526 | 524 | 16 | 24 | 0% | 50% |
| 3M VIP | ATSM EC Film | 526 | 566 | 7 | 11 | 8% | 57% |
| Avery | Avery Ink | 923 | 854 | 65 | 59 | -7% | -9% |
| Avery | ATSM Film | 725 | 631 | 9 | 13 | -13% | 44% |
| 3M DG3 | 3M EC Film | 901 | 826 | 16 | 18 | -8% | 13% |
| 3M DG3 | 3M Ink | 1003 | 955 | 33 | 44 | -5% | 33% |
| 3M DG3 | ATSM EC Film | 1045 | 964 | 15 | 19 | -8% | 27% |

| Panel 7 - 18 months exposure | | Reflectivity Readings | | | | | |
|------------------------------|--------------|-----------------------|-----------|---------|-----------|-----------------------------|------------------------------|
| | | White | | Purple | | | |
| White | Purple | Initial | 18 months | Initial | 18 months | White Percent Changed | Purple Percent Changed |
| 3M VIP | 3M EC Film | 565 | 571 | 9 | 12 | -1% | -33% |
| 3M VIP | 3M Ink | 517 | 533 | 16 | 26 | -3% | -63% |
| 3M VIP | ATSM EC Film | 513 | 525 | 8 | 12 | -2% | -50% |
| Avery | Avery Ink | 879 | 824 | 65 | 60 | 6% | 8% |
| Avery | ATSM Film | 768 | 714 | 10 | 13 | 7% | -30% |
| 3M DG3 | 3M EC Film | 994 | 929 | 17 | 20 | 7% | -18% |
| 3M DG3 | 3M Ink | 975 | 943 | 30 | 44 | 3% | -47% |
| 3M DG3 | ATSM EC Film | 993 | 891 | 14 | 19 | 10% | -36% |

| Panel 8 - 21 months exposure | | Reflectivity Readings | | | | | |
|------------------------------|--------------|-----------------------|-----------|---------|-----------|-----------------------|------------------------|
| | | White | | Purple | | | |
| White | Purple | Initial | 21 months | Initial | 21 months | White Percent Changed | Purple Percent Changed |
| 3M VIP | 3M EC Film | 551 | 528 | 9 | 11 | -4% | 22% |
| 3M VIP | 3M Ink | 540 | 489 | 17 | 27 | -9% | 59% |
| 3M VIP | ATSM EC Film | 545 | 518 | 8 | 12 | -5% | 50% |
| Avery | Avery Ink | 792 | 634 | 56 | 57 | -20% | 2% |
| Avery | ATSM Film | 870 | 736 | 10 | 16 | -15% | 60% |
| 3M DG3 | 3M EC Film | 884 | 824 | 17 | 20 | -7% | 18% |
| 3M DG3 | 3M Ink | 1007 | 930 | 34 | 49 | -8% | 44% |
| 3M DG3 | ATSM EC Film | 936 | 878 | 14 | 20 | -6% | 43% |

| Panel 9 - 24 months exposure | | Reflectivity Readings | | | | | |
|------------------------------|--------------|-----------------------|-----------|---------|-----------|-----------------------------|------------------------------|
| | | White | | Purple | | | |
| | | Initial | 24 months | Initial | 24 months | | |
| White | Purple | Initial | 24 months | Initial | 24 months | White Percent Changed | Purple Percent Changed |
| 3M VIP | 3M EC Film | 549 | 537 | 8 | 11 | -2% | 38% |
| 3M VIP | 3M Ink | 536 | 526 | 15 | 28 | -2% | 87% |
| 3M VIP | ATSM EC Film | 560 | 550 | 8 | 13 | -2% | 63% |
| Avery | Avery Ink | 758 | 839 | 54 | 63 | 11% | 17% |
| Avery | ATSM Film | 748 | 868 | 9 | 17 | 16% | 89% |
| 3M DG3 | 3M EC Film | 1014 | 954 | 17 | 22 | -6% | 29% |
| 3M DG3 | 3M Ink | 1000 | 957 | 34 | 56 | -4% | 65% |
| 3M DG3 | ATSM EC Film | 976 | 899 | 12 | 21 | -8% | 75% |

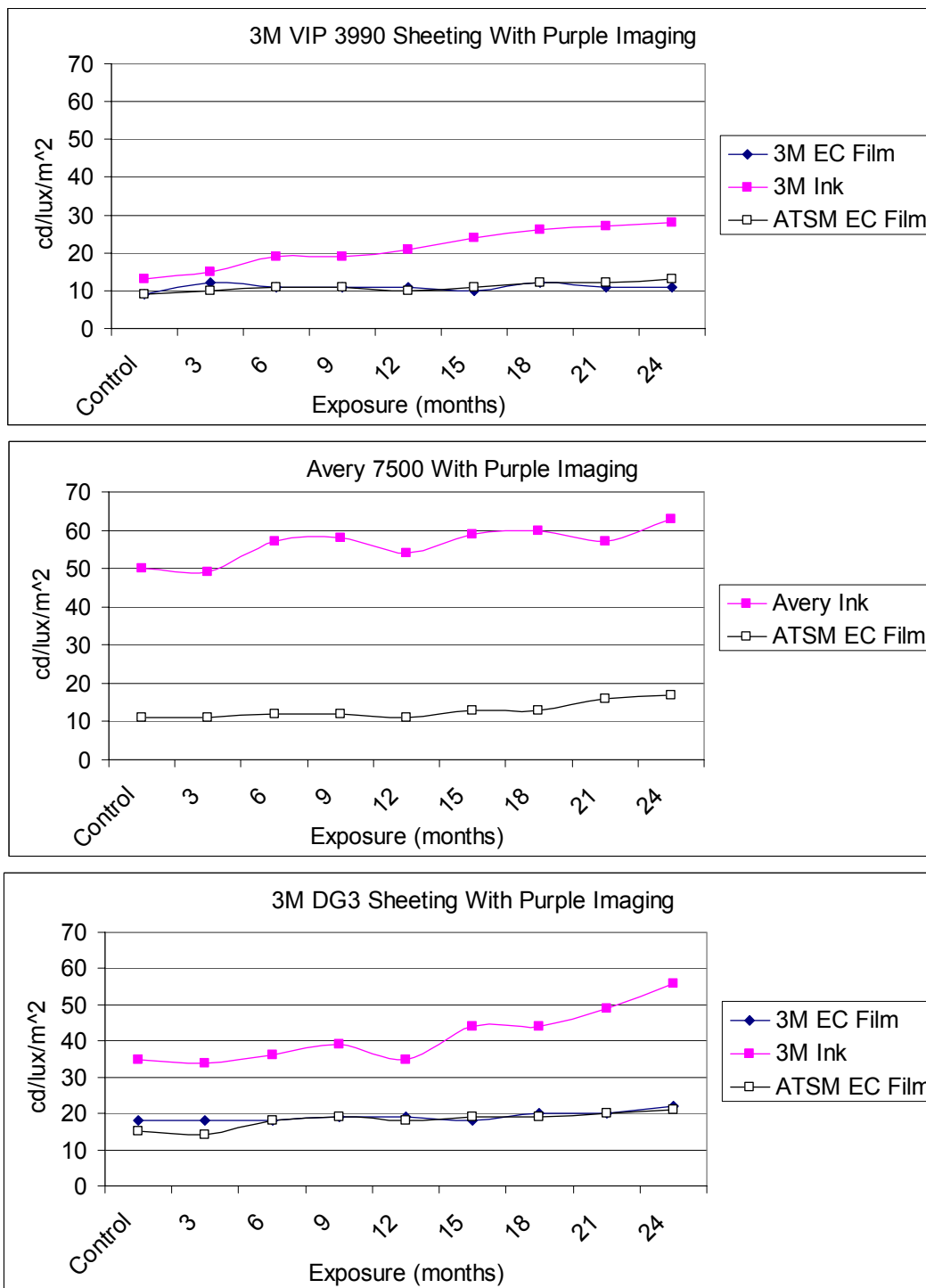


Figure 48. Retroreflectivity Values for Purple Samples Over Time.

Color Measurements

Color measurements are plotted in CIE color space as shown in the figure below which also illustrates the FHWA proposed color boxes. The color measurements taken as part of this study are shown in an enlarged area of this chart in Figure 50. The complete data, including the cap Y luminance values is shown in Table 15.

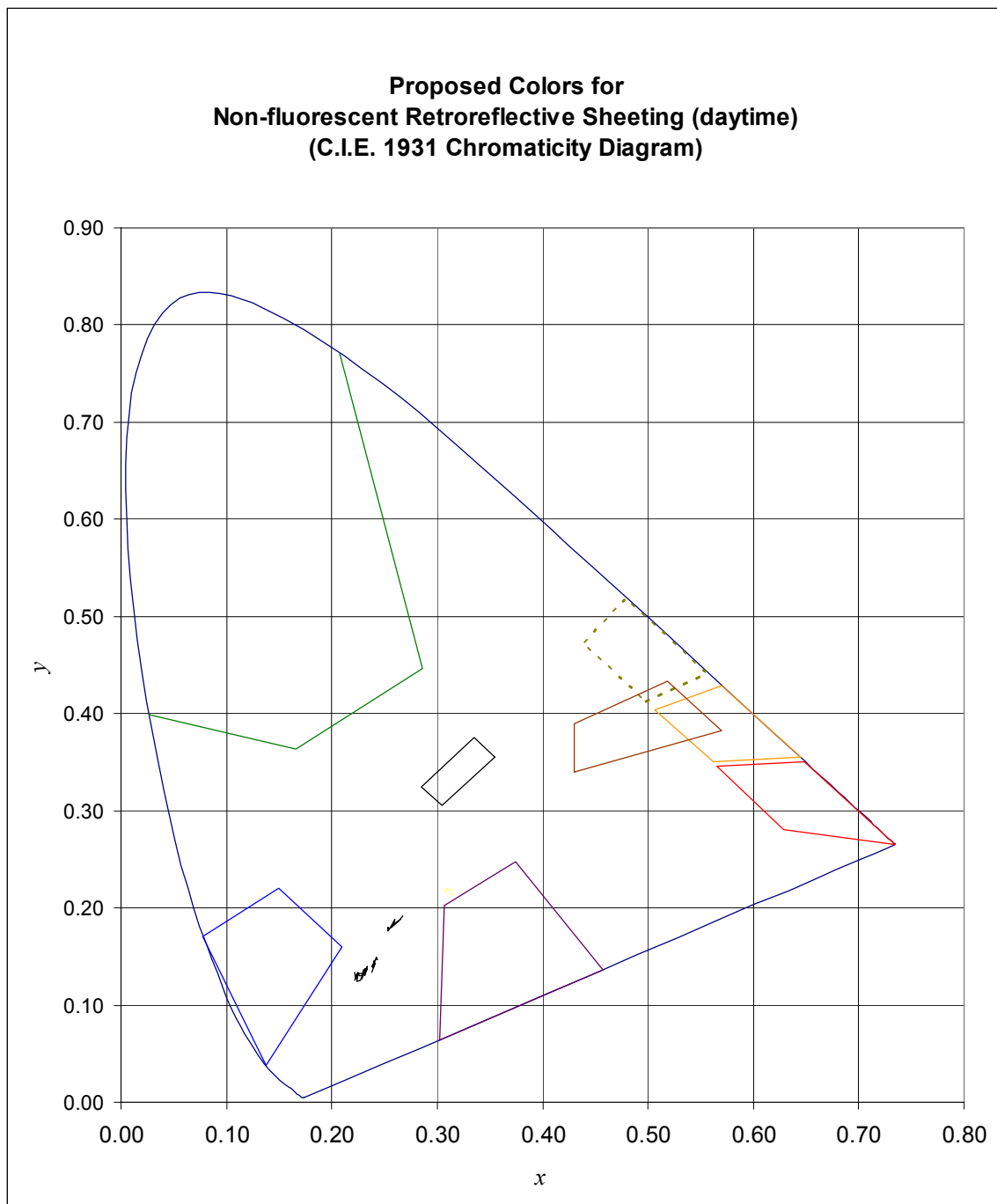


Figure 49. Proposed Colors for Non-Fluorescent Sheeting (daytime).

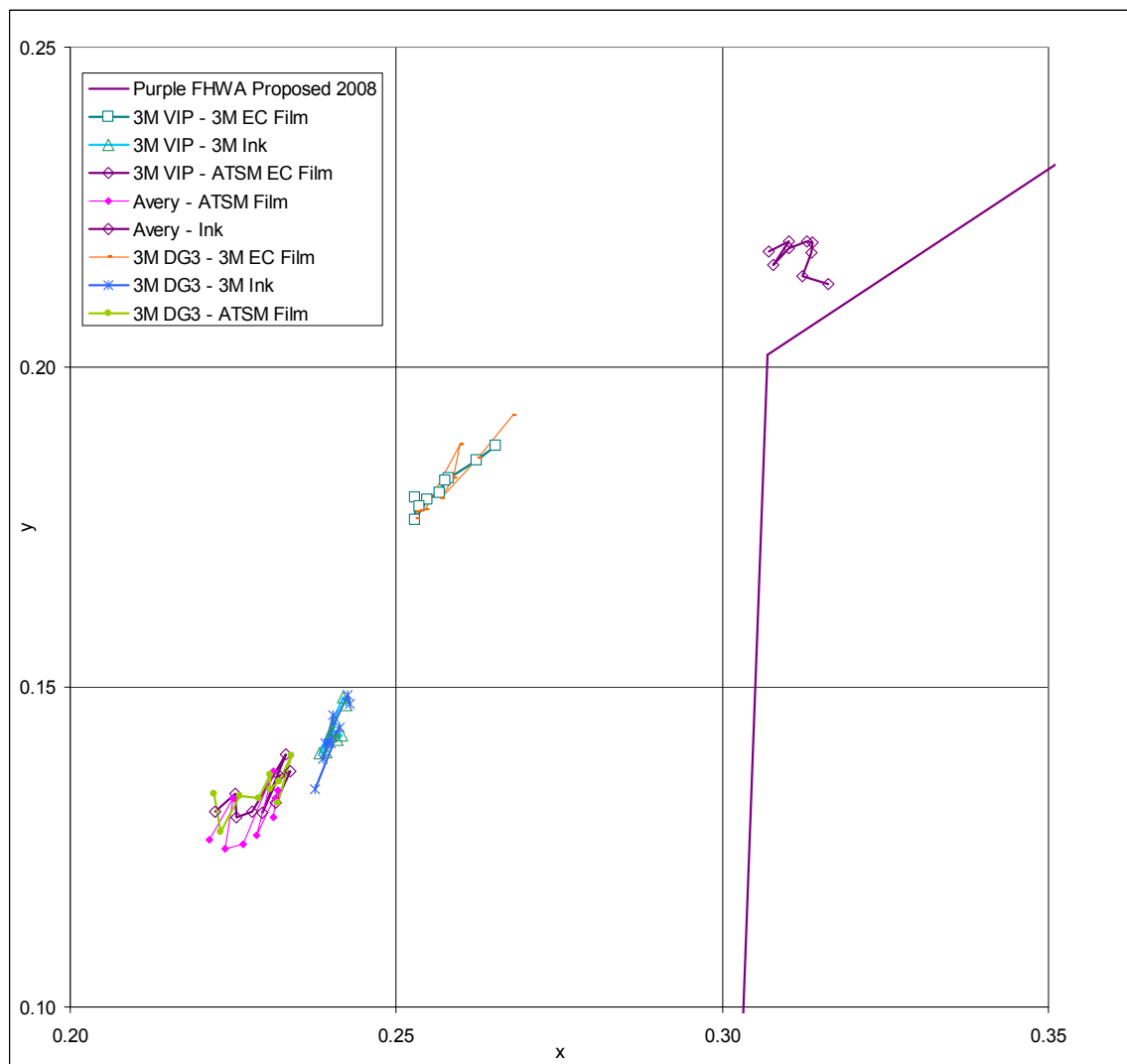


Figure 50. Close-up of CIE Color Space Showing Purple Measurements.

Table 15. Colorimetry Results for All Panels.

| Material | Color Coordinates Y _x y | | | | | | | | |
|---------------|------------------------------------|--------|--------|---------|--------|--------|---------|--------|--------|
| | Panel 1 | | | Panel 2 | | | Panel 3 | | |
| | Y | x | y | Y | x | y | Y | x | y |
| White | | | | | | | | | |
| 3M VIP 3990 | 52.60 | 0.3118 | 0.3666 | 52.41 | 0.3122 | 0.3716 | 52.19 | 0.3120 | 0.3691 |
| 3M VIP 3990 | 52.47 | 0.3113 | 0.3718 | 51.77 | 0.3126 | 0.3713 | 51.66 | 0.3125 | 0.3721 |
| 3M VIP 3990 | 52.31 | 0.3128 | 0.3713 | 52.07 | 0.3113 | 0.3746 | 52.25 | 0.3121 | 0.3748 |
| Avery 7500 | 54.53 | 0.3123 | 0.3470 | 54.46 | 0.3142 | 0.3436 | 51.60 | 0.3038 | 0.3127 |
| Avery 7500 | 51.51 | 0.3109 | 0.3352 | 51.19 | 0.3104 | 0.3428 | 51.22 | 0.3062 | 0.3254 |
| 3M DG3 | 39.11 | 0.3103 | 0.3330 | 39.11 | 0.3122 | 0.3353 | 39.58 | 0.3130 | 0.3343 |
| 3M DG3 | 39.43 | 0.3103 | 0.3324 | 39.46 | 0.3117 | 0.3361 | 39.39 | 0.3129 | 0.3381 |
| 3M DG3 | 40.10 | 0.3109 | 0.3331 | 40.02 | 0.3111 | 0.3347 | 38.75 | 0.3125 | 0.3339 |
| Purple | | | | | | | | | |
| 3M EC Film | 2.84 | 0.2679 | 0.1913 | 2.70 | 0.2624 | 0.1855 | 2.72 | 0.2581 | 0.1826 |
| 3M Ink | 1.80 | 0.2413 | 0.1379 | 1.93 | 0.2416 | 0.1425 | 2.18 | 0.2402 | 0.1432 |
| ATSM EC Film | 1.50 | 0.2356 | 0.1359 | 1.69 | 0.2337 | 0.1368 | 1.72 | 0.2320 | 0.1361 |
| Avery Ink | 3.22 | 0.3181 | 0.2108 | 3.58 | 0.3123 | 0.2142 | 3.65 | 0.3136 | 0.2179 |
| ATSM EC Film | 1.60 | 0.2322 | 0.1314 | 1.79 | 0.2315 | 0.1327 | 1.75 | 0.2319 | 0.1339 |
| 3M EC Film | 2.81 | 0.2689 | 0.1917 | 2.82 | 0.2625 | 0.1858 | 2.80 | 0.2568 | 0.1795 |
| 3M Ink | 2.12 | 0.2399 | 0.1374 | 2.42 | 0.2414 | 0.1436 | 2.42 | 0.2396 | 0.1413 |
| ATSM EC Film | 1.55 | 0.2344 | 0.1339 | 1.82 | 0.2339 | 0.1393 | 1.76 | 0.2321 | 0.1352 |

| Material | | | | | | | | | |
|---------------|---------|--------|--------|---------|--------|--------|---------|--------|--------|
| | Panel 4 | | | Panel 5 | | | Panel 6 | | |
| | Y | x | y | Y | x | y | Y | x | y |
| White | | | | | | | | | |
| 3M VIP 3990 | 53.26 | 0.3108 | 0.3704 | 49.68 | 0.2979 | 0.3023 | 52.65 | 0.3107 | 0.3733 |
| 3M VIP 3990 | 52.44 | 0.3113 | 0.3740 | 48.94 | 0.2992 | 0.3044 | 52.40 | 0.3121 | 0.3727 |
| 3M VIP 3990 | 52.94 | 0.3104 | 0.3758 | 49.78 | 0.3006 | 0.0780 | 52.38 | 0.3124 | 0.3673 |
| Avery 7500 | 57.59 | 0.3100 | 0.3421 | 50.95 | 0.3148 | 0.3372 | 53.62 | 0.3101 | 0.3242 |
| Avery 7500 | 51.58 | 0.3137 | 0.3445 | 51.44 | 0.3115 | 0.3357 | 55.90 | 0.3125 | 0.3460 |
| 3M DG3 | 38.09 | 0.3121 | 0.3357 | 39.72 | 0.3139 | 0.3382 | 39.82 | 0.3123 | 0.3347 |
| 3M DG3 | 39.25 | 0.3113 | 0.3356 | 40.98 | 0.3190 | 0.3376 | 40.39 | 0.3120 | 0.3350 |
| 3M DG3 | 38.82 | 0.3113 | 0.3350 | 39.93 | 0.3144 | 0.3369 | 39.74 | 0.3123 | 0.3342 |
| Purple | | | | | | | | | |
| 3M EC Film | 2.69 | 0.2576 | 0.1823 | 2.71 | 0.2566 | 0.1804 | 2.70 | 0.2548 | 0.1793 |
| 3M Ink | 2.12 | 0.2392 | 0.1398 | 2.35 | 0.2406 | 0.1446 | 2.36 | 0.2399 | 0.1423 |
| ATSM EC Film | 1.65 | 0.2295 | 0.1304 | 1.88 | 0.2331 | 0.1395 | 1.73 | 0.2279 | 0.1305 |
| Avery Ink | 3.58 | 0.3142 | 0.2174 | 3.74 | 0.3130 | 0.2196 | 3.86 | 0.3103 | 0.2186 |
| ATSM EC Film | 1.69 | 0.2286 | 0.1268 | 2.32 | 0.2357 | 0.1487 | 1.66 | 0.2265 | 0.1254 |
| 3M EC Film | 2.73 | 0.2588 | 0.1827 | 1.94 | 0.2312 | 0.1368 | 2.81 | 0.2545 | 0.1778 |
| 3M Ink | 2.38 | 0.2387 | 0.1387 | 2.65 | 0.2403 | 0.1457 | 2.63 | 0.2400 | 0.1413 |
| ATSM EC Film | 1.78 | 0.2306 | 0.1340 | 1.83 | 0.2307 | 0.1364 | 1.77 | 0.2290 | 0.1326 |

| Material | Panel 7 | | | Panel 8 | | | Panel 9 | | |
|---------------|---------|--------|--------|---------|---------|--------|---------|--------|--------|
| White | Y | x | y | Y | x | y | Y | x | y |
| 3M VIP 3990 | 54.27 | 0.3101 | 0.3693 | 49.94 | 0.3023 | 0.3110 | 50.74 | 0.2985 | 0.3028 |
| 3M VIP 3990 | 52.88 | 0.3119 | 0.3695 | 49.78 | 0.3021 | 0.3122 | 51.45 | 0.2991 | 0.3061 |
| 3M VIP 3990 | 52.93 | 0.3118 | 0.3675 | 50.43 | 0.3033 | 0.3111 | 51.57 | 0.3033 | 0.3121 |
| Avery 7500 | 55.25 | 0.3116 | 0.3501 | 54.30 | 0.3111 | 0.3481 | 52.20 | 0.3055 | 0.3196 |
| Avery 7500 | 53.47 | 0.3080 | 0.3362 | 50.69 | 31.5800 | 0.3406 | 52.98 | 0.3155 | 0.3451 |
| 3M DG3 | 38.69 | 0.3112 | 0.3336 | 40.51 | 0.3128 | 0.3178 | 40.95 | 0.3114 | 0.3375 |
| 3M DG3 | 40.44 | 0.3119 | 0.3352 | 39.30 | 0.3140 | 0.3371 | 40.89 | 0.3110 | 0.3344 |
| 3M DG3 | 38.35 | 0.3133 | 0.3354 | 40.01 | 0.3142 | 0.3368 | 41.34 | 0.3117 | 0.3354 |
| Purple | | | | | | | | | |
| 3M EC Film | 2.74 | 0.2528 | 0.1762 | 2.97 | 0.2528 | 0.1796 | 2.82 | 0.2535 | 0.1782 |
| 3M Ink | 2.45 | 0.2383 | 0.1397 | 2.71 | 0.2418 | 0.1485 | 2.72 | 0.2423 | 0.1472 |
| ATSM EC Film | 1.78 | 0.2255 | 0.1297 | 1.87 | 0.2253 | 0.1333 | 1.93 | 0.2222 | 0.1306 |
| Avery Ink | 3.93 | 0.3078 | 0.2160 | 3.88 | 0.3103 | 0.2197 | 4.08 | 0.3071 | 0.2181 |
| ATSM EC Film | 1.76 | 0.2238 | 0.1247 | 2.06 | 0.2262 | 0.1362 | 1.90 | 0.2203 | 0.1271 |
| 3M EC Film | 2.89 | 0.2538 | 0.1776 | 2.98 | 0.2530 | 0.1773 | 2.99 | 0.2531 | 0.1764 |
| 3M Ink | 2.71 | 0.2391 | 0.1413 | 2.91 | 0.2425 | 0.1487 | 2.91 | 0.2425 | 0.1487 |
| ATSM EC Film | 1.91 | 0.2260 | 0.1330 | 1.79 | 0.2231 | 0.1273 | 2.12 | 0.2220 | 0.1334 |

The Cap Y Luminance Factor values are shown in graphical form on the following page in

SUMMARY AND CONCLUSIONS

The material measurements taken through 24 months are equivalent to 4 years vertical exposure. For both retroreflectivity and daytime color, the materials are holding up quite well and still appear purple day and night. Some of the materials have just started to show evidence of noticeable fading in the 24 month readings.

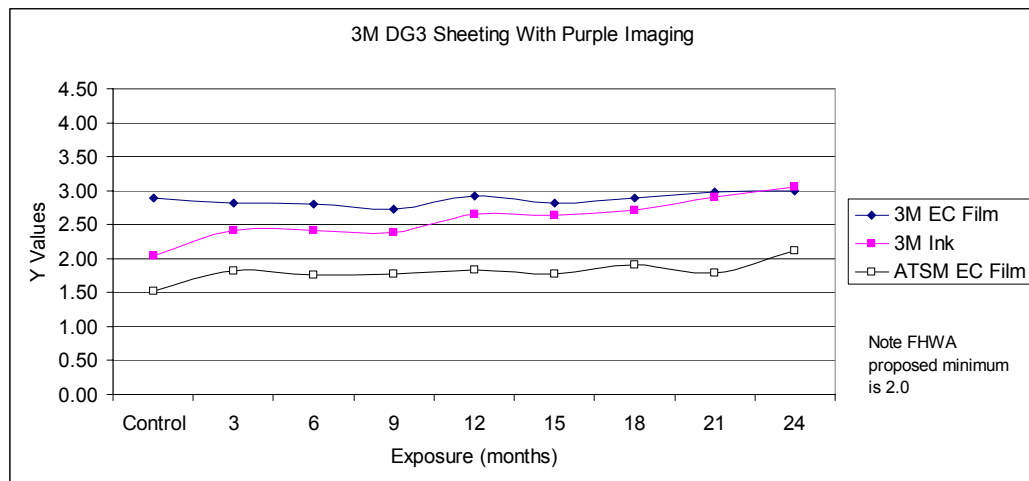
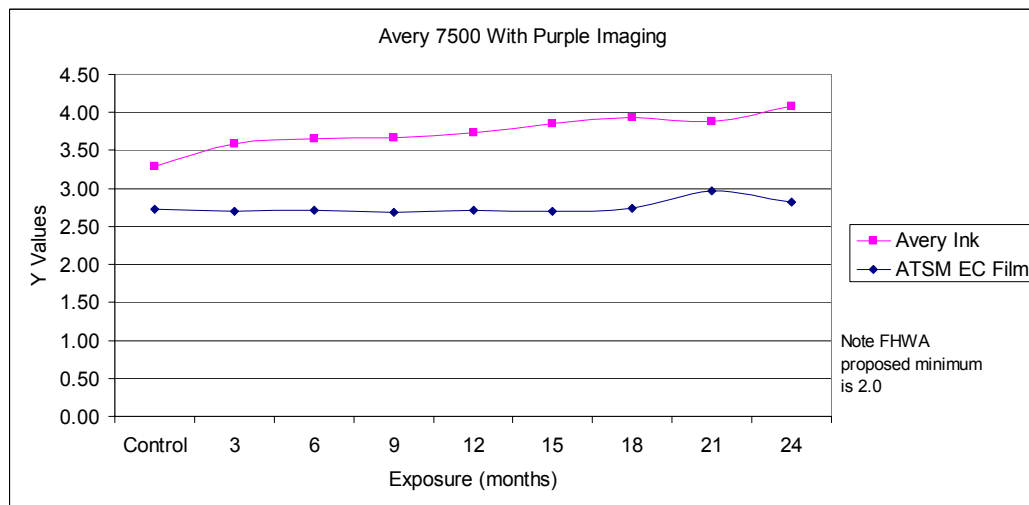
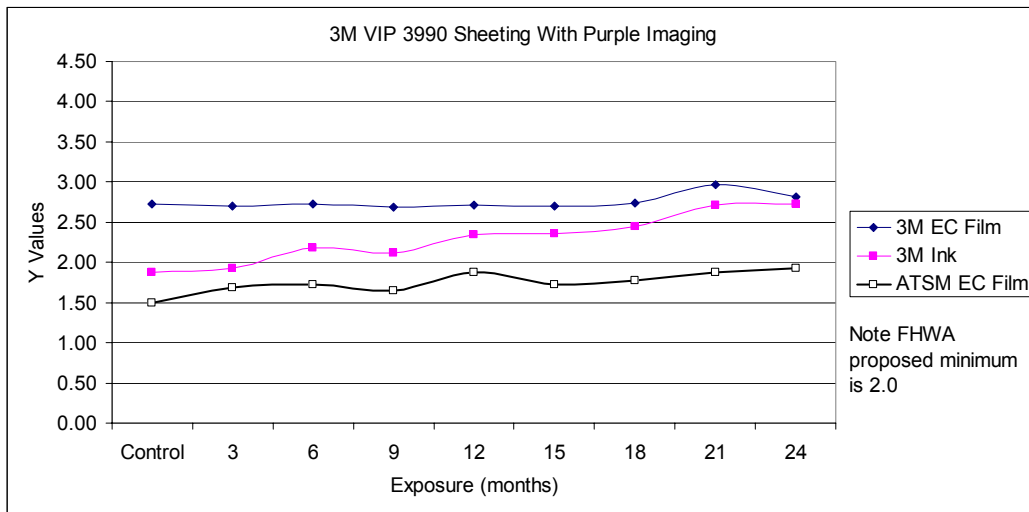


Figure 51. Cap Y Luminance Factor Values for Purple Materials.

APPENDIX A
Mail Survey

Please fill in the blanks, or check the appropriate box.

1. Are you: ☐ Male or ☐ Female

2. Age: _____ years old

3. Home ZIP Code _____

4. How often do you drive on the **Sam Houston Tollway**?

☐ Never ☐ Once or twice ☐ Once or twice ☐ Once or twice ☐ 3 or more
 a year a month a week a week

5. How often do you drive on the **Westpark Tollway**?

☐ Never ☐ Once or twice ☐ Once or twice ☐ Once or twice ☐ 3 or more
 a year a month a week a week

6. How often do you drive on the **Hardy Tollway**?

☐ Never ☐ Once or twice ☐ Once or twice ☐ Once or twice ☐ 3 or more
 a year a month a week a week

7. Have you ever paid a toll with an EZTag in the Houston area ?

☐ Yes ☐ No ☐ Not sure

8. Have you ever used a similar electronic toll tag outside of Texas ? ☐ No ☐ Yes

If Yes, please list the location and the type of tag if you remember:

Based on your knowledge of Houston tollways, please answer these questions.

9. What forms of payment can be used on the **Sam Houston Tollway**?

Check **all** types that are accepted.

☐ Exact Change ☐ Cash (full service) ☐ EZ Tag ☐ Not sure

10. What forms of payment can be used on the **Westpark Tollway**?

Check **all** types that are accepted.

☐ Exact Change ☐ Cash (full service) ☐ EZ Tag ☐ Not sure

11. What forms of payment can be used on the **Hardy Tollway**?

Check **all** types that are accepted.

☐ Exact Change ☐ Cash (full service) ☐ EZ Tag ☐ Not sure

12. Have you seen this sign in the Houston area? →

☐ Yes ☐ No ☐ Not sure

If you checked yes, on what road did you see it ? Please be as specific as you can:



13. Have you seen this sign in the Houston area? →

☐ Yes ☐ No ☐ Not sure

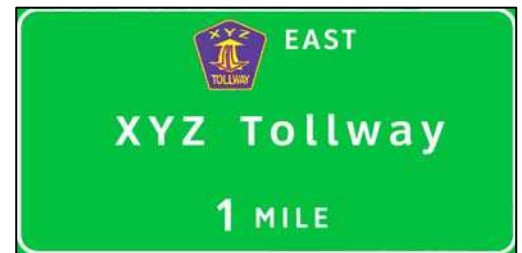
If you checked yes, on what road did you see it? Please be as specific as you can:



Pretend the XYZ Tollway is a new tollway in the Houston area. Use your experience driving on other tollways in Houston to answer the following questions.

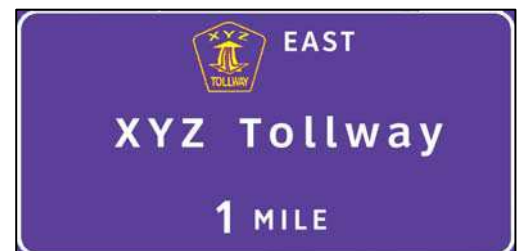
14. Based on your experience and the sign shown to the right, check **all** forms of payment allowed on the XYZ Tollway.

☐ Exact Change ☐ Cash (full service) ☐ EZ Tag



15. Based on your experience and the sign shown to the right, check **all** forms of payment allowed on the XYZ Tollway.

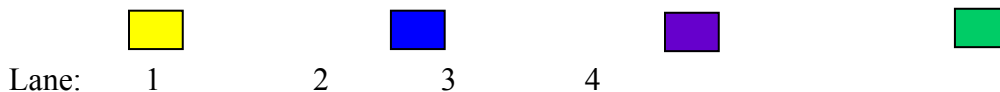
☐ Exact Change ☐ Cash (full service) ☐ EZ Tag



16. Look at the picture below. Based on the color of the signs and your knowledge of Houston tollways, circle the lane number of all of the lanes drivers could use if they have the exact change to pay the toll.



17. Looking at the same picture, assume the toll fee is \$1.00. Based on the color of the signs and your knowledge of Houston tollways, circle the lane number of all of the lanes drivers could use if they have a dollar bill to pay the toll.

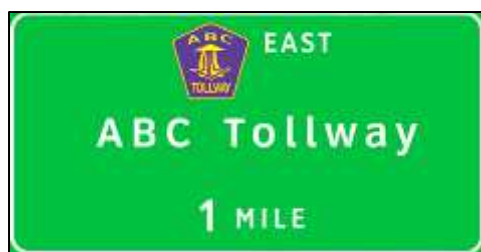


Pretend the ABC Tollway is a planned tollway to be built in the Houston area. It will be an EZ Tag only facility, and cash or exact change will not be accepted. The Tollway authority would like your help designing the signs to get the message across that you must have a toll tag to use this road. Keep in mind Houston has many out of town drivers not familiar with the local roadways.

18. Please rate each of the six signs on the following page on a scale from 1-10, based on how well you think drivers would be able to understand the sign at highway speeds. Rate a sign 1 if you think it's a "VERY BAD" sign, 5 if it is "OK or Average", and 10 if it's a "VERY GOOD" sign.

Circle the number corresponding to your rating for how well the sign gets the message across that you must have a toll tag to use this road each sign. Remember, 1 = Very Bad, 10 = Very Good.

Sign A



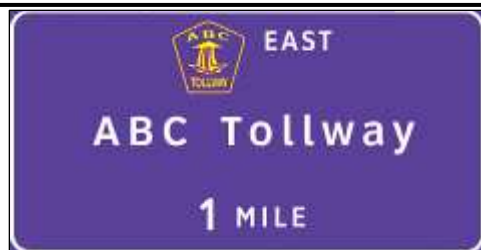
Rate Sign A: 1 2 3 4 5 6 7 8 9 10
10

Sign D



Rate Sign D: 1 2 3 4 5 6 7 8 9

Sign B



Rate Sign B: 1 2 3 4 5 6 7 8 9 10

Sign E



Rate Sign E: 1 2 3 4 5 6 7 8 9 10

Sign C



Rate Sign C: 1 2 3 4 5 6 7 8 9 10 **Rate Sign F:** 1 2 3 4 5 6 7 8 9 10

Sign F



Do you have any comments to add concerning why you selected the above ratings or on the appearance of any of the signs ?

19. Imagine you are driving outside of Texas and you see purple signs on a toll road, check all forms of payment allowed: ☐ Exact Change ☐ Cash (full service) ☐ EZ Tag

20. If new signs that have purple backgrounds are created to direct drivers to enter tollways, how do you think these purple signs should be used ? (Choose only one answer)

- ☐ For all toll roads
- ☐ For toll roads where only vehicles with toll tags are allowed
- ☐ There's nothing wrong with the signs now, we don't need new ones.

Thanks again for your time in completing this survey. Please return this survey in the enclosed addressed envelope.

APPENDIX B

Survey Response Tables

1. Respondent Gender

| Gender | Total (%) |
|---------|-----------|
| Female | 44.3 |
| Male | 55.1 |
| Unknown | 0.6 |
| Total | 100.0 |

N = 473

2. Respondent Age

| Age | Total (%) |
|---------|-----------|
| 20-29 | 5.9 |
| 30-39 | 20.1 |
| 40-49 | 24.3 |
| 50-59 | 28.8 |
| 60-69 | 14.4 |
| 70-84 | 4.9 |
| Unknown | 1.7 |
| Total | 100.0 |

N = 473

3. Respondent ZIP Codes by Frequency of Driving on Westpark Tollway

| Never Drive on Westpark | | | Occasionally Drive on Westpark | | | Frequently Drive on Westpark | | |
|-------------------------|-------|--------|--------------------------------|-------|--------|------------------------------|--------|--------|
| ZIP Code | % | Cum % | ZIP Code | % | Cum % | ZIP Code | % | Cum % |
| 77084 | 4.71% | 4.71% | 77450 | 4.85% | 4.85% | 77077 | 13.59% | 13.59% |
| 77382 | 4.71% | 9.41% | 77429 | 4.37% | 9.22% | 77469 | 10.68% | 24.27% |
| 77546 | 4.71% | 14.12% | 77479 | 4.37% | 13.59% | 77079 | 5.83% | 30.10% |
| 77429 | 3.53% | 17.65% | 77401 | 3.88% | 17.48% | 77082 | 5.83% | 35.92% |
| 77381 | 3.53% | 21.18% | 77077 | 3.40% | 20.87% | 77450 | 3.88% | 39.81% |
| 77356 | 3.53% | 24.71% | 77469 | 2.91% | 23.79% | 77494 | 3.88% | 43.69% |
| 77388 | 3.53% | 28.24% | 77095 | 2.91% | 26.70% | 77024 | 2.91% | 46.60% |
| 77380 | 3.53% | 31.76% | 77449 | 2.43% | 29.13% | 77096 | 2.91% | 49.51% |
| 77581 | 2.35% | 34.12% | 77459 | 2.43% | 31.55% | 77429 | 1.94% | 51.46% |
| 77477 | 2.35% | 36.47% | 77084 | 1.94% | 33.50% | 77084 | 1.94% | 53.40% |
| 77069 | 2.35% | 38.82% | 77079 | 1.94% | 35.44% | 77401 | 1.94% | 55.34% |
| 77080 | 2.35% | 41.18% | 77024 | 1.94% | 37.38% | 77449 | 1.94% | 57.28% |
| 77338 | 2.35% | 43.53% | 77005 | 1.94% | 39.32% | 77027 | 1.94% | 59.22% |
| 77386 | 2.35% | 45.88% | 77009 | 1.46% | 40.78% | 77042 | 1.94% | 61.17% |
| 77551 | 2.35% | 48.24% | 77027 | 1.46% | 42.23% | 77063 | 1.94% | 63.11% |
| 77571 | 2.35% | 50.59% | 77042 | 1.46% | 43.69% | 77083 | 1.94% | 65.05% |
| 77479 | 1.18% | 51.76% | 77063 | 1.46% | 45.15% | 77072 | 1.94% | 66.99% |
| 77095 | 1.18% | 52.94% | 77066 | 1.46% | 46.60% | 77478 | 1.94% | 68.93% |
| 77449 | 1.18% | 54.12% | 77099 | 1.46% | 48.06% | 77055 | 1.94% | 70.87% |
| 77009 | 1.18% | 55.29% | 77373 | 1.46% | 49.51% | 77095 | 0.97% | 71.84% |

3. Respondent ZIP Codes by Frequency of Driving on Westpark Tollway

| Never Drive on Westpark | | | Occasionally Drive on Westpark | | | Frequently Drive on Westpark | | |
|-------------------------|-------|--------|--------------------------------|-------|--------|------------------------------|-------|---------|
| ZIP Code | % | Cum % | ZIP Code | % | Cum % | ZIP Code | % | Cum % |
| 77066 | 1.18% | 56.47% | 77082 | 0.97% | 50.49% | 77459 | 0.97% | 72.82% |
| 77489 | 1.18% | 57.65% | 77381 | 0.97% | 51.46% | 77581 | 0.97% | 73.79% |
| 77584 | 1.18% | 58.82% | 77581 | 0.97% | 52.43% | 77009 | 0.97% | 74.76% |
| 77064 | 1.18% | 60.00% | 77096 | 0.97% | 53.40% | 77005 | 0.97% | 75.73% |
| 77346 | 1.18% | 61.18% | 77489 | 0.97% | 54.37% | 77477 | 0.97% | 76.70% |
| 77036 | 1.18% | 62.35% | 77584 | 0.97% | 55.34% | 77489 | 0.97% | 77.67% |
| 77065 | 1.18% | 63.53% | 77083 | 0.97% | 56.31% | 77584 | 0.97% | 78.64% |
| 77511 | 1.18% | 64.71% | 77064 | 0.97% | 57.28% | 77069 | 0.97% | 79.61% |
| 77043 | 1.18% | 65.88% | 77346 | 0.97% | 58.25% | 77036 | 0.97% | 80.58% |
| 77044 | 1.18% | 67.06% | 77056 | 0.97% | 59.22% | 77065 | 0.97% | 81.55% |
| 77062 | 1.18% | 68.24% | 77098 | 0.97% | 60.19% | 77511 | 0.97% | 82.52% |
| 77316 | 1.18% | 69.41% | 77379 | 0.97% | 61.17% | 77056 | 0.97% | 83.50% |
| 77357 | 1.18% | 70.59% | 77433 | 0.97% | 62.14% | 77098 | 0.97% | 84.47% |
| 77505 | 1.18% | 71.76% | 77021 | 0.97% | 63.11% | 77379 | 0.97% | 85.44% |
| 77536 | 1.18% | 72.94% | 77030 | 0.97% | 64.08% | 77433 | 0.97% | 86.41% |
| 77554 | 1.18% | 74.12% | 77035 | 0.97% | 65.05% | 77018 | 0.97% | 87.38% |
| 77018 | 1.18% | 75.29% | 77040 | 0.97% | 66.02% | 77377 | 0.97% | 88.35% |
| 77377 | 1.18% | 76.47% | 77070 | 0.97% | 66.99% | 77008 | 0.97% | 89.32% |
| 76051 | 1.18% | 77.65% | 77074 | 0.97% | 67.96% | 77017 | 0.97% | 90.29% |
| 77034 | 1.18% | 78.82% | 77092 | 0.97% | 68.93% | 77031 | 0.97% | 91.26% |
| 77058 | 1.18% | 80.00% | 77302 | 0.97% | 69.90% | 77071 | 0.97% | 92.23% |
| 77061 | 1.18% | 81.18% | 77389 | 0.97% | 70.87% | 77002 | 0.97% | 93.20% |
| 77068 | 1.18% | 82.35% | 77441 | 0.97% | 71.84% | 77004 | 0.97% | 94.17% |
| 77318 | 1.18% | 83.53% | 77586 | 0.97% | 72.82% | 77007 | 0.97% | 95.15% |
| 77325 | 1.18% | 84.71% | 77382 | 0.49% | 73.30% | 77025 | 0.97% | 96.12% |
| 77365 | 1.18% | 85.88% | 77546 | 0.49% | 73.79% | 77041 | 0.97% | 97.09% |
| 77414 | 1.18% | 87.06% | 77494 | 0.49% | 74.27% | 77485 | 0.97% | 98.06% |
| 77447 | 1.18% | 88.24% | 77356 | 0.49% | 74.76% | 78934 | 0.97% | 99.03% |
| 77515 | 1.18% | 89.41% | 77388 | 0.49% | 75.24% | 79056 | 0.97% | 100.00% |
| 77530 | 1.18% | 90.59% | 77477 | 0.49% | 75.73% | 77479 | 0.00% | 100.00% |
| 77532 | 1.18% | 91.76% | 77036 | 0.49% | 76.21% | 77382 | 0.00% | 100.00% |
| 77563 | 1.18% | 92.94% | 77065 | 0.49% | 76.70% | 77546 | 0.00% | 100.00% |
| 77573 | 1.18% | 94.12% | 77511 | 0.49% | 77.18% | 77381 | 0.00% | 100.00% |
| 77583 | 1.18% | 95.29% | 77072 | 0.49% | 77.67% | 77356 | 0.00% | 100.00% |
| 77589 | 1.18% | 96.47% | 77478 | 0.49% | 78.16% | 77388 | 0.00% | 100.00% |
| 77706 | 1.18% | 97.65% | 77043 | 0.49% | 78.64% | 77066 | 0.00% | 100.00% |
| 78727 | 1.18% | 98.82% | 77044 | 0.49% | 79.13% | 77380 | 0.00% | 100.00% |
| 77077 | 0.00% | 98.82% | 77062 | 0.49% | 79.61% | 77064 | 0.00% | 100.00% |
| 77469 | 0.00% | 98.82% | 77316 | 0.49% | 80.10% | 77346 | 0.00% | 100.00% |
| 77450 | 0.00% | 98.82% | 77357 | 0.49% | 80.58% | 77099 | 0.00% | 100.00% |
| 77401 | 0.00% | 98.82% | 77505 | 0.49% | 81.07% | 77373 | 0.00% | 100.00% |
| 77079 | 0.00% | 98.82% | 77536 | 0.49% | 81.55% | 77080 | 0.00% | 100.00% |
| 77082 | 0.00% | 98.82% | 77554 | 0.49% | 82.04% | 77338 | 0.00% | 100.00% |
| 77024 | 0.00% | 98.82% | 77008 | 0.49% | 82.52% | 77386 | 0.00% | 100.00% |
| 77459 | 0.00% | 98.82% | 77017 | 0.49% | 83.01% | 77551 | 0.00% | 100.00% |
| 77005 | 0.00% | 98.82% | 77031 | 0.49% | 83.50% | 77571 | 0.00% | 100.00% |

3. Respondent ZIP Codes by Frequency of Driving on Westpark Tollway

| Never Drive on Westpark | | | Occasionally Drive on Westpark | | | Frequently Drive on Westpark | | |
|-------------------------|-------|--------|--------------------------------|-------|--------|------------------------------|-------|---------|
| ZIP Code | % | Cum % | ZIP Code | % | Cum % | ZIP Code | % | Cum % |
| 77027 | 0.00% | 98.82% | 77071 | 0.49% | 83.98% | 77043 | 0.00% | 100.00% |
| 77042 | 0.00% | 98.82% | 77003 | 0.49% | 84.47% | 77044 | 0.00% | 100.00% |
| 77063 | 0.00% | 98.82% | 77006 | 0.49% | 84.95% | 77062 | 0.00% | 100.00% |
| 77096 | 0.00% | 98.82% | 77014 | 0.49% | 85.44% | 77316 | 0.00% | 100.00% |
| 77494 | 0.00% | 98.82% | 77015 | 0.49% | 85.92% | 77357 | 0.00% | 100.00% |
| 77083 | 0.00% | 98.82% | 77019 | 0.49% | 86.41% | 77505 | 0.00% | 100.00% |
| 77099 | 0.00% | 98.82% | 77057 | 0.49% | 86.89% | 77536 | 0.00% | 100.00% |
| 77373 | 0.00% | 98.82% | 77059 | 0.49% | 87.38% | 77554 | 0.00% | 100.00% |
| 77056 | 0.00% | 98.82% | 77073 | 0.49% | 87.86% | 77021 | 0.00% | 100.00% |
| 77098 | 0.00% | 98.82% | 77075 | 0.49% | 88.35% | 77030 | 0.00% | 100.00% |
| 77379 | 0.00% | 98.82% | 77088 | 0.49% | 88.83% | 77035 | 0.00% | 100.00% |
| 77433 | 0.00% | 98.82% | 77089 | 0.49% | 89.32% | 77040 | 0.00% | 100.00% |
| 77072 | 0.00% | 98.82% | 77090 | 0.49% | 89.81% | 77070 | 0.00% | 100.00% |
| 77478 | 0.00% | 98.82% | 77304 | 0.49% | 90.29% | 77074 | 0.00% | 100.00% |
| 77021 | 0.00% | 98.82% | 77339 | 0.49% | 90.78% | 77092 | 0.00% | 100.00% |
| 77030 | 0.00% | 98.82% | 77345 | 0.49% | 91.26% | 77302 | 0.00% | 100.00% |
| 77035 | 0.00% | 98.82% | 77355 | 0.49% | 91.75% | 77389 | 0.00% | 100.00% |
| 77040 | 0.00% | 98.82% | 77375 | 0.49% | 92.23% | 77441 | 0.00% | 100.00% |
| 77070 | 0.00% | 98.82% | 77378 | 0.49% | 92.72% | 77586 | 0.00% | 100.00% |
| 77074 | 0.00% | 98.82% | 77396 | 0.49% | 93.20% | 76051 | 0.00% | 100.00% |
| 77092 | 0.00% | 98.82% | 77418 | 0.49% | 93.69% | 77034 | 0.00% | 100.00% |
| 77302 | 0.00% | 98.82% | 77461 | 0.49% | 94.17% | 77058 | 0.00% | 100.00% |
| 77389 | 0.00% | 98.82% | 77521 | 0.49% | 94.66% | 77061 | 0.00% | 100.00% |
| 77441 | 0.00% | 98.82% | 77541 | 0.49% | 95.15% | 77068 | 0.00% | 100.00% |
| 77586 | 0.00% | 98.82% | 77545 | 0.49% | 95.63% | 77318 | 0.00% | 100.00% |
| 77008 | 0.00% | 98.82% | 77566 | 0.49% | 96.12% | 77325 | 0.00% | 100.00% |
| 77017 | 0.00% | 98.82% | 77568 | 0.49% | 96.60% | 77365 | 0.00% | 100.00% |
| 77031 | 0.00% | 98.82% | 77590 | 0.49% | 97.09% | 77414 | 0.00% | 100.00% |
| 77071 | 0.00% | 98.82% | 77651 | 0.49% | 97.57% | 77447 | 0.00% | 100.00% |
| 77055 | 0.00% | 98.82% | 77833 | 0.49% | 98.06% | 77515 | 0.00% | 100.00% |
| 77003 | 0.00% | 98.82% | 78258 | 0.49% | 98.54% | 77530 | 0.00% | 100.00% |
| 77006 | 0.00% | 98.82% | 77380 | 0.00% | 98.54% | 77532 | 0.00% | 100.00% |
| 77014 | 0.00% | 98.82% | 77069 | 0.00% | 98.54% | 77563 | 0.00% | 100.00% |
| 77015 | 0.00% | 98.82% | 77080 | 0.00% | 98.54% | 77573 | 0.00% | 100.00% |
| 77019 | 0.00% | 98.82% | 77338 | 0.00% | 98.54% | 77583 | 0.00% | 100.00% |
| 77057 | 0.00% | 98.82% | 77386 | 0.00% | 98.54% | 77589 | 0.00% | 100.00% |
| 77059 | 0.00% | 98.82% | 77551 | 0.00% | 98.54% | 77706 | 0.00% | 100.00% |
| 77073 | 0.00% | 98.82% | 77571 | 0.00% | 98.54% | 78727 | 0.00% | 100.00% |
| 77075 | 0.00% | 98.82% | 77018 | 0.00% | 98.54% | 77003 | 0.00% | 100.00% |
| 77088 | 0.00% | 98.82% | 77377 | 0.00% | 98.54% | 77006 | 0.00% | 100.00% |
| 77089 | 0.00% | 98.82% | 77055 | 0.00% | 98.54% | 77014 | 0.00% | 100.00% |
| 77090 | 0.00% | 98.82% | 76051 | 0.00% | 98.54% | 77015 | 0.00% | 100.00% |
| 77304 | 0.00% | 98.82% | 77034 | 0.00% | 98.54% | 77019 | 0.00% | 100.00% |
| 77339 | 0.00% | 98.82% | 77058 | 0.00% | 98.54% | 77057 | 0.00% | 100.00% |
| 77345 | 0.00% | 98.82% | 77061 | 0.00% | 98.54% | 77059 | 0.00% | 100.00% |
| 77355 | 0.00% | 98.82% | 77068 | 0.00% | 98.54% | 77073 | 0.00% | 100.00% |

3. Respondent ZIP Codes by Frequency of Driving on Westpark Tollway

| Never Drive on Westpark | | | Occasionally Drive on Westpark | | | Frequently Drive on Westpark | | |
|-------------------------|--------|---------|--------------------------------|--------|---------|------------------------------|--------|---------|
| ZIP Code | % | Cum % | ZIP Code | % | Cum % | ZIP Code | % | Cum % |
| 77375 | 0.00% | 98.82% | 77318 | 0.00% | 98.54% | 77075 | 0.00% | 100.00% |
| 77378 | 0.00% | 98.82% | 77325 | 0.00% | 98.54% | 77088 | 0.00% | 100.00% |
| 77396 | 0.00% | 98.82% | 77365 | 0.00% | 98.54% | 77089 | 0.00% | 100.00% |
| 77418 | 0.00% | 98.82% | 77414 | 0.00% | 98.54% | 77090 | 0.00% | 100.00% |
| 77461 | 0.00% | 98.82% | 77447 | 0.00% | 98.54% | 77304 | 0.00% | 100.00% |
| 77521 | 0.00% | 98.82% | 77515 | 0.00% | 98.54% | 77339 | 0.00% | 100.00% |
| 77541 | 0.00% | 98.82% | 77530 | 0.00% | 98.54% | 77345 | 0.00% | 100.00% |
| 77545 | 0.00% | 98.82% | 77532 | 0.00% | 98.54% | 77355 | 0.00% | 100.00% |
| 77566 | 0.00% | 98.82% | 77563 | 0.00% | 98.54% | 77375 | 0.00% | 100.00% |
| 77568 | 0.00% | 98.82% | 77573 | 0.00% | 98.54% | 77378 | 0.00% | 100.00% |
| 77590 | 0.00% | 98.82% | 77583 | 0.00% | 98.54% | 77396 | 0.00% | 100.00% |
| 77651 | 0.00% | 98.82% | 77589 | 0.00% | 98.54% | 77418 | 0.00% | 100.00% |
| 77833 | 0.00% | 98.82% | 77706 | 0.00% | 98.54% | 77461 | 0.00% | 100.00% |
| 78258 | 0.00% | 98.82% | 78727 | 0.00% | 98.54% | 77521 | 0.00% | 100.00% |
| 77002 | 0.00% | 98.82% | 77002 | 0.00% | 98.54% | 77541 | 0.00% | 100.00% |
| 77004 | 0.00% | 98.82% | 77004 | 0.00% | 98.54% | 77545 | 0.00% | 100.00% |
| 77007 | 0.00% | 98.82% | 77007 | 0.00% | 98.54% | 77566 | 0.00% | 100.00% |
| 77025 | 0.00% | 98.82% | 77025 | 0.00% | 98.54% | 77568 | 0.00% | 100.00% |
| 77041 | 0.00% | 98.82% | 77041 | 0.00% | 98.54% | 77590 | 0.00% | 100.00% |
| 77485 | 0.00% | 98.82% | 77485 | 0.00% | 98.54% | 77651 | 0.00% | 100.00% |
| 78934 | 0.00% | 98.82% | 78934 | 0.00% | 98.54% | 77833 | 0.00% | 100.00% |
| 79056 | 0.00% | 98.82% | 79056 | 0.00% | 98.54% | 78258 | 0.00% | 100.00% |
| No Response | 0.00% | 98.82% | No Response | 1.46% | 100.00% | No Response | 0.00% | 100.00% |
| Error | 1.18% | 100.00% | Error | 0.00% | 100.00% | Error | 0.00% | 100.00% |
| Grand Total | 100.0% | 100.00% | Grand Total | 100.0% | 100.00% | Grand Total | 100.0% | 100.00% |

4. How often do you drive on the Sam Houston Tollway?

| Use Frequency | Total (%) |
|---------------|-----------|
| Never | 0.6 |
| Occasionally | 40.2 |
| Frequently | 59.1 |
| Total | 100.0 |

N = 470

5. How often do you drive on the Westpark Tollway?

| Use Frequency | Total (%) |
|---------------|-----------|
| Never | 20.0 |
| Occasionally | 52.0 |
| Frequently | 28.0 |
| Total | 100.0 |

N = 471

**1 & 5. How often do you drive on the Westpark Tollway?
(by Respondent Gender)**

| Use Frequency | Female (%) | Male (%) | Total (%) |
|---------------|------------|----------|-----------|
| Never | 21.3 | 19.1 | 20.0 |
| Occasionally | 50.2 | 53.1 | 51.8 |
| Frequently | 28.5 | 27.9 | 28.1 |
| Total | 100.0 | 100.0 | 100.0 |

N = 469

2 & 5. Respondent Age (by Westpark Tollway use frequency)

| Age | Westpark Tollway Use Frequency | | | |
|---------|--------------------------------|------------------|----------------|-----------|
| | Never (%) | Occasionally (%) | Frequently (%) | Total (%) |
| 20-29 | 4.3 | 6.1 | 6.8 | 5.9 |
| 30-39 | 13.8 | 21.2 | 22.0 | 20.0 |
| 40-49 | 23.4 | 22.0 | 29.5 | 24.4 |
| 50-59 | 30.9 | 29.4 | 26.5 | 28.9 |
| 60-69 | 19.1 | 14.7 | 10.6 | 14.4 |
| 70-84 | 6.4 | 5.7 | 2.3 | 4.9 |
| Unknown | 2.1 | 0.8 | 2.3 | 1.5 |
| Total | 100.0 | 100.0 | 100.0 | 100.0 |

N = 471

6. How often do you drive on the Hardy Tollway?

| Use Frequency | Total (%) |
|---------------|-----------|
| Never | 28.0 |
| Occasionally | 63.5 |
| Frequently | 8.5 |
| Total | 100.0 |

N = 471

7. Have you ever paid a toll with an EZ Tag in the Houston area?

| Used EZ Tag | Total (%) |
|-------------|-----------|
| Yes | 87.2 |
| No | 9.2 |
| Not sure | 3.6 |
| Total | 100.0 |

N = 469

8. Have you ever used a similar electronic toll tag outside of Texas?

| Used EZ Tag | Total (%) |
|-------------|-----------|
| Yes | 9.7 |
| No | 90.3 |
| Total | 100.0 |

N = 464

**9. What forms of payment can be used on the Sam Houston Tollway?
(by Westpark Tollway use frequency)**

| Payment Type | Westpark Tollway Use Frequency | | | |
|-----------------------|--------------------------------|------------------|----------------|-----------|
| | Never (%) | Occasionally (%) | Frequently (%) | Total (%) |
| EZ Tag (only) | 0.0 | 2.9 | 0.8 | 1.7 |
| Exact Change & EZ Tag | 4.3 | 0.4 | 3.8 | 2.1 |
| Cash & EZ Tag | 1.1 | 0.4 | 0.8 | 0.6 |
| All Forms | 92.6 | 95.1 | 94.7 | 94.5 |
| Not sure | 2.1 | 1.2 | 0.0 | 1.1 |
| Total | 100.0 | 100.0 | 100.0 | 100.0 |

N = 471

**10. What forms of payment can be used on the Westpark Tollway?
(by Westpark Tollway use frequency)**

| Payment Type | Westpark Tollway Use Frequency | | | |
|-----------------------|--------------------------------|------------------|----------------|-----------|
| | Never (%) | Occasionally (%) | Frequently (%) | Total (%) |
| Exact Change (only) | 1.1 | 0.4 | 0.0 | 0.4 |
| Cash (only) | 0.0 | 0.4 | 0.0 | 0.2 |
| EZ Tag (only) | 26.9 | 82.4 | 91.7 | 74.0 |
| Exact Change & EZ Tag | 5.4 | 2.9 | 4.5 | 3.8 |
| Cash & EZ Tag | 0.0 | 2.0 | 0.0 | 1.1 |
| All Forms | 5.4 | 6.5 | 3.8 | 5.5 |
| Not sure | 61.3 | 5.3 | 0.0 | 14.9 |
| Total | 100.0 | 100.0 | 100.0 | 100.0 |

N = 470

**11. What forms of payment can be used on the Hardy Tollway?
(by Westpark Tollway use frequency)**

| Payment Type | Westpark Tollway Use Frequency | | | |
|-----------------------|--------------------------------|------------------|----------------|-----------|
| | Never (%) | Occasionally (%) | Frequently (%) | Total (%) |
| Cash (only) | 1.1 | 0.0 | 0.0 | 0.2 |
| EZ Tag (only) | 2.1 | 4.9 | 4.5 | 4.3 |
| Exact Change & EZ Tag | 6.4 | 2.9 | 3.8 | 3.8 |
| Cash & EZ Tag | 2.1 | 1.6 | 0.8 | 1.5 |
| All Forms | 68.1 | 63.5 | 54.5 | 61.9 |
| Not sure | 20.2 | 27.0 | 36.4 | 28.3 |
| Total | 100.0 | 100.0 | 100.0 | 100.0 |

N = 470

**12. Have you seen this sign in the Houston area? (Purple Fondren Rd sign)
(by Westpark Tollway use frequency)**

| Seen Purple Fondren Sign | Westpark Tollway Use Frequency | | | |
|--------------------------|--------------------------------|------------------|----------------|-----------|
| | Never (%) | Occasionally (%) | Frequently (%) | Total (%) |
| Yes | 11.8 | 34.4 | 51.1 | 34.6 |
| No | 49.5 | 24.5 | 14.5 | 26.7 |
| Not sure | 38.7 | 41.1 | 34.4 | 38.7 |
| Total | 100.0 | 100.0 | 100.0 | 100.0 |

N = 465

**13. Have you seen this sign in the Houston area? (Green Hillcroft sign)
(by Westpark Tollway use frequency)**

| Seen Green Hillcroft Sign | Westpark Tollway Use Frequency | | | |
|---------------------------|--------------------------------|------------------|----------------|-----------|
| | Never (%) | Occasionally (%) | Frequently (%) | Total (%) |
| Yes | 34.4 | 44.5 | 46.5 | 43.0 |
| No | 31.2 | 13.0 | 10.1 | 15.9 |
| Not sure | 34.4 | 42.4 | 43.4 | 41.1 |
| Total | 100.0 | 100.0 | 100.0 | 100.0 |

N = 460

14. Based on your experience and the sign shown to the right, check all forms of payment allowed on the XYZ Tollway (by Westpark Tollway use frequency)

| Payment Type | Westpark Tollway Use Frequency | | | |
|-----------------------|--------------------------------|------------------|----------------|-----------|
| | Never (%) | Occasionally (%) | Frequently (%) | Total (%) |
| Exact Change (only) | 2.3 | 2.5 | 1.6 | 2.2 |
| Cash (only) | 3.4 | 0.8 | 0.8 | 1.3 |
| EZ Tag (only) | 0.0 | 5.9 | 7.9 | 5.3 |
| Exact Change & Cash | 4.6 | 3.4 | 2.4 | 3.3 |
| Exact Change & EZ Tag | 3.4 | 2.5 | 4.7 | 3.3 |
| Cash & EZ Tag | 2.3 | 1.3 | 0.8 | 1.3 |
| All Forms | 83.9 | 83.6 | 81.9 | 83.2 |
| Total | 100.0 | 100.0 | 100.0 | 100.0 |

N = 452

15. Based on your experience and the sign shown to the right, check all forms of payment allowed on the XYZ Tollway (by Westpark Tollway use frequency)

| Payment Type | Westpark Tollway Use Frequency | | | |
|-----------------------|--------------------------------|------------------|----------------|-----------|
| | Never (%) | Occasionally (%) | Frequently (%) | Total (%) |
| Exact Change (only) | 7.4 | 3.9 | 0.8 | 3.7 |
| Cash (only) | 1.2 | 1.7 | 1.6 | 1.6 |
| EZ Tag (only) | 25.9 | 56.1 | 67.2 | 53.7 |
| Exact Change & Cash | 3.7 | 2.6 | 1.6 | 2.5 |
| Exact Change & EZ Tag | 9.9 | 4.3 | 3.2 | 5.0 |
| Cash & EZ Tag | 1.2 | 0.4 | 0.8 | 0.7 |
| All Forms | 50.6 | 30.9 | 24.8 | 32.8 |
| Total | 100.0 | 100.0 | 100.0 | 100.0 |

N = 436

16. Based on the color of the signs and your knowledge of Houston tollways, circle the lane number of all of the lanes drivers could use if they have the exact change to pay the toll (by Westpark Tollway use frequency)

| Exact Change Lanes | Westpark Tollway Use Frequency | | | |
|-----------------------|--------------------------------|------------------|----------------|-----------|
| | Never (%) | Occasionally (%) | Frequently (%) | Total (%) |
| Yellow | 11.5 | 3.5 | 5.2 | 5.6 |
| Blue | 10.3 | 5.4 | 10.3 | 7.8 |
| Purple | 1.3 | 1.0 | 0.9 | 1.0 |
| Green | 17.9 | 27.2 | 23.3 | 24.2 |
| Yellow & Blue | 0.0 | 1.0 | 0.9 | 0.8 |
| Yellow & Purple | 1.3 | 0.0 | 0.0 | 0.3 |
| Yellow & Green | 1.3 | 1.5 | 2.6 | 1.8 |
| Blue & Purple | 3.8 | 6.9 | 4.3 | 5.6 |
| Blue & Green | 11.5 | 20.3 | 14.7 | 16.9 |
| Purple & Green | 1.3 | 4.0 | 4.3 | 3.5 |
| Yellow, Blue & Purple | 0.0 | 0.0 | 0.9 | 0.3 |
| Yellow, Blue & Green | 0.0 | 1.5 | 1.7 | 1.3 |
| Blue, Purple & Green | 35.9 | 24.3 | 31.0 | 28.5 |
| All Lanes | 3.8 | 3.5 | 0.0 | 2.5 |
| Total | 100.0 | 100.0 | 100.0 | 100.0 |

N = 396

17. Looking at the same picture, assume the toll fee is \$1.00. Circle the lane number of all of the lanes drivers could use if they have a dollar bill to pay the toll (by Westpark Tollway use frequency)

| "Dollar Bill" Lanes | Westpark Tollway Use Frequency | | | |
|----------------------|--------------------------------|------------------|----------------|-----------|
| | Never (%) | Occasionally (%) | Frequently (%) | Total (%) |
| Yellow | 1.2 | 0.4 | 1.6 | 0.9 |
| Blue | 12.3 | 18.6 | 20.6 | 18.0 |
| Purple | 6.2 | 4.4 | 2.4 | 4.2 |
| Green | 33.3 | 44.2 | 35.7 | 39.7 |
| Yellow & Blue | 0.0 | 0.4 | 0.8 | 0.5 |
| Yellow & Green | 1.2 | 0.4 | 0.8 | 0.7 |
| Blue & Purple | 3.7 | 3.5 | 11.1 | 5.8 |
| Blue & Green | 4.9 | 7.1 | 5.6 | 6.2 |
| Purple & Green | 9.9 | 8.4 | 6.3 | 8.1 |
| Yellow, Blue & Green | 0.0 | 0.4 | 1.6 | 0.7 |
| Blue, Purple & Green | 25.9 | 11.1 | 13.5 | 14.5 |
| All Lanes | 1.2 | 0.9 | 0.0 | 0.7 |
| Total | 100.0 | 100.0 | 100.0 | 100.0 |

N = 433

**18. Circle all the lanes drivers could use if they an EZ TAG to pay the toll.
(by Westpark Tollway use frequency)**

| EZ Tag Lanes | Westpark Tollway Use Frequency | | | |
|-----------------------|--------------------------------|------------------|----------------|-----------|
| | Never (%) | Occasionally (%) | Frequently (%) | Total (%) |
| Yellow | 50.6 | 45.2 | 50.4 | 47.8 |
| Blue | 0.0 | 0.4 | 0.0 | 0.2 |
| Purple | 1.1 | 3.5 | 10.1 | 4.9 |
| Green | 1.1 | 1.7 | 2.3 | 1.8 |
| Yellow & Blue | 3.4 | 5.2 | 6.2 | 5.2 |
| Yellow & Purple | 1.1 | 7.8 | 7.0 | 6.3 |
| Yellow & Green | 4.6 | 4.3 | 1.6 | 3.6 |
| Blue & Purple | 1.1 | 0.9 | 0.8 | 0.9 |
| Purple & Green | 1.1 | 0.4 | 0.0 | 0.4 |
| Yellow, Blue & Purple | 2.3 | 3.0 | 1.6 | 2.5 |
| Yellow, Blue & Green | 5.7 | 6.5 | 3.9 | 5.6 |
| Blue, Purple & Green | 3.4 | 1.3 | 2.3 | 2.0 |
| All Lanes | 24.1 | 19.6 | 14.0 | 18.8 |
| Total | 100.0 | 100.0 | 100.0 | 100.0 |

N = 446

**19A Sign Ratings (1 = Very bad - 10 = Very good)
(by Westpark Tollway use frequency)**

| Rating | Westpark Tollway Use Frequency | | | |
|-------------|--------------------------------|------------------|----------------|-----------|
| | Never (%) | Occasionally (%) | Frequently (%) | Total (%) |
| 1 | 72.2 | 74.7 | 70.4 | 73.0 |
| 2 | 4.4 | 4.2 | 7.2 | 5.1 |
| 3 | 5.6 | 4.6 | 4.8 | 4.9 |
| 4 | 4.4 | 2.5 | 2.4 | 2.9 |
| 5 | 1.1 | 3.8 | 2.4 | 2.9 |
| 6 | 2.2 | 0.8 | 2.4 | 1.5 |
| 7 | 0.0 | 0.8 | 1.6 | 0.9 |
| 8 | 3.3 | 2.1 | 4.8 | 3.1 |
| 9 | 1.1 | 0.4 | 1.6 | 0.9 |
| 10 | 5.6 | 5.9 | 2.4 | 4.9 |
| Total | 100.0 | 100.0 | 100.0 | 100.0 |
| Mean rating | 2.59 | 2.17 | 2.23 | 2.20 |
| N | 90 | 237 | 125 | 452 |

19B Sign Ratings (1 = Very bad - 10 = Very good)
(by Westpark Tollway use frequency)

| Rating | Westpark Tollway Use Frequency | | | |
|-------------|--------------------------------|------------------|----------------|-----------|
| | Never (%) | Occasionally (%) | Frequently (%) | Total (%) |
| 1 | 73.3 | 67.5 | 61.0 | 66.9 |
| 2 | 2.2 | 9.0 | 8.9 | 7.6 |
| 3 | 6.7 | 4.3 | 6.5 | 5.4 |
| 4 | 3.3 | 2.6 | 1.6 | 2.5 |
| 5 | 4.4 | 6.4 | 6.5 | 6.0 |
| 6 | 1.1 | 1.7 | 1.6 | 1.6 |
| 7 | 0.0 | 2.1 | 4.1 | 2.2 |
| 8 | 4.4 | 1.3 | 4.9 | 2.9 |
| 9 | 1.1 | 0.9 | 1.6 | 1.1 |
| 10 | 3.3 | 4.3 | 3.3 | 3.8 |
| Total | 100.0 | 100.0 | 100.0 | 100.0 |
| Mean rating | 2.27 | 2.26 | 2.62 | 2.34 |
| N | 90 | 234 | 123 | 447 |

19C Sign Ratings (1 = Very bad - 10 = Very good)
(by Westpark Tollway use frequency)

| Rating | Westpark Tollway Use Frequency | | | |
|-------------|--------------------------------|------------------|----------------|-----------|
| | Never (%) | Occasionally (%) | Frequently (%) | Total (%) |
| 1 | 4.4 | 2.1 | 0.8 | 2.2 |
| 2 | 1.1 | 1.3 | 2.3 | 1.5 |
| 3 | 4.4 | 1.3 | 2.3 | 2.2 |
| 4 | 3.3 | 3.3 | 2.3 | 3.1 |
| 5 | 17.8 | 19.2 | 8.6 | 16.0 |
| 6 | 5.6 | 8.4 | 7.0 | 7.4 |
| 7 | 8.9 | 10.9 | 12.5 | 10.9 |
| 8 | 25.6 | 16.7 | 14.1 | 17.7 |
| 9 | 11.1 | 13.0 | 23.4 | 15.5 |
| 10 | 17.8 | 23.8 | 26.6 | 23.4 |
| Total | 100.0 | 100.0 | 100.0 | 100.0 |
| Mean rating | 7.00 | 7.33 | 7.84 | 7.40 |
| N | 90 | 239 | 128 | 457 |

19D Sign Ratings (1 = Very bad - 10 = Very good)
(by Westpark Tollway use frequency)

| Rating | Westpark Tollway Use Frequency | | | |
|-------------|--------------------------------|------------------|----------------|-----------|
| | Never (%) | Occasionally (%) | Frequently (%) | Total (%) |
| 1 | 4.5 | 3.9 | 2.4 | 3.6 |
| 2 | 5.6 | 2.1 | 0.8 | 2.5 |
| 3 | 6.7 | 6.0 | 3.2 | 5.4 |
| 4 | 6.7 | 6.0 | 9.5 | 7.1 |
| 5 | 33.7 | 22.7 | 16.7 | 23.2 |
| 6 | 5.6 | 11.6 | 11.1 | 10.3 |
| 7 | 1.1 | 13.3 | 17.5 | 12.1 |
| 8 | 14.6 | 16.3 | 9.5 | 14.1 |
| 9 | 5.6 | 6.9 | 9.5 | 7.4 |
| 10 | 15.7 | 11.2 | 19.8 | 14.5 |
| Total | 100.0 | 100.0 | 100.0 | 100.0 |
| Mean rating | 5.98 | 6.30 | 6.84 | 6.39 |
| N | 89 | 233 | 126 | 448 |

19E Sign Ratings (1 = Very bad - 10 = Very good)
(by Westpark Tollway use frequency)

| Rating | Westpark Tollway Use Frequency | | | |
|-------------|--------------------------------|------------------|----------------|-----------|
| | Never (%) | Occasionally (%) | Frequently (%) | Total (%) |
| 1 | 5.6 | 0.8 | 0.0 | 1.5 |
| 2 | 1.1 | 0.8 | 0.0 | 0.7 |
| 3 | 3.3 | 0.4 | 1.6 | 1.3 |
| 4 | 0.0 | 1.2 | 2.4 | 1.3 |
| 5 | 1.1 | 2.1 | 5.5 | 2.8 |
| 6 | 4.4 | 5.0 | 0.0 | 3.5 |
| 7 | 0.0 | 4.1 | 4.7 | 3.5 |
| 8 | 3.3 | 7.5 | 8.7 | 7.0 |
| 9 | 12.2 | 11.2 | 9.4 | 10.9 |
| 10 | 68.9 | 66.8 | 67.7 | 67.5 |
| Total | 100.0 | 100.0 | 100.0 | 100.0 |
| Mean rating | 8.76 | 9.07 | 9.06 | 9.01 |
| N | 90 | 241 | 127 | 458 |

19F Sign Ratings (1 = Very bad - 10 = Very good)

(by Westpark Tollway use frequency)

| Rating | Westpark Tollway Use Frequency | | | |
|-------------|--------------------------------|------------------|----------------|-----------|
| | Never (%) | Occasionally (%) | Frequently (%) | Total (%) |
| 1 | 12.2 | 10.0 | 15.6 | 12.0 |
| 2 | 8.9 | 3.8 | 2.3 | 4.4 |
| 3 | 23.3 | 11.3 | 7.8 | 12.7 |
| 4 | 7.8 | 10.5 | 9.4 | 9.6 |
| 5 | 17.8 | 25.5 | 14.8 | 21.0 |
| 6 | 4.4 | 10.0 | 14.1 | 10.1 |
| 7 | 2.2 | 9.2 | 10.2 | 8.1 |
| 8 | 8.9 | 7.5 | 6.3 | 7.4 |
| 9 | 5.6 | 5.0 | 4.7 | 5.0 |
| 10 | 8.9 | 7.1 | 14.8 | 9.6 |
| Total | 100.0 | 100.0 | 100.0 | 100.0 |
| Mean rating | 4.72 | 5.22 | 5.52 | 5.20 |
| N | 90 | 239 | 128 | 457 |

20. Imagine you are driving outside of Texas and you see purple signs on a toll road, check all forms of payment allowed:

(by Westpark Tollway use frequency)

| Payment Type | Westpark Tollway Use Frequency | | | |
|-----------------------|--------------------------------|------------------|----------------|-----------|
| | Never (%) | Occasionally (%) | Frequently (%) | Total (%) |
| Exact Change (only) | 5.3% | 2.4% | 2.7% | 3.0% |
| Cash (only) | 10.7% | 8.3% | 5.3% | 7.9% |
| EZ Tag (only) | 41.3% | 54.9% | 58.4% | 53.3% |
| Exact Change & Cash | 6.7% | 5.3% | 5.3% | 5.6% |
| Cash & EZ Tag | 2.7% | 1.5% | 1.8% | 1.8% |
| Exact Change & EZ Tag | 1.3% | 2.9% | 1.8% | 2.3% |
| All Forms | 32.0% | 24.8% | 23.9% | 25.9% |
| Not sure | 0.0% | 0.0% | 0.9% | 0.3% |
| Total | 100.0% | 100.0% | 100.0% | 100.0% |

N = 394

21. If new signs that have purple backgrounds are created to direct drivers to enter tollways, how do you think these purple signs should be used?

(by Westpark Tollway use frequency)

| Use purple signs: | Westpark Tollway Use Frequency | | | |
|--|--------------------------------|------------------|----------------|-----------|
| | Never (%) | Occasionally (%) | Frequently (%) | Total (%) |
| For all toll roads | 22.1% | 18.0% | 19.5% | 19.2% |
| For toll roads where only tags allowed | 29.1% | 49.1% | 55.3% | 46.9% |
| Nothing wrong with signs | 48.8% | 32.9% | 25.2% | 33.9% |
| Total | 100.0% | 100.0% | 100.0% | 100.0% |

N = 437

APPENDIX C
LEGIBILITY STUDY PAPERWORK

Pre Drive Questions
Route A Script
Route B Script

PRE DRIVE QUESTIONS

SUBJECT # _____

Based on your knowledge of Houston tollways, please answer these questions.

1. What forms of payment can be used on the Sam Houston Tollway?

Check **all** types that are accepted.

☐ Exact Change ☐ Cash (full service) ☐ EZ Tag ☐ Not sure

2. What forms of payment can be used on the Westpark Tollway?

Check **all** types that are accepted.

☐ Exact Change ☐ Cash (full service) ☐ EZ Tag ☐ Not sure

3. What forms of payment can be used on the Hardy Tollway?

Check **all** types that are accepted.

☐ Exact Change ☐ Cash (full service) ☐ EZ Tag ☐ Not sure

Researcher Use Only

Video Release Allowed: _____ Yes _____ No

Eye Chart Score: _____

Colorblindness Test Misses: _____ None Misses: _____

1. Do you drive on the Sam Houston Tollway South between I-10 and 59?

☐ Never ☐ Once or twice ☐ Once or twice ☐ Once or twice ☐ 3 or more
a year a month a week a week

2. Do you drive on the Sam Houston Tollway on the northwest side of town between 290 and 45, near the race tracks?

☐ Never ☐ Once or twice ☐ Once or twice ☐ Once or twice ☐ 3 or more
a year a month a week a week

GROUP A (YELLOW) SCRIPT

SUBJECT #_____

Weather Conditions_____

Sunglasses yes no

- Instruct subject to take a right out of the TTI parking lot and enter the **610 South** freeway at the first opportunity.

*******START RECORDING*******

- Instruct the subject to take the **59 South** exit.

Q1. As the subject is entering 59

“As soon as you recognize a Westpark Tollway sign, say ‘Westpark’”

- Instruct subject to enter **Westpark Tollway**



Q2. After they respond

“How did you know it was a Westpark Tollway sign?”

Q3. After the last Westpark exit sign

“What color was the top banner sign on the right you just drove under?” (purple)



Q4. Once on Westpark---

“What does the top line of the next sign on the right say?” (Fondren)



Q5. After

| | |
|------------------|--|
| | Fondren Rd Gessner Ave EXIT 3/4 MILE |
| Westpark Tollway | |

“What color were those signs?” (purple)

Q5A. After subject is on Westpark

“Do you expect to go through a toll booth on this road?” (yes no)

Q5B. After response

“How do you know that?” (ez tag only)

Q5C. After response

“Have you seen any signs today that told you that it was EZ Tag only ?”

Q6. After

Fondren Rd
Gessner ^

(long distance)

“What does the bottom line of the next sign say?” (EXIT 1 MILE)



Q7. After

Sam Houston
Tollway EXIT
1 MILE

“What does the top line of the small sign on the right shoulder say?” (WESTCHASE)



Q8. After response

“What color was that same sign?” (brown)

Q9. After response (referring to the Sam Houston exit shoulder sign)

“What color was that rectangular sign for that exit?” (purple)



Q10. After you’ve passed Sam Houston

“What does the top line of the sign on the right shoulder say?” (Toll)

| TOLL | |
|----------|--------|
| 2 AXLES | \$1.00 |
| 3 AXLES | \$2.75 |
| 4 AXLES | \$3.75 |
| 5 AXLES | \$5.00 |
| 6+ AXLES | \$6.25 |

Q11. After response

“What color was that same sign?” (blue)

Q12. After

W. Houston Center Blvd
Dairy Ashford
EXIT 3/4 MILE

“What does the top line of the sign over the exit ramp say?” (West Houston Center Blvd)



Q13. After

W. Houston Center Blvd
Dairy Ashford
^

(long distance)

“What does the middle line of the sign coming up say?” (Eldridge Pkwy)



Q14. After

To 6 SOUTH
Eldridge Pkwy
1/4 MILE

“What color was the sign we just passed?” (purple)



Q15. Wait for 3 signs, After

6 NORTH
1/2 MILE

“What does the bottom banner of the next sign say?” (EXIT 35 MPH)



Q16. After response

“What color was that bottom banner?” (yellow)

Q17. After 6 NORTH exit

“What is the top line say on next sign?” (Westpark Dr)



Q18. After

Westpark Dr
EXIT 1/2 MILE

(notice you'll see the

westpark gore sign too)

“On the second sign ahead with the two white boxes, what is the number in the box on the top right?” (1093)



Q19. After

| | |
|---------------|------|
| 1464 | 1093 |
| EXIT 1/2 MILE | |

“What is the number in the box on the top left of the next sign say?” (1464)



Q20. After

| | |
|------|------|
| 1464 | 1093 |
| ^ | |

(long distance)

“What is the top line of the next sign say?”
(Grand Mission Blvd)



Q21. After response

“What color was that same sign?” (green)

Q22. After Gantries (long distance, up hill)

“What is the top line of the next sign say?” (Mason Rd)

Q23. After

| | |
|----------|---|
| Mason Rd | ^ |
|----------|---|

“What is the top line of the right sign say?” (Peek Rd)

Q24. After

| | |
|----------------------|----------------|
| Grand Parkway 1/2 | Peek Rd 1/4 |
|----------------------|----------------|

“What is the word in the upper left corner of the left sign?” (SOUTH)

- Instruct subject to exit on **99 Grand Parkway**, stay in left lane, take U turn and reenter **Westpark Tollway East**. (45 mph on frontage road)

Q25. After Entering Westpark

“What is the bottom line on the overhead sign say?” (Exit 1/2 MILE)



Q26. After

| |
|--|
| Mason Rd. Grand Mission Blvd Exit 1/2 MILE |
|--|

“What does the bottom line on the next sign say?”
(Grand Mission Blvd)



Mason Rd. Grand
 Mission Blvd ^
Q27. After (long distance, uphill)
 “What does the bottom line on the next sign say?” (EXIT 1 MILE)

6 1093 1464
 Barker Cypress Rd
 Exit 1 Mile
Q28. After
 “What does the middle line say?” (Barker Cypress Rd)



6 1093 1464
 Barker Cypress Rd
 Exit 1/2 Mile
Q29. After
 “What does the very bottom panel of the next sign say?” (Next Exit 8 Miles)



6 1093 1464
 Barker Cypress ^
 Next Exit 8 Miles
Q30. After
 “What are the last 4 digits of the second, larger, rectangular sign on the right shoulder of the road?” (7328)



Q31. After response
 “What color was that same sign?” (blue)

North * South
 Sam Houston
 Tollway
 EXIT 1 MILE
Q32. Before!!! (long distance)
 “What is the word in the upper right corner?” (SOUTH)

Q33. After Response

“What color was the last sign?” (purple)

- Instruct subject to exit **Sam Houston South**.
- *“You can relax, we’re not going to ask any questions until after we turn around.”*
- Subject will drive until **W. Airport Blvd**, and will exit. Have the subject make the first U-turn available to get back on **Sam Houston North**.

Q34. After Sam Houston Tollway Sign (sign in work zone, shopping on right)

“As soon as you recognize a Westpark Tollway sign, say ‘Westpark’”

- Instruct subject to enter **Westpark Tollway East**. They will have to **move to the right two lanes** to do this



Q35. After they respond

“How did you know it was a Westpark Tollway sign?”

Q36. After subject is in the correct lane

“What color was the sign you just drove under?” (purple)

Q37. After subject is on Westpark

“Do you expect to go through a toll booth on this road?” (yes no)

Q38. After response

“How do you know that?” (ez tag only)

Q38A. After response

“Have you seen any signs today that told you that it was EZ Tag only ?”

Q39. After

| | |
|-----------------------|------------------------|
| 59 NORTH 3/4 MILES | Fondren Rd 1/2 MILE |
|-----------------------|------------------------|



“On the signs coming up, what does the middle line say on the right sign?”
(Downtown)

Q40. After

| | |
|---|---------------|
| ? | 59 NORTH ^ |
|---|---------------|

“On the sign coming up, what does the bottom line say?” (EXIT ½ MILE)

- Instruct subject to stay on Westpark Tollway at 59 split in **left lane**.

*****STOP RECORDING DATA*****

- Instruct subject to exit **Westpark Dr** to the right. Once on Westpark Dr, have the subject move into the left lane, they will be turning **left onto 610 frontage**. Continue on the frontage until you are approaching Memorial Dr. Have the subject move into the left lane and take a **left at Memorial**, take a **right on Post Oak Rd** and head back to the TTI office.

GROUP B (PINK) SCRIPT

SUBJECT #_____

Weather Conditions_____

Sunglasses yes no

- Researcher enters 610 S and exits S Post Oak. At 90, continue straight thru intersection, then turn left onto 90's frontage road into shopping area (**Fiesta**) to switch drivers.
- Subject exits shopping center on 90's frontage, and does a u-turn to head on 90 in the Southwest direction
- Subject takes a right onto Beltway 8 North, then enters the Sam Houston Tollway North through a tollbooth. **Either side** of the tollbooth is fine. Once on the tollway, instruct the subject to **move to the left one lane**.

*******START RECORDING*******

Q1. After Sam Houston Tollway Sign (sign in work zone, shopping on right)

"As soon as you recognize a Westpark Tollway sign, say 'Westpark'"

- Instruct subject to enter **Westpark Tollway East**. They will have to **move to the right two lanes** to do this



Q2. After they respond

"How did you know it was a Westpark Tollway sign?"

Q3. After subject is in the correct lane

"What color was the sign you just drove under?" (purple)

Q4. After subject is on Westpark

"Do you expect to go through a toll booth on this road?" (yes no)

Q5. After response

"How do you know that?" (ez tag only)

Q5A. After asking about toll booth presence

"Have you seen any signs today that told you that it was EZ Tag only?"

Q6. After

| | |
|-----------------------|------------------------|
| 59 NORTH 3/4 MILES | Fondren Rd 1/2 MILE |
|-----------------------|------------------------|

“On the signs coming up, what does the middle line say on the right sign?” (Downtown)



Q7. After

| | |
|---|---------------|
| ? | 59 NORTH ^ |
|---|---------------|

“On the sign coming up, what does the bottom line say?” (EXIT 1/2 MILE)

- Instruct subject to stay on Westpark Tollway at 59 split in **left lane**.
- “You can relax, we’re not going to ask any questions until after we turn around.”
- Instruct subject to exit on **Westpark Dr** to the right. “We’re exiting the tollway, be aware of other vehicles and traffic signals.”
- Once on Westpark Dr, have the subject move into the left lane, they will be turning **left on Wesleyan**. (it’s the first signal over the hill) Have the subject make another **left onto the 59 frontage and enter the freeway** at the first opportunity. **(40 mph on Westpark Dr)**
- Once Entering 59, must **move 3 lanes to left** immediately to avoid getting on 610.

Q8. Once on 59, past 610

“As soon as you recognize a Westpark Tollway sign, say ‘Westpark’”

- Instruct subject to enter **Westpark Tollway**



Q9. After they respond

“How did you know it was a Westpark Tollway sign?”

Q10. After the last Westpark exit sign

“What color was the top banner sign on the right you just drove under?” (purple)



Q11. Once on Westpark---

"What does the top line of the next sign on the right say?" (Fondren)

Q12. After

| | |
|------------------|--|
| Westpark Tollway | Fondren Rd Gessner Ave EXIT 3/4 MILE |
|------------------|--|

"What color were those signs?" (purple)



Q12A. After subject is on Westpark Ask after Question 12 (Fondren Rd Color)

"Do you expect to go through a toll booth on this road?" (yes no)

Q12B. After response

"How do you know that?" (ez tag only)

Q12C. After response

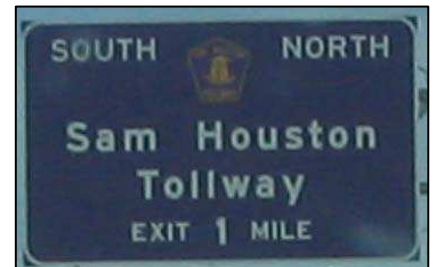
"Have you seen any signs today that told you that it was EZ Tag only?"

Q13. After

| |
|-------------------------|
| Fondren Rd Gessner ^ |
|-------------------------|

(long distance)

"What does the bottom line of the next sign say?" (EXIT 1 MILE)



Q14. After

| | |
|------------------------|----------------|
| Sam Houston Tollway | EXIT 1 MILE |
|------------------------|----------------|

"What does the top line of the small sign on the right shoulder say?" (WESTCHASE)



Q15. After response

"What color was that same sign?" (brown)



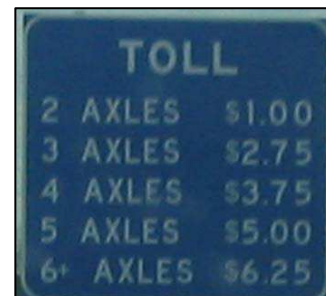
Q16. After response (referring to the Sam Houston exit shoulder sign)

"What color was that rectangular sign for that exit?" (purple)

Q17. After you've passed Sam Houston

"What does the top line of the sign on the right shoulder say?"

(Toll)



Q18. After response

"What color was that same sign?" (blue)

Q19. After

W. Houston Center Blvd
Dairy Ashford
EXIT 3/4 MILE

"What does the top line of the sign over the exit ramp say?" (West Houston Center Blvd)



Q20. After

W. Houston Center Blvd
Dairy Ashford
^

(long distance)

"What does the middle line of the sign coming up say?"

(Eldridge Pkwy)



Q21. After

To 6 SOUTH
Eldridge Pkwy
3/4 MILE

"What color was the sign we just passed?" (purple)



Q22. Wait for 3 signs, After

6 NORTH
1/4 MILE

"What does the bottom banner of the next sign say?"

(EXIT 35 MPH)



Q23. After response

"What color was that bottom banner?" (yellow)



Q24. After 6 NORTH exit

“What is the top line say on next sign?” (Westpark Dr)

Q25. After

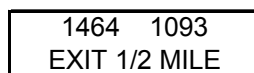
| |
|---------------|
| Westpark Dr |
| EXIT 1/2 MILE |

(you’ll see the westpark gore sign too)

“On the second sign ahead with the two white boxes, what is the number in the box on the top right?” (1093)



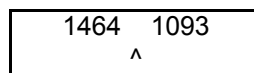
Q26 After



“What is the number in the box on the top left of the next sign say?” (1464)



Q27. After



(long distance)

“What is the top line of the next sign say?”
(Grand Mission Blvd)



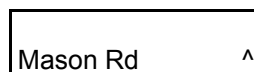
Q28. After response

“What color was that same sign?” (green)

Q29. After Gantries (long distance, up hill)

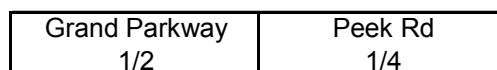
“What is the top line of the next sign say?” (Mason Rd)

Q30. After



“What is the top line of the right sign say?” (Peek Rd)

Q31. After



“What is the word in the upper left corner of the left sign?” (SOUTH)

- Instruct subject to exit on **99 Grand Parkway**, stay in left lane, take U turn and reenter **Westpark Tollway East**. (45 mph on frontage road)



Q32. After Entering Westpark

“What is the bottom line on the overhead sign say?” (Exit ½ MILE)

Mason Rd.
Grand Mission Blvd
Exit 1/2 MILE

Q33. After

“What does the bottom line on the next sign say?”
(Grand Mission Blvd)



Mason Rd. Grand
Mission Blvd ^

Q34. After

“What does the bottom line on the next sign say?” (EXIT 1 MILE)

(long distance, uphill)

6 1093 1464
Barker Cypress Rd
Exit 1 Mile

Q35. After

“What does the middle line say?” (Barker Cypress Rd)



6 1093 1464
Barker Cypress Rd
Exit 1/2 Mile

Q36. After

“What does the very bottom panel of the next sign say?” (Next Exit 8 Miles)



6 1093 1464
Barker Cypress ^
Next Exit 8 Miles

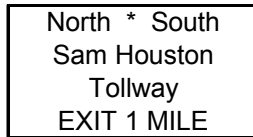
Q37. After

“What are the last 4 digits of the second, larger, rectangular sign on the right shoulder of the road?”
(7328)



Q38. After response

“What color was that same sign?” (blue)



Q39. Before!!! (long distance)

“What is the word in the upper right corner?” (**SOUTH**)

Q40. After passing Sam Houston

















“What color was the last sign?” (**purple**)

******STOP RECORDING DATA******

- Instruct subject to exit **Westpark Dr** to the right. Once on Westpark Dr, have the subject move into the left lane, they will be turning **left onto 610 frontage**. Continue on the frontage until you are approaching Memorial Dr. Have the subject move into the left lane and take a **left at Memorial**, take a **right on Post Oak Rd** and head back to the TTI office.

APPENDIX D

Guide Signs used for In-Car Study

| Sign Type | Purple Sign | Green Sign | Key Legend |
|------------------------------------|---|--|----------------------------------|
| Guide |  |  | EXIT 1/2 MILE |
| Guide |  |  | EXIT 1 MILE |
| Guide |  |  | SOUTH |
| Guide |  |  | Downtown / Grand Mission Blvd |
| Guide |  |  | Fondren / Mason Rd. |
| Guide |  |  | Eldridge / Peek |
| Guide |  |  | Westpark Dr. /Barker Cypress |
| Purple And Purple Westpark Tollway | |  | Westpark Tollway(from SH) |
| Green and Purple Westpark Tollway | |  | Westpark Tollway(from 59) |