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16. Abstract

This report describes two research activities. One research study tested the effects of adding commercial logos acknowledging sponsorship to Changeable Message Signs. A driving simulator study was conducted using test signs with travel times and safety message both with and without logos, while complying with the Texas Manuals on Uniform Traffic Control Devices guidance regarding overall message length and phase timing. Measures of performance included eye gaze duration and last look distance as well as driving performance measures of speed limit compliance and lane maintenance. Forty-two drivers in old and young age groups participated in the study. Another research study evaluated various rumble strip alternatives that have been used on various roadways in Texas. In this study, vehicles were instrumented with specialized equipment to measure the sound and vibration of various rumble strip alternatives. The vehicles were driven at various speeds during the testing. The primary measure of effectiveness was the change in vibration and sound from the control condition of driving in the lane.

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TRAFFIC CONTROL DEVICE EVALUATION PROGRAM: SIMULATOR EVALUATION OF SPONSORED CHANGEABLE MESSAGE SIGNS AND IN-SITU EVALUATION OF RUMBLE STRIP ALTERNATIVES

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DISCLAIMER

This research was performed in cooperation with the Texas Department of Transportation (TxDOT) and the Federal Highway Administration (FHWA). The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official view or policies of the FHWA or TxDOT. This report does not constitute a standard, specification, or regulation.

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CHAPTER 1. BACKGROUND – SPONSORED CHANGEABLE MESSAGE SIGNS

INTRODUCTION

As state and local transportation agencies grapple with continuing fiscal shortfalls, innovative funding mechanisms are being considered. The federal and Texas Manuals on Uniform Traffic Control Devices (MUTCD) provide guidance and standards concerning the use of acknowledgement signs. The signs in this program "are a way of recognizing a company, business, or volunteer group that provides a highway-related service" (MUTCD Section 2H.08). The current federal MUTCD prescribes a static sign that shall not be installed near other traffic control devices, including changeable message signs (CMSs). The Texas Department of Transportation (TxDOT) is investigating the use of static acknowledgement sponsor logo images that would appear in a portion of a CMS. TxDOT has received permission from the Federal Highway Administration (FHWA) to experiment with this concept in a three-step process (FHWA Request to Experiment ruling number "2(09)-83 (E) - Sponsorship Acknowledgment on CMS – TX):

1. A driving simulator study to evaluate the distraction potential of having sponsor logos on CMS.
2. A closed-course driving study evaluating legibility and investigating any effects of veiling glare on roadway hazard detection.
3. An open road study examining eyes off road time.

The driving simulator study is described here. The closed-course testing is underway and the open road study will not begin until FHWA has reviewed the findings of the first two steps.

The driving simulator study explored the effects of sponsored CMSs on driver comprehension and gaze patterns. A sponsored CMS includes the graphical logo(s) of one or more commercial sponsors in addition to the sign's primary message. The research questions of interest were as follows:

- Does the presence of a sponsored logo significantly impact the time drivers' eyes are on a CMS sign?
- Do the glances at the sponsored logo CMS suggest a possible decrease in safety?
- Does the sponsored logo CMS continue to attract the driver's attention beyond the traditional last look distance?
- Does the presence of a sponsored logo CMS significantly impact the driver's awareness of their surroundings related to traffic regulations?
- How does the presence of the sponsor logo CMS affect driver comprehension and accuracy of the traffic related message?

During the simulation study, researchers used eye tracking equipment to record where participants were looking during the drive (e.g., at the forward roadway, at the overhead CMS, or elsewhere in the scene). These gaze patterns, along with participants' recall of CMS messages and driving performance data recorded by the simulator, were analyzed to determine the effects, if any, of the addition of one or more sponsor logos to standard CMS sign formats and messages.

CURRENT TEXAS MUTCD STANDARDS

Sponsor logos on CMS do not conform to the current edition of the Texas Manual on Uniform Traffic Control Devices (TMUTCD). The TMUTCD also prescribes a maximum of three units of information per phase of a CMS message, where each unit is defined as a "single answer to a single question a driver can use to make a decision." At posted speeds of 35 mph or more, a maximum of four information units per message are allowed. The limits on information units are related to the time needed for a driver traveling at roadway speeds to read, comprehend, and respond to a message. A potential concern if a sponsor logo is added to a CMS is whether the logo effectively adds another information unit to the sign, adding to driver workload and affecting the amount of time the driver's gaze is on the sign rather than on the road.

The following TMUTCD excerpts outline current requirements for CMS signs and messages:

"Section 2L.02 paragraph 02 states:

> Changeable message signs may be used by State and local highway agencies to display safety messages, transportation-related messages, emergency homeland security messages, and America's Missing: Broadcast Emergency Response (AMBER) alert messages.

The standard in paragraph 06 states:

> When a CMS is used to display a safety, transportation-related, emergency homeland security, or AMBER alert message, the display format shall not be of a type that could be considered similar to advertising displays.

Section 2L.03 Guidance:

> 04 Changeable message signs used on roadways with speed limits of 55 mph or higher should be visible from 1/2 mile under both day and night conditions. The message should be designed to be legible from a minimum distance of 600 feet for nighttime conditions and 800 feet for normal daylight conditions. When environmental conditions that reduce visibility and legibility are present, or when the legibility distances stated in the previous sentences in this paragraph cannot be practically achieved, messages composed of fewer units of information should be used and consideration should be given to limiting the message to a single phase (see Section 2L.05 for information regarding the lengths of messages displayed on changeable message signs)

Section 2L.04 Standard:

> 01 Changeable message signs shall not include advertising, animation, rapid flashing, dissolving, exploding, scrolling, or other dynamic elements.

Section 2L.05 Message Length and Units of Information Guidance:

> 01 The maximum length of a message should be dictated by the number of units of information contained in the message, in addition to the size of the CMS. A unit of information, which is a single answer to a single question that a driver can use to make a decision, should not be more than four words.

Guidance:

> 06 When designing and displaying messages on changeable message signs, the following principles relative to message design should be used:

A. The minimum time that an individual phase is displayed should be based on 1 second per word or 2 seconds per unit of information, whichever produces a lesser value. The display time for a phase should never be less than 2 seconds.
B. The maximum cycle time of a two-phase message should be 8 seconds.
C. The duration between the display of two phases should not exceed 0.3 seconds.
D. No more than three units of information should be displayed on a phase of a message.
E. No more than four units of information should be in a message when the traffic operating speeds are 35 mph or more.
F. No more than five units of information should be in a message when the traffic operating speeds are less than 35 mph.
G. Only one unit of information should appear on each line of the CMS.
H. Compatible units of information should be displayed on the same message phase."

The Texas MUTCD does allow acknowledgment signs (Section 2H.08) to recognize sponsors of highway maintenance and beautification programs. The current standards, however, prohibit the use of light-emitting diodes on such acknowledgment signs (Section 2H.08, paragraph 9, item F).

CHAPTER 2. STUDY TREATMENTS AND EXPERIMENTAL DESIGN - SPONSORED CHANGEABLE MESSAGE SIGNS

SIGN MESSAGES

Because the objective of this study was to test the effects of adding sponsorship acknowledgment logos to CMS, test signs for the simulator study were designed both with and without logos, while complying with TMUTCD guidance on overall message length and phase timing.

The first step in determining the test sign designs was to determine the types of messages that TxDOT would be likely to display on graphics-capable CMS. In consultation with TxDOT, the Texas A&M Transportation Institute (TTI) selected three categories of messages to test in the driving simulator: travel time messages, warning messages, and TxDOT sponsored public safety outreach campaign messages. Travel time messages were shown as a single CMS phase, while both the warning messages and the TxDOT safety campaign messages were shown in two phases. TxDOT provided pictures of sample signs provided by the CMS vendor for each of the three message categories; these pictures plus guidance from TxDOT provided the basis for the overall look of the test signs, including color choices and the size of the sponsor logos when logos were present.

TxDOT's proposed rules for using sponsor logos prohibit their use for warning messages, but the other two types of messages could potentially be viewed without a logo, with a single logo, and with two different sponsor logos shown in two sign phases. When a sponsor logo is present, it fills 1/3 of the total sign's width on the right side of the traffic message (Figure 1).

(NOTE: This photograph was taken while the simulation was in motion, so it is not representative of the actual clarity of the message)

Figure 1. Example of Overhead Test Sign in Simulator.

Sign messages were created with assistance from the TxDOT advisory panel members, using examples of current TxDOT-approved CMS messages. Currently, TxDOT has a mixed inventory of CMS equipment. Some signs only provide up to 15 characters per line, so all TxDOT messages must conform to this length. To accommodate the limited sign viewing time available in the simulator, some of the TxDOT-approved messages were shortened slightly. The original sample sign pictures sent by the CMS vendor varied considerably in background color and in font style, color, and size. The logo and any accompanying taglines that are part of the trademarked logo were not altered for the study. Logo background color was set to white for all but two of the signs. Black backgrounds were used for two single-phase travel time signs. The black background color was the most typical color for those particular logos. Researchers did not expect logo background color to affect driver distraction, but this factor was investigated more fully in the closed-course visibility study conducted as Phase 1B of the evaluation. Timing for two-phase signs was also held constant at three seconds per phase; message phases and logos (if two logos were used) changed at the same time. For the two-phase warning signs, the second phase of the message was always the same as per TxDOT typical practice.

EXPERIMENTAL DESIGN

A total of 14 sign designs were developed for testing in the driving simulator, including one-phase travel time and two-phase warning and TxDOT campaign messages, and incorporating either a single-phase logo, a two-phase logo, or no logo. Many of the sign designs appeared twice as treatments in the study (referred to as repetitions), viewed one time following a 10-mph speed increase and a different time following a 10-mph speed decrease from the baseline posted speed of 60 mph. In addition to the test signs, No Sign (an empty sign bridge) and Blank (a bridge and a sign that is black) were added as baseline conditions. This resulted in a total of 25 treatments (Table 1).

Table 1. Sign Treatments Tested in Simulator Study.

Sign Images (Sign is two phase if two images are shown)	Message Type	Sponsor Logo	# of Logo Phases	Repetition	Sign Code
No Sign	N/A	N	N/A	1	None_1
				2	None_2
	N/A	N	N/A	1	Blank_1
				2	Blank_2
TRAVEL TIME TO 43 6 Mins	Travel Time	N	0	1	TT__0_1
				2	TT__0_2
TRAVEL TIME TO 23 11 Mins	Travel Time	N	0	1	TT__0_3
TRAVEL TIME TO 24 7 Mins / MIDAS Trust the Midas touch.	Travel Time	Y	1	1	TT__1_1
				2	TT__1_2
TRAVEL TIME TO 76 12 Mins / JUST DO IT.	Travel Time	Y	1	1	TT__1_3
TRAVEL TIME TO 19 9 Mins / at&t Rethink Possible; TRAVEL TIME TO 19 9 Mins / GET TO A BETTER STATE	Travel Time	Y	2	1	TT__2_1
				2	TT_2_2
TRAVEL TIME TO 65 14 Mins / Ford GO FURTHER; TRAVEL TIME TO 65 14 Mins / SOUTHWEST share the spirit	Travel Time	Y	2	1	TT__2_3
US 59 SOUTH AT SH 288 FREEWAY CLOSED; USE ALTERNATE ROUTE	Warning	N	0	1	WM_1
				2	WM_2
FREEWAY CLOSED AT SH 281 MAJOR ACCIDENT; USE ALTERNATE ROUTE	Warning	N	0	1	WM_3

Table 1. Continued. Sign Treatments Tested in Simulator Study.

Sign Images (Sign is two phase if two images are shown)	Message Type	Sponsor Logo	# of Logo Phases	Repetition	Sign Code
DRIVE SOBER OR GET PULLED OVER / DRINK DRIVE GO TO JAIL	TxDOT Campaign	N	0	1	TxM_0_1
				2	TxM_0_2
USE CAUTION IN WORK ZONES / BE SAFE DRIVE SMART IN WORK ZONES	TxDOT Campaign	N	0	1	TxM_0_3
DRIVE NOW TALK LATER / TEXT TALK CRASH	TxDOT Campaign	Y	1	1	TxM_1_1
				2	TxM_1_2
2157 DEATHS THIS YEAR ON TEXAS ROADS / PROTECT YOUR KIDS BUCKLE THEM UP	TxDOT Campaign	Y	1	3	TxM_1_3
CLICK IT OR TICKET / BUCKLE UP EVERY RIDER EVERY RIDE	TxDOT Campaign	Y	2	1	TxM_2_1
				2	TxM_2_2
SHARE THE ROAD LOOK TWICE FOR MOTORCYCLES / 2157 DEATHS THIS YEAR ON TEXAS ROADS	TxDOT Campaign	Y	2	3	TxM_2_3

During the simulated drives, after participants passed each CMS, they were asked questions to test their recall of the sign messages. The specific questions varied according to each category of sign message.

- For travel time signs, questions were as follows:

    1. What was the travel time to [destination]?
    2. Was there a logo on the sign? How many?

- For public education campaign signs, questions were:

    1. What was the first message?
    2. What was the second message?
    3. Was there a logo on the sign? How many?

- For action-based message signs, questions were:

    1. What did the sign say is the traffic problem?
    2. What did the sign tell you to do?
    3. Was there a logo on the sign? How many?

- For the blank sign:

    1. What did the sign tell you? (expected answer was "nothing")
    2. Was there a logo on the sign? How many?

No questions were asked after participants passed the empty sign bridge.

From previous experience with driving simulator studies, researchers decided that simulator driving sessions should last no longer than 15 minutes each followed by a short break. In order to achieve this, participants viewed the 25 treatments by driving three different 15-minute drives, each containing eight to nine sign treatments. In order to minimize learning effects across the different sign treatments, six different worlds were created, each with a different treatment order (Table 2). Each subject then drove three worlds in an order counterbalanced across the subject sample (Table 3).

Table 2. Six Orders for Sign Treatments.

World 1a	**World 2a**	**World 3a**
TxM_0_3	TT_1_1	TT_1_2
Blank_2	WM_1	TxM_1_3
TT_0_1	TxM_2_3	TT__2_1
WM_2	TT_2_2	TxM_0_1
TT_1_3	Blank_1	None_2
None_1	TxM__0_1	TT_1_2
TxM_2_1	TT__0_3	WM_3
TT_2_3	TxM_1_1	TxM_2_2
TxM_1_2		
World 1b	**World 2b**	**World 3b**
TxM_1_2	TxM_1_1	TxM_2_2
TT_2_3	TT_0_3	WM_3
TxM_2_1	TxM_1_2	TT_1_2
None_2	Blank__1	None_1
TT_1_3	TT_2_2	TxM_0_1
WM_2	TxM_2_3	TT_2_1
TT_0_1	WM_1	TxM_1_3
Blank_2	TT_1_1	TT_0_2
TxM_0_3		

Table 3. 12 Group Drive Orders.

Group	Drive 1	Drive 2	Drive 3
A	World 1a	World 2a	World 3a
B	World 3a	World 2a	World 1a
C	World 2a	World 1a	World 3a
D	World 3a	World 1a	World 2a
E	Worlds 2a	World 3a	World 1a
F	World 1a	World 3a	World 2a
G	World 1b	World 2b	World 3b
H	World 3b	World 2b	World 1b
I	World 2b	World 1b	World 3b
J	World 3b	World 1b	World 2b
K	Worlds 2b	World 3b	World 1b
L	World 1b	World 3b	World 2b

CHAPTER 3. METHODS – SPONSORED CHANGEABLE MESSAGE SIGNS

SIMULATION DESCRIPTION

TTI houses a Realtime Technologies Inc. desktop driving simulator that was operated with three 48-in. screens for viewing the roadway (NOTE: only two screens are actually visible in Figure 2). The simulator is also equipped with a steering wheel, accelerator, and brake pedals mounted within a simulated vehicle cab with an adjustable seat. Depending on the position of the seat, subjects viewed the center screen from a distance of 56 to 62 in. The driving environment included a four-lane urban freeway with moderate traffic. Insets on the screens replicated a rear-view and two side-view mirrors; the rear-view mirror was offset to the right upper edge of the center screen to avoid obscuring the message on the overhead CMS during the test drives. The test signs were placed overhead in the center of the four lanes on a sign bridge. Speed limit signs were placed periodically throughout the drive on both sides of the road to increase the likelihood that they would be visible to the participant.

Figure 2. TTI's Desktop Driving Simulator.

SECONDARY TASKS

Researchers wanted to encourage drivers to visually scan for roadway elements other than the CMSs, as they would need to do on an actual roadway. To this end, participants were asked to perform two recurring secondary driving tasks during each of the study drives. The first task involved making a lane change in the direction of an arrow that would periodically appear on the screen as seen in Figure 3.

Figure 3. Example of the Arrow Use in the Lane Change Secondary Task.

Variation in the surrounding traffic drastically influenced participant performance of this task and could not adequately be measured. For example, if there was a car alongside the participant at the time an arrow appeared on the screen, they would not be able to move over. Also, from time to time, the arrow would appear on the screen when there was a car driving in the simulation behind the arrow on the screen. If there was not much contrast (i.e., a red arrow on top of a red car), the participant sometimes did not notice the arrow and did not make the lane change. For these reasons, participants' performance of the secondary tasks could not be consistently compared; however, the driving data indicate that most participants accomplished these tasks most of the time.

The second task was to drive at the posted speed limits (PSLs), which drivers were told would change periodically during each drive. Each of these secondary tasks occurred each time drivers approached an overhead CMS. The lane change arrow appeared 1,680 ft prior to each sign bridge location, approximately 20 seconds prior to the sign bridge at the baseline speed of 60 mph; this was several seconds prior to the point where participants would be able to read the CMS message. Speed limit signs requiring a 10 mph increase or decrease from the baseline speed appeared on both sides of the road 820 ft (approximately 9 seconds) prior to each sign bridge; this was the approximate distance at which the CMS message became legible. To the extent that drivers were concentrating solely on the CMS message at this point, they may miss the speed limit change. With this placement and manipulation, researchers created the possibility of using compliance with speed limit as a measure of workload. The higher the CMS workload, the greater probability drivers would miss other signs in the vicinity of the CMS and not change their speed as posted. This method has been used in past studies of distraction (*1*). The indicated speed change was sometimes hindered by a lead vehicle in the participant's lane generated in the random traffic stream provided by the simulator.

After they passed the test CMS signs, participants would pass a 60 mph speed limit sign intended to bring them back to the baseline speed. These speed limit signs were positioned at a sufficient distance downstream of the CMS to allow time for participants to answer the researcher's questions about the CMS prior to making the change back to baseline speed.

EYE TRACKER DESCRIPTION

The faceLAB® eye-tracking system by Seeing Machines, Inc. is a remote sensing device that uses two infrared cameras to track the movements of participants' eyes (Figure 4 [a]). The eye-tracking equipment used in this study also included a forward-facing scene camera that can be connected with the infrared cameras to show on-screen where the study participant is looking (Figure 4 [b]). The infrared cameras operate at 60 Hz (60 frames per second) and the scene camera operates at 30 Hz. The eye-tracking system was calibrated to each participant at the start of the study session.

(a) Infrared cameras and infrared light source, viewed through simulator steering wheel

(b) Screen Capture of Eye Tracking Video
(Green circle on the capture indicates where a driver looks)

Figure 4. TTI's Eye Tracking Systems.

PARTICIPANT RECRUITMENT

Participants were recruited from the Bryan/College Station community through TTI's existing recruiting pool, through social media, and by word of mouth. Data from 43 participants are presented in this report (more data collection was attempted but not used due to eye tracking or simulator issues). Forty-three participants are represented in the open ended data, and 42 in both the driving and eye tracking data. Recruitment was broken into two age ranges, 19–35 and 60 and older. Ages ranged from 19 to 83. Table 4 summarizes the age and gender distribution of the participants. With an attempt to evenly distribute the demographics, participants were divided into the 12 groups previously mentioned to introduce different treatment presentation orders to reduce bias.

Table 4. Participant Age and Gender.

Gender	19–35		60+		
	Number	Average Age (yrs)	Number	Average Age (yrs)	Number
Female	11	24	11	66	22
Male	11	24	10	70	21
Total	22		21		43

PROCEDURE

Upon arrival, the participants read and signed an informed consent document. Following consent, the participants were read the following while a practice simulation drive was loading on the computers:

> The driving simulator you are in will react to your steering and pedal inputs to provide a realistic driving experience. During your drive in the simulator, please drive in a normal fashion. We can adjust your seat at a position that is comfortable for you. You will be using the right paddle on the wheel to signal when you turn right, and the left paddle on the wheel to signal when you turn left. *[Show them how to hold their hands so they don't block the cameras]*
>
> You'll also notice there are three insets on your screens, one for your rearview mirror and two side mirrors. *[Adjust pedals and point out paddles or mirrors if there is any confusion]*
>
> We will begin with a practice session to get you comfortable with driving in the simulator. One of your driving tasks is to drive at the posted speed limit at all times. This means you should change your speed limit whenever you see a new speed limit sign, even if it means speeding up. Also along your drive you will see a red arrow on the screen pointing either to the left or right. Whenever you see this arrow, move one, and only one, lane over to the right or left in the direction the arrow is pointing as soon

> as you can safely do so. You also need to use the right and left paddle on the wheel when you see the arrow and decide to change lanes. I would like you to practice these tasks during this drive.
>
> You can slowly pull out onto the roadway and as you become comfortable, accelerate to a speed of approximately 60 mph. *[Participant should be pulling out]*
>
> You may notice that you tend to drive closer to the left edge of the lane because of how your view of the roadway lines up with your seat position. This is not something you need to worry about or try to correct.
>
> *[Once they are up to speed*] How are you doing? Practice switching back and forth from the accelerator to the brake to get comfortable with the pedals.
>
> *[Once you feel they are driving comfortably and have practiced the arrow and speed tasks]* Do you feel you've had enough practice? [*If no, allow them to practice a little longer*] Please slowly coast to a stop.

Once the facilitator felt the participant had had enough practice, the following instructions about the experimental drivers were read before the first experimental drive:

> For the experimental sessions, you will be driving 3 different drives at approximately 15 minutes each. Remember you are given the tasks of driving as close to the posted speed limits as you can, and moving over a lane when you see an arrow. Finally, your last task will be to periodically answer questions about signs you see overhead. The signs may or may not have a logo on them such as this one, representing a sponsor for the sign. *[show logo example]* Please answer these questions as short and precise as you can. Other than answering questions, or if you have any questions yourself, please refrain from talking during the experimental sessions. Do you have any questions at this time?

After passing each test sign, the facilitator verbally asked questions pertaining to sign comprehension (as detailed in the previous chapter under "Experimental Design") and the presence of a logo. These questions were the same for each type of sign message and can be found in the results section. At the conclusion of all three drives, participants were compensated for their time.

CHAPTER 4. RESULTS – SPONSORED CHANGEABLE MESSAGE SIGNS

OPEN ENDED RESPONSE DATA

For some trials, a lead vehicle was blocking the view of the sign as noted by the experimenter. Recall data for these trials were omitted from the analysis (32 of 884 measurements). The analysis included a within-subjects non-parametric analysis using the Friedman test treatment differences in a randomized complete block design. Each individual driver was used as a block in the analysis and in the experiment. Because the scores are neither continuous nor normally distributed, the Friedman test was employed to test whether there is a difference in the recall scores due to different Logo_Count while reducing extraneous variability caused by driver differences.

The open ended responses were initially scored in three categories:

- Incorrect (0) – participant could not remember sign at all, or gave an answer that had nothing to do with the message. On a few rare occasions a participant would state one or two words from the entire sign message but not enough to take away any relevant info.
- Partially Correct (1) – participant could remember some portion of what the message was about, but not all of the information (e.g., in the warning sign example, may have remembered "use alternate route," but not the first part of the message about the freeway closure). If a participant remembered one phase of the message, but nothing of the other phase, it was automatically scored as partially correct. Partially correct also applied if the participant remembered one phase and then part of another phase but was missing a crucial phrase of the campaign message (e.g., the participant said "DRIVE SOBER" when the sign said "DRIVE SOBER OR GET PULLED OVER").
- Correct or verbatim (2) – participant could remember all of the relevant bits of information, but either paraphrased the wording or repeated it exactly as worded on the sign. This score was also given if minor words were left out but none of the message was lost (e.g., if the participant said "DRIVE DRUNK GO TO JAIL" instead of the sign's wording "DRINK DRIVE GO TO JAIL").

Warning Messages

The warning messages were always seen without any logos. The messages were created with guidance from TxDOT as examples of what are used on Texas roadways today. The entire message was always two phase with the second phase being the same for all three treatments. These conditions can serve as a conceptual baseline for performance for recall of sign messages. Recall scores overall ranged from 63 percent to 90 percent (Table 5). This number included the partially correct and correct responses. The sign with a single highway route number in the message (WM_dwn2) showed better recall for the other sign messages that contained two route numbers.

Travel Time Messages

The travel time messages were seen without a logo and with single and dual phase logos (Logo_Count= 0, 1, 2). There were 304 valid observations for travel time signs. The percentages of participants recalling the correct travel time on all of the travel time messages range from 86 to 100 percent (Table 6). Memory for the travel time message was not significantly different when there was no logo, one logo, or two logos present in the sign ($p=0.8742$). The analysis was repeated separately for Young and Old drivers and again there was no difference in recall as a function of the number of logos (Young drivers $p=0.293$, $N=171$; Old drivers $p=0.3333$, $N=133$). An additional analysis was conducted to test whether the mere presence of any logo at all affected recall. For this analysis, the single and dual phase sign data were combined to create a new binary variable Logo_Presence. For travel time signs, the Friedman test again showed no difference in recall as a function of logo presence for either age group.

TxDOT Safety Campaign Messages

The TxDOT campaign messages were seen without a logo and with single and dual phase logos. The message portions of the signs were always two-phase and were created with guidance from TxDOT as examples of what are used on Texas roadways today. For some signs, the logos stayed the same throughout the two-phase safety message, and for other signs, the logo changed when the safety message changed through its two phases. Table 7 shows the percent correct recall for the message and for logo presence and count. The test for the effect of Logo_Count (0,1,or two logos) failed to reach significant levels at the $\alpha=0.05$ testing ($p=0.0543$). This indicates that having logos on the sign did not affect recall for the safety messages. In order to check for any interaction between Logo_Count and Subject age, the test for Logo_Count was conducted on each age group separately. Again, no significant effect of logo count was found (Young drivers, $p=0.213$; Older drivers, $p=0.693$).

Next, researchers tested the effect of the presence of logo regardless of whether logo changes in phasing. A new variable Logo_presence was defined to be 1 when Logo_Count=1 or Logo_Count=2 and 0 when Logo_Count=0. The main factor of interest in this analysis was Logo_presence (with values 0, 1). As before, the Friedman test was employed to test whether there was a difference in the recall scores due to Logo_presence while reducing extraneous variability caused by driver differences by controlling for participant.

For Travel Time message sign, the conclusions stay the same as testing for the effect of Logo_Count. That is, the recall of message content does not seem to be significantly affected by the presence of the sponsor logo CMS for either the Young or Old driver group. However, for the Safety message sign, the effect of the presence of the sponsor logo CMS became statistically significant at $\alpha=0.05$ when Young and Old drivers were considered together (i.e., Age_group was ignored) and also when only Old drivers were considered. For both age groups combined, the p value for the Friedman test was 0.0159, for Young it was 0.1534, and for Old it was 0.0412. Because the Friedman test is a rank-based test, the amount of the difference in the recall scores when the logo is present and when the logo is not present cannot be easily quantified. Just to get an idea on roughly how much difference there is, the Analysis of Variance (ANOVA) having Logo presence and Age Group and interaction between them as fixed effects and Participant as a random effect was also performed on the Safety message sign data while recognizing that the p-values from this test may not be correct. The predicted recall scores for Safety message sign from the ANOVA were 1.37 when the logo was not present and 1.22 when the logo was present. This indicates that the difference (here 0.15) in the recall scores may not be practically significant with respect to the current scale (0, 1, 2).

Table 5. Open Ended Responses for Warning Message Treatments.

Treatment	Sign Images	Age Group	Results			
			% Incorrect	% Partially Correct	% Correct	Combined Ages % Message Correctness (including Partially Correct)
WM_1	US 59 SOUTH AT SH 288 FREEWAY CLOSED / USE ALTERNATE ROUTE	Y	13.64%	63.64%	22.73%	79.07%
		O	28.57%	66.67%	4.76%	
WM_2	US 59 SOUTH AT SH 288 FREEWAY CLOSED / USE ALTERNATE ROUTE	Y	18.18%	59.09%	27.28%	62.79%
		O	57.14%	33.33%	9.52%	
WM_3	FREEWAY CLOSED AT SH 281 MAJOR ACCIDENT / USE ALTERNATE ROUTE	Y	0%	72.73%	36.36%	90.70%
		O	19.05%	76.19%	4.76%	

NOTE
1: The total sample size equals 43, with the Young (Y) age group n=22 and the Old (O) age group n=21.
2: In order to test recall of these messages, the participants were first asked "What did the message say was the problem?" followed by "What did the sign say to do?" Both responses together determined their total recall for the sign.
3: Responses of "I don't know" or "Didn't see" were scored as incorrect.

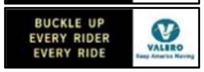
Table 6. Open Ended Responses for Travel Time Message Treatments.

Treatment	Sign Images	Age Group	What was the travel time? (% correct)	Combined Ages % Message Correctness	Was there a logo on the sign? (% correct)	Combined Ages % Logo Recognition Correctness	If so, how many? (% correct)	Combined Ages % Number of Logos Correctness
TT__0_1		Y	100.00%	95.35%	100.00%	100.00%	N/A	N/A
		O	90.48%		100.00%			
TT__0_2		Y	100.00%	95.35%	100.00%	97.67%	N/A	N/A
		O	90.48%		95.24%			
TT__0_3		Y	95.45%	93.02%	100.00%	95.35%	N/A	N/A
		O	90.48%		90.48%			
TT__1_1		Y	90.91%	90.70%	90.91%	88.37%	90.91%	88.37%
		O	90.48%		85.71%		85.71%	
TT__1_2		Y	95.45%	93.02%	100.00%	100.00%	100.00%	100.00%
		O	90.48%		100.00%		100.00%	
TT__1_3		Y	90.91%	88.37%	100.00%	100.00%	95.45%	97.67%
		O	85.71%		100.00%		100.00%	
TT__2_1		Y	100.00%	100.00%	100.00%	97.67%	90.91%	72.09%
		O	100.00%		95.24%		52.38%	
TT_2_2		Y	100.00%	90.70%	100.00%	95.35%	86.36%	65.12%
		O	80.95%		90.48%		42.86%	
TT__2_3		Y	90.91%	86.05%	100.00%	97.67%	90.91%	76.74%
		O	80.95%		95.24%		61.90%	

NOTE
1: Friedman test showed no statistically significant different between any of the recall results.
2: Responses of “I don’t know” or “Didn’t see” were scored as incorrect

Table 7. Open Ended Responses for TxDOT Safety Campaign Messages.

Treatment	Sign Images	Age Group	Sign Message Recall: % In-correct	Sign Message Recall: % Partially Correct	Sign Message Recall: % Correct	Sign Message Recall: Correct and Partial for Combined Ages	Was there a logo on the sign? (% correct): By Age Group	Was there a logo on the sign? (% correct): Combined Ages	If so, how many? (% correct): By Age Group	If so, how many? (% correct): Combined Ages
TxM_0_1	DRINK DRIVE GO TO JAIL	Y	--	36.36%	63.64%	100.00%	100.00%	95.34%	N/A	N/A
	DRIVE SOBER OR GET PULLED OVER	O	--	85.71%	14.29%		90.48%			
TxM_0_2	DRIVE SOBER OR GET PULLED OVER	Y	--	36.36%	63.64%	97.67%	100.00%	97.67%	N/A	N/A
	DRINK DRIVE GO TO JAIL	O	4.76%	80.95%	14.28%		95.24%			
TxM_0_3	USE CAUTION IN WORK ZONES	Y	--	50.00%	50.00%	95.35%	100.00%	93.02%	N/A	N/A
	BE SAFE DRIVE SMART IN WORK ZONES	O	9.52%	71.43%	19.05%		85.71%			
TxM_1_1	DRIVE NOW TALK LATER	Y	9.09%	31.82%	59.09%	81.39%	100.00%	90.69%	100.00%	90.70%
	TEXT TALK CRASH	O	28.57%	71.43%	0.00%		80.95%		80.95%	
TxM_1_2	TEXT TALK CRASH	Y	--	40.91%	59.09%	90.70%	95.45%	90.70%	90.91%	86.05%
	DRIVE NOW TALK LATER	O	19.05%	71.43%	9.52%		85.71%		85.71%	
TxM_1_3	2157 DEATHS THIS YEAR ON TEXAS ROADS / Walmart Save money. Live better.	Y	4.55%	59.09%	36.36%	90.70%	95.45%	86.05%	100.00%	86.05%
	PROTECT YOUR KIDS BUCKLE THEM UP / Walmart Save money. Live better.	O	14.29%	66.67%	19.05%		76.19%		71.43%	
TxM_2_1	CLICK IT OR TICKET / T-Mobile simply closer	Y	--	36.36%	63.63%	100.00%	100.00%	86.05%	81.82%	51.16%
	BUCKLE UP EVERY RIDER EVERY RIDE / VALERO	O	--	85.71%	9.52%		71.43%		19.05%	

Treatment	Sign Images	Age Group	Sign Message Recall				Was there a logo on the sign? (% correct)		If so, how many? (% correct)	
			% In-correct	% Partially Correct	% Correct	Correct and Partial for Combined Ages	By Age Group	Combined Ages	By Age Group	Combined Ages
TxM_2_2		Y	4.55%	40.91%	54.55%	90.69%	95.45%	93.02%	68.18%	44.19%
		O	14.29%	71.43%	14.28%		90.48%		19.05%	
TxM_2_3		Y	9.09%	22.73%	68.19%	72.09%	100.00%	90.70%	68.18%	51.16%
		O	47.62%	52.38%	--		80.95%		33.33%	

NOTE
1: Data table presented for information only, statistical analyses showed no significant differences among age groups or across sign type.
2: In order to test memory of these messages, the participants were first asked “What was the first message?” followed by “What was the second message?” Both responses together determined their total recall for the sign.
3: Responses of “I don’t know” or “Didn’t see” were scored as incorrect.

DRIVING PERFORMANCE DATA

Driving performance was assessed by measures of lateral and longitudinal control. Standard deviation of lane position has been shown to be sensitive to driver distraction due to cell phone use (*2*) and is a common measure used in human factors studies. Drivers who are distracted show a higher degree of variation in their lane position as evidenced by a higher standard deviation around the center of the lane. Lane encroachment is a safety surrogate measure indicative of poor lane maintenance due to distraction. Naturalistic driving studies have shown that distracted drivers are more likely to have unintended lane line encroachments than undistracted drivers (*3*). Compliance with PSL is a measure of cognitive distraction because of the manipulation of the PSL introduced along the approach to the signs (*1*).

In addition to the main study factor, Logo Presence (with values 0, 1), other factors of interest in the analysis are Sign Type (with 2 levels S or T), Age Group (Old: 55 years of age and older, Young: 18 to 35 years of age), and Gender (1: Male, 0: Female). Out of 13,636 observations sampled at 30 Hz (every 0.5 seconds) in the original dataset, 3,822 observations have Sign Type =W, N, or B and 8 observations have Sign Type = #N/A. Because the logo was not present for those sign types, the subset of the data (with the sample size of 9,806) having Sign Type = T or S was used for testing the effect of Logo Presence.

Offset from Center line/Standard Deviation of Lane Position

Because researchers are mainly interested in how variability of Offset from Center line is affected by the presence of logo and by other factors mentioned above, the residuals from the regression model were standardized and used as the data of interest for the analysis. In this way homogeneity of variance can be assessed across treatment factors within drivers. For the lane offset data, there were 143 blank values that correspond to the cases that the driver changed the lane within the 6-second period. Those 143 blank values were removed from the data, which left n=9,663 observations for the lane offset variability analysis. These can be viewed as observations from the split-plot design with Driver (Subject) as a whole-plot (a random effect). There were 42 drivers in the data. Of those 42 drivers, 20 drivers were males and 22 drivers were females. Within each Gender group, half of them belong to the Old category and the other half belong to the Young category. The demographic variables on Driver, Gender, and Age Group serve as whole-plot factors, and the variables Logo Presence and Sign Type serve as split-plot factors.

For testing equality of variances for a split-plot design with multiple factors and a random effect, there are no tests that are available in major statistical packages. The well-known Bartlett's test or Hartley's F-max test on equality of variances is available only for a one-way unblocked design (i.e., when there is only one factor), and those tests are highly sensitive to departures from the assumption of normality. Levene's test (which uses pseudo-observations defined as absolute deviations of the data points from an estimate of the group mean and applies ANOVA tests on those pseudo-observations) and several modifications of Levene's test have been suggested as robust alternatives to Bartlett's test (*4*). However, most of them are suitable only for a one-way unblocked design.

In this study, researchers have multiple study factors and a random effect (Drivers). Researchers employed a modification of the method suggested by O'Neill and Mathews (*4*) that extended the weighted least squares formulation of Levene's test based on the absolute values of mean-adjusted standardized residuals to more general experimental designs such as a randomized block design or a split-plot design. As pointed out by O'Neill and Mathews (*4*), conceptually, Levene's test can be generalized for any design for testing equality of variances. The generalized version of Levene's test researchers used to handle multiple factors and a random effect in this analysis (*5*) consists of the following three steps:

1. Save the standardized residuals from the ANOVA of the data.
2. Form absolute values of the standardized residuals.
3. Analyze these using the original ANOVA structure.

The mixed effects ANOVA model having Logo Presence, Sign Type, Age Group, Gender, and two-way interactions among them as fixed effects and Participant as a random effect was first run to obtain the standardized residuals in Step 1 above. The absolute values of the standardized residuals are then fitted by the same mixed ANOVA model (Step 3).

Appendix A contains the analysis results based on the absolute values of the standardized residuals from Step 3. The interaction effects between Logo Presence and Sign Type (Logo Presence*Sign Type) is statistically significant at the 5 percent significance level (see also Appendix A Table 12 Fixed Effects Tests). This indicates that when the logo was present, the lane position variability for travel time sign was about 6% larger than for safety message signs. On the other hand, when the logo was not present, the lane position variability for travel time sign was about 5 percent smaller than that for safety message signs. The practical significance of this result is very minor as the differences between the sign treatments are on the order of 0.01 m. The statistically significant finding, however, indicates that the experimental design was sensitive to detect any other differences across sign types that may have been present.

Appendix A also presents the predicted values (least squares means) for Absolute standardized residuals for each level of factors in the model along with their standard errors (in effect details). The Absolute standardized residuals are significantly higher for Old drivers compared to Young drivers. Driver age was also statistically significant (see Appendix A), with older drivers showing more variation in lane position. It has been researcher's experience with a simulator using a gaming steering wheel that older drivers often have more trouble adapting their steering movements to the sensitive smaller steering wheel. Researchers believe this main effect of age is due to this artifact of simulation rather than any response to the specific study.

Based on the analysis, the following conclusions can be obtained:

1. The variability (variance) of Lane Offset appears to be higher for Old drivers compared to Young drivers in general (regardless of the logo presence).
2. When the logo is not present, there does not seem to be a statistically significant difference between Sign Type = T and Sign Type =S. When the logo is present, however, the variability of Lane Offset appears to be higher for Sign Type =T than for Sign Type =S. The magnitude of this difference was very small and not practically significant

Lane Encroachment

The distribution of lane encroachment provided in Appendix A shows that 97 percent of the measurements in the data (out of a total of 9,806 measurements) have the value 0 and only 3 percent of the measurements have the value 1. A logistic regression model for repeated measures that can account for correlations in the measurements for the same driver (participant) and having Logo Presence, Sign Type, Age group, Gender, and PSL as independent variables was fitted to the lane encroachment data. Appendix A Table 13 contains the results of the analysis performed by PROC GENMOD in SAS. Only Age Group was statistically significant at $\alpha=0.05$. The coefficient of Age Group was 1.1462. In terms of odds ratio, it corresponds to 3.1462 ($= e^{1.1462}$) , which suggests that lane encroachment is more than three times as likely to occur for Old drivers than for Young drivers. The main factor of interest, Logo Presence, does not appear to significantly affect lane encroachment.

Speed Limit Compliance Analysis

For Speed Limit Compliance Analysis, researchers used the difference between the observed speed and the PSL, computed for each PSL level, as the dependent variable. A bigger difference may imply noncompliance due to driver distraction and loss of situational awareness. Appendix B contains the distributions of Speed and Speed-PSL by PSL. The distributions of Speed and Speed –PSL when PSL= 70 mph shows that there are 13 extreme outliers (very low speeds) in the data. The investigation of those outliers revealed that they are all from one driver (Subject #24) and the corresponding Lane offset measurements were also all missing for those cases. Researchers removed those 13 extreme outliers from the data. Appendix B presents the distributions of speed and Speed-PSL without those 13 outliers when PSL=70 mph.

Initially, the mixed effects ANOVA model having Logo Presence, Sign Type, Age Group, Gender, PSL and two-way interactions among them as fixed effects and Participant as a random effect was fitted to the speed difference. However, all of two-way interactions of PSL with other factors were statistically significant, which suggested the effects of those factors are different for each PSL level. Researchers fitted a separate mixed effects ANOVA model to each dataset with PSL=50 mph and PSL=70 mph, including Logo Presence, Sign Type, Age Group, Gender, and two-way interactions among them as fixed effects and Participant as a random effect. Appendix B Table 14 and Table 15 contain the analysis results when PSL=50 mph and when PSL=70 mph, respectively.

The results for the 50 mph speed limit can be seen in Appendix B Table 14. The analysis showed that many of the interaction effects are statistically significant but of questionable practical significance. The differences among conditions are nearly all less than 1 mph. The largest difference was that older drivers tended to drive slightly more than 1 mph more over the PSL than younger drivers did. This was an overall effect and not dependent on any sign manipulation.

Appendix B Table 15 shows that the interaction effects, Logo Presence*Sign Type and Sign Type*Age Group are statistically significant at $\alpha=0.05$. The magnitude of the differences across groups is less than 1 mph which is of questionable practical significance. The predicted values for speed difference for each level of factors in the model in Appendix B Table 15, however, are all negative, which suggests that the speed was in compliance most of times when the PSL is 70 mph.

EYE TRACKING DATA

Signs with logos may change the way drivers distribute their visual glances either by demanding overly long glances or by demanding glances at closer distances than signs without logos.

The National Highway Traffic Safety Administration has issued guidelines to reduce driver distraction due to in-vehicle devices (*6*). One of the acceptance criteria for an in-vehicle task (such as using a navigation system) is a mean eyes off road time of 2 seconds or less per glance. They cite data from Rockwell showing driving performance degradation when eye glances exceed 2 seconds (*7*). For this reason, researchers analyzed the eye tracking data to identify instances of eye glances greater than 2 seconds as an indication of distraction due to CMSs.

A second measure of distraction derived from the eye glance data was last glance distance. Last look distance has been used as a measure of sign legibility difficulty (*8*). Signs that are hard to read, such as complex symbol signs, generally show shorter last look distances (i.e., drivers are closer to the sign when they last look at them). While not directly a measure of distraction, last look distance is a measure of sign visual demand.

Eyes Off Road Time Greater than 2 Seconds

This analysis tested whether the glances at the sponsored logo CMS suggest a possible decrease in safety. The researchers examined the distribution of individual eye glance durations and counted how many were greater or equal to 2 seconds in duration. In total, 604 eye glances exceeded 2 seconds. The results are presented in detail in Appendix C. The analysis of variance to test the effect of logo presence on the number of glances greater than 2 seconds is found in Table 16 and shows that the main effect of log presence was significant but none of the two-way interactions were significant. A second model, without the interaction terms included, was fitted and results show that sign type and logo presence are each statistically significant (Appendix C Table 17). The size of these differences is quite small; the average number of glances greater than 2 seconds for signs without logos was 1.059 while for signs with logos the average was just 1.107. Age and gender variables were not statistically significant in any of the analyses.

Last Glance Distance

The objective of this analysis was to test whether the sponsored logo CMS continues to attract the driver's attention beyond the traditional last look distance. The dependent variable is Last Glance Distance from Sign (ft). Because researchers were mainly interested in determining whether the presence of a sponsored logo (regardless of whether logo changes in phasing) significantly impact the dependent variable, the Logo Presence variable defined previously was used again:

Logo Presence = 1 when Logo_Count=1 or 2, = 0 when Logo_Count=0.

The mixed effects ANOVA model having Logo Presence, Sign Type, Age Group, Gender, and two-way interactions among them as fixed effects, and Participant as a random effect was employed to test the effect of Logo Presence on Last Glance Distance from Sign (ft). The analysis showed that none of the two-way interaction effects were statistically significant at the 5 percent significance level (Appendix C, Table 18).

To see whether the removal of the two-way interaction effects from the model will change the results, the two-way interaction effects were removed from the model, and the data were refitted with the model without the interaction effects. The predicted Last Glance Distance from Sign (ft) is significantly lower when the logo is present compared to when the logo is not present, which suggests that the sponsored logo CMS continues to attract the driver's attention beyond a last look distance without a logo (Appendix C, Table 19). Across all both age groups and sign types, when a logo was present on the sign the distance of the last look averaged 78 ft compared to 114 ft when a logo was not present. Sign Type=S leads to lower predicted Last Glance Distance from Sign (86 ft) compared to Sign Type=T (106 ft), and Old drivers (80 ft) are also associated with lower predicted Last Glance Distance from Sign (ft) compared to Young drivers (112 ft). These results indicate that signs with more content, whether words on a safety message or a sponsor logo, elicit later last looks than simpler signs.

SUMMARY

The simulator study tested signs with and without sponsor logos for both travel time signs and safety message signs. Driver distraction was operationally defined using several variables:

- Recall for message content.
- Lane position variability.
- Lane encroachment.
- Compliance with speed limit.
- Glances greater than 2 seconds.
- Last look distance.

No effect of logo presence was found for recall of the message content. This suggests that drivers were able to completely read and comprehend the safety and travel time messages when a logo was present.

The driving simulator measures of driving performance showed some small differences in lane position variability and speed limit compliance due to sign type and logo presence. These differences were less than 0.01 m and 1 mph, respectively, and are of questionable practical significance.

The eye glance data showed a very small difference in the number of glances exceeding 2 seconds for signs with logos. Given the manual nature of the eye tracked coding for glance duration, the size of this difference could be considered within measurement error. The finding that signs with logos present produce shorter last look distances may have been due to the relatively low resolution of the logos used in the simulator (compared to full size logos that would be used on the signs). This finding will be further explored during the closed-course testing. If nothing else, it suggests that the design of each logos may also need to be considered so that poorly designed logos are not used because they attract driver attention closer to the sign. The fact that the safety message signs also produced shorter last look distances, regardless of logo presence, suggest that this finding is more about the amount of information on the sign. The safety messages tested were quite wordy and exceeded conventional recommendations about the maximum units of information presented on changeable message signs (*9*).

Overall the results of the driving simulator study showed no obvious increase in driver distraction due to the presence of sponsor logos on changeable message signs.

CHAPTER 5. EVALUATION OF RUMBLE DEVICES

EVALUATION OF RUMBLE DEVICES

Rumble strips have proven to be a cost effective safety countermeasure on all categories of roadways. Unfortunately, rumble strips cannot be milled into many seal coat roadways due to insufficient roadway structure or limited shoulder width. Several alternative systems have been tried on seal coat roadways to provide similar sound and vibration alerts to drivers. In this task, researchers evaluated the performance (sound and vibration produced) of several rumble devices.

Study Design

The study design provides an overview of the elements associated with the data collection. The study design describes the equipment used, the data collection locations and specific treatments evaluated, and how the researchers collected the data.

Data Collection Equipment

The two main metrics for evaluating the effectiveness of the various rumble devices are sound level measured in decibels (dB) and vibration measured in gravitational acceleration (g). To capture sound data, the research team used an integrating sound level meter. This device was attached to a laptop computer and recorded sound pressure levels as the researchers drove through the test areas. Figure 5 provides an image of the sound level meter inside the car.

To capture vibration data, the research team used an accelerometer. The accelerometer recorded the change in vertical acceleration that was caused by the rumble devices. The accelerometer was connected to a laptop so that data could be logged and saved as the researchers drove through the test areas. Figure 6 provides an image of the accelerometer inside the car. The accelerometer was mounted inside the silver box that was placed between the seat and the floor of the vehicle. The driver's seat was then lowered onto the box so that the vibrations that transferred from the floor of the vehicle to the seat would also be transferred to the accelerometer. A camera system was also mounted on the side of the vehicle to capture the interaction of the tire with the rumble device (Figure 7).

Three separate vehicles were used for the data collection, a 2012 Ford F150 passenger truck, a 2014 Ford Fusion mid-size car, and a 2012 Ford Fusion mid-size car. The tires on each vehicle were inflated to the recommended levels. The truck was used at all data collection locations. The 2014 car was used at the Atlanta District locations and the 2012 car was used at the Austin District locations. The vehicles used can be seen in Figure 8.

Figure 5. Sound Level Meter inside Vehicle.

Figure 6. Accelerometer Monitoring Vibration of Drivers Seat.

Figure 7. Exterior Camera Setup (Left), Screenshot of Video (Right).

Figure 8. Test Vehicles (2012 Truck Left, 2014 Car Middle, 2012 Car Right).

Data Collection Locations and Treatments

The data collection took place in TxDOT's Atlanta and Austin Districts. The Atlanta District had numerous locations of profile pavement markings, rumble strips, and rumble bars of various designs. The Austin District had several new installations of profiled pavement markings on various road surfaces and one older installation of a profiled marking. The research team evaluated the following types of treatments:

- Shoulder rumble strips (SRS), the rumble strip is outside of the edge line.
- Edge line rumble strips (ELRS), the rumble strip is under the edge line, also referred to as a rumble stripe.
- Center line rumble strips (CLRS), the rumble stripe is under or between the center line(s).
- Inverted profile pavement markings with audible humps.
- Profile pavement markings.
- Raised rumble strips, also referred to as rumble bars.

Figure 9 through Figure 15 present examples of the treatments evaluated.

Figure 9. 6-In. Inverted Profile with Audible Markings and SRS.

Figure 10. 4-In. Inverted Profile with Audible (Left) and 4-In. Profile Marking (Right).

Figure 11. 4-In. Profile Markings.

Figure 12. CLRS with Rumble Bars (Left), ELRS with Rumble Bars (Right).

Figure 13. 4-In. Inverted Profile with Audible with Center Line Rumble Bars.

Figure 14. 4-In. Profile Markings, Square Design (Left), Circular Design (Right).

Figure 15. CLRS (Left), Shoulder Rumble Bars (Right).

Table 8 lists the test section locations and associated treatment types. Appendix D provides a more detailed description of each treatment. The more detailed descriptions include height, width, length, and spacing information for each treatment type.

Table 8. Test Section Locations and Treatments.

District	Location[1]	Road Surface	Treatment Type(s)
Atlanta	US 79 West of Carthage	Seal Coat	Standard milled SRS and CLRS, Inverted profile with audible edge line
Atlanta	US 79 East of DeBerry	New Asphalt	Standard milled ELRS and CLRS, rumble bars on center and edge lines
Atlanta	US 80 East of Marshal	Seal Coat	Rumble bars on center line and shoulder. Inverted profile with audible center line
Atlanta	US 59 South of Atlanta	Portland Cement Concrete	Standard milled SRS, Inverted profile with audible edge line
Atlanta	SH 43 South of Atlanta	Seal Coat	Profile markings and rumble bars on center line
Atlanta	FM 2328 Between US 59 and SH 43	Seal Coat	Rumble bars on center line
Atlanta	FM 3129 North of Atlanta	Seal Coat	Inverted profile with audible and rumble bars on center line, Inverted profile with audible edge line
Austin	US 290 by Manor	New Asphalt	Profile markings on left and right edge lines
Austin	US 290 by Manor	Seal Coat	Profile markings on left and right edge lines
Austin	FM 12 North of Dripping Springs	Old Asphalt	Profile markings on center line
Austin	FM 12 South of Dripping Springs	New Asphalt	Profile markings on center and edge lines

[1]U.S. Route (US), State Highway (SH), Farm-to-Market (FM)

Data Collection

All data were collected during dry conditions. The data collection team collected three types of data: 1) interior sound, 2) interior vibration, and 3) exterior sound. Interior sound and vibration data were collected simultaneously at all study locations. Exterior sound data were collected at select sites in the Atlanta District after the collection of the interior data.

Interior sound data were collected adjacent to the drivers head (Figure 5). The vibration data were collected at the base of the driver's seat (Figure 6). The exterior sound data were collected using the same sound meter from the interior sound data collection. The sound meter was removed from the vehicle and placed on a tripod 50 ft away from the edge line pavement marking. The sound meter was placed approximately 5 ft above the height of the road surface. The exterior sound data collection was at a stationary location adjacent to the roadway to evaluate the noise pollution created by the audible devices.

Data were collected while the vehicle encountered the rumble device and also in an ambient condition where the vehicle was not on the device (vehicle was centered in the travel lane). The data collection test areas were on tangent sections of roadway to make it easier for the driver to maintain position on the rumble devices for a sufficient length. The ambient condition data were evaluated in the same section of road as the rumble devices. The research team drove through the test sections at two different speeds (55 mph and 70 mph) if the conditions allowed. The research team used two different vehicle types (car and truck) for data collection. A summary of the different factors considered during the data collection are listed below:

- Vehicle – Car, Passenger Truck.
- Speed – 55 mph, 70 mph.
- Position of Rumble Device on Roadway – Edge line, Center line.
- Road Surface – Asphalt, PCC, Sealcoat.
- Condition – Ambient, On device.
- Measurement Locations – In-vehicle, Adjacent to Roadway.
- Exterior Noise Distance from Road – 50 ft.

While at the data collection sites, the research team evaluated the condition of the rumble devices and took measurements of the devices physical properties. The research team measured the height/depth, length, width, and spacing of the devices. The research team also took notes on the road surface type and the condition of the road surface.

Data Summary

The sound and vibration data were summarized to determine the effectiveness of the various rumble devices. The data were summarized to determine the sound (in and outside vehicle) and vibration levels for the various rumble devices and the ambient conditions when not on the rumble device. Appendix E provides a detailed summary of the data collected.

The following sections describe the data for the interior sound, interior vibration, and exterior sound separately. The data presented show the difference in sound and vibration of the rumble devices compared to the ambient road noise that is generated while traveling in the lane adjacent the rumble devices. The change in interior sound and vibration from the ambient condition to the condition when the rumble system is encountered is what provides the alerting benefit to drivers. The change in exterior sound from the ambient condition to the condition when the rumble system is encountered is what provides additional noise pollution to the surrounding area.

Interior Sound

Figure 16 through Figure 26 present the interior sound data. The data presented are the average value along the test section. Each individual figure represents a different study site. The data, ambient or on the rumble device, are for the indicated vehicles at the indicated speeds. Each site has the in lane ambient condition represented in blue. The data for the rumble devices are provided in various colors depending on the treatment location/type. The data for the rumble device are indicated at the top of the associated ambient condition to represent the increase in sound produced by the device. A large colored band for the treatment represents a large increase in the sound produced inside the vehicle. Table 9 indicates the ambient interior sound levels and the increase in sound provided by each type of rumble device. The sound increase was averaged for treatments that were on more than one test area. The specific treatments at each site can be found in Appendix D.

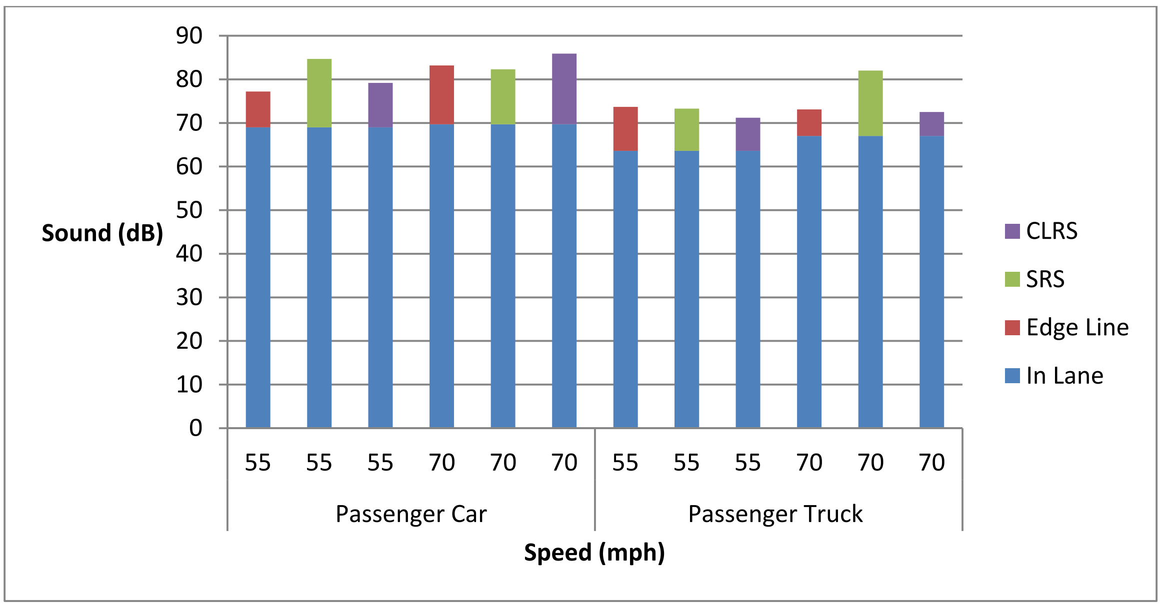


Figure 16. Atlanta District US 79 Carthage Interior Sound.

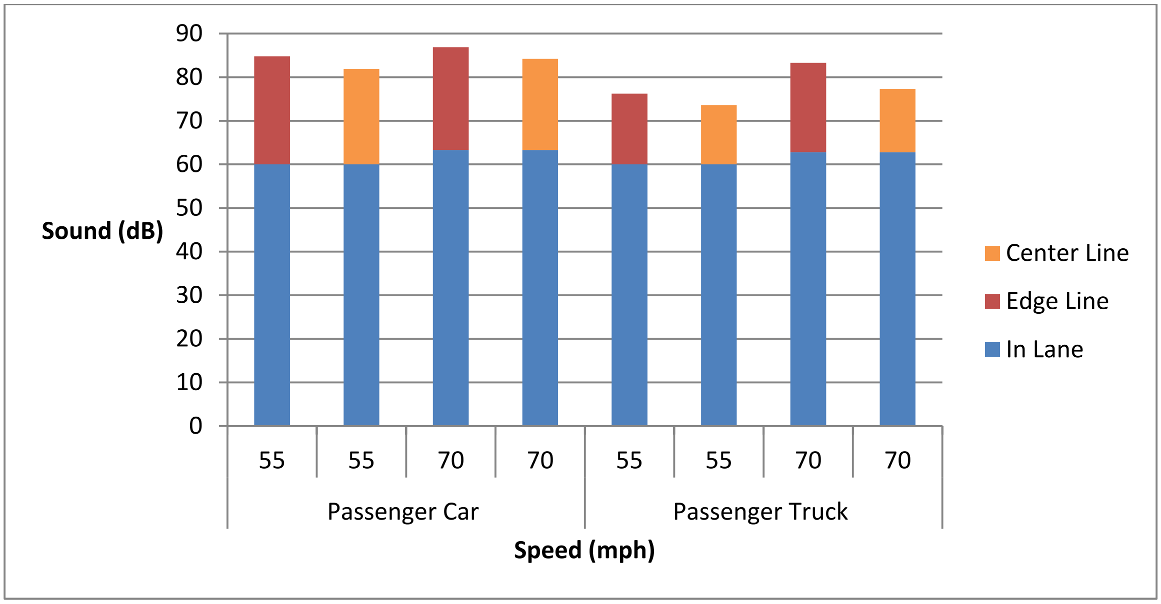


Figure 17. Atlanta District US 79 DeBerry Interior Sound.

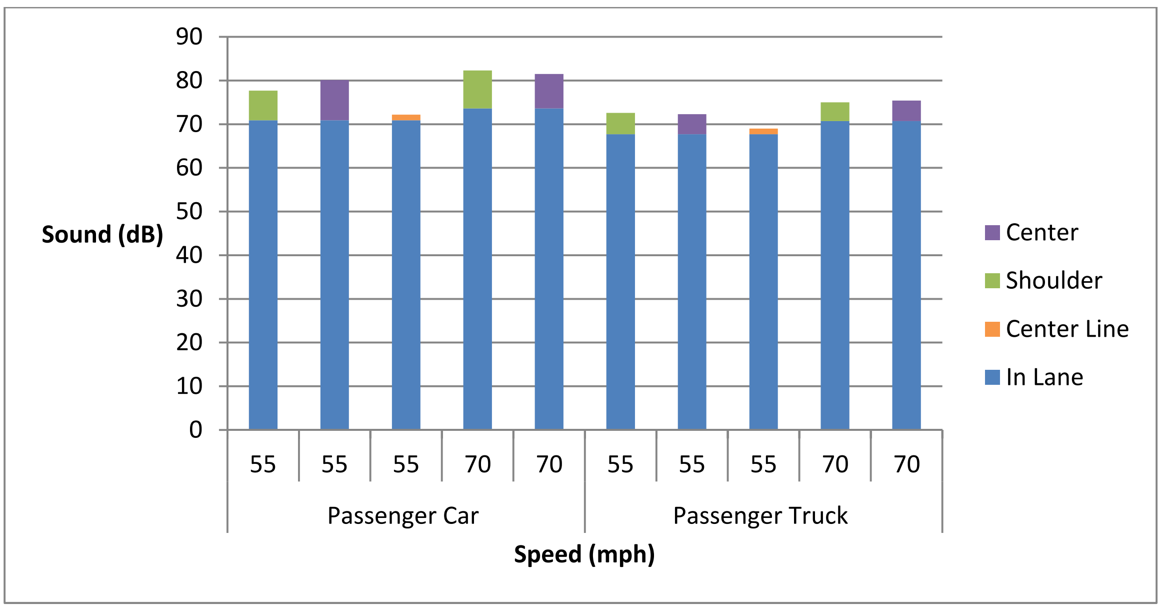


Figure 18. Atlanta District US 80 Interior Sound.

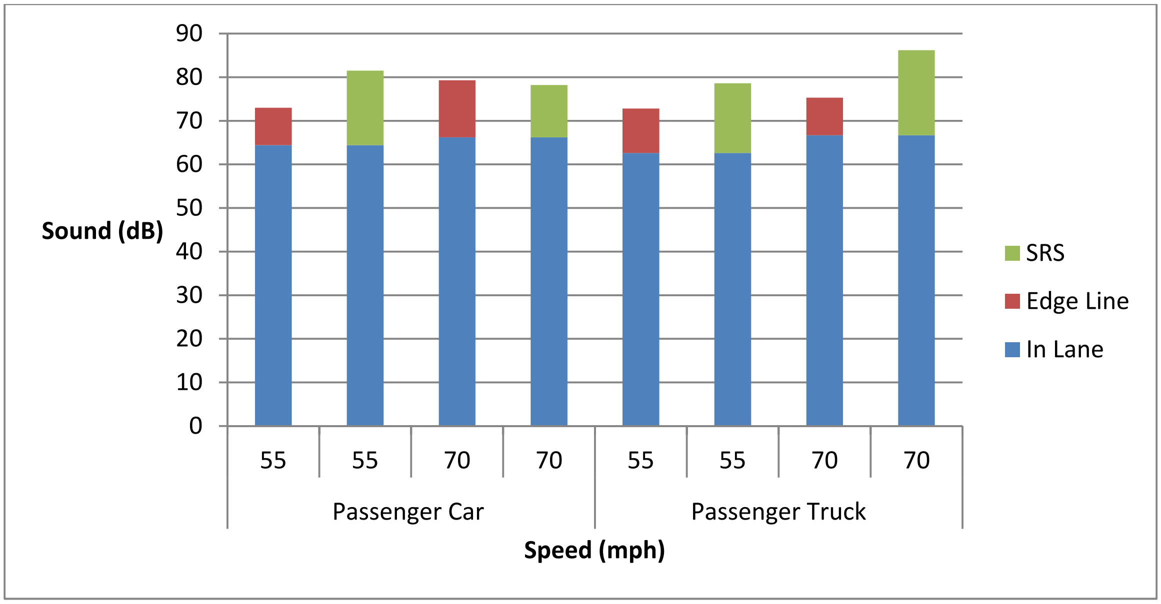


Figure 19. Atlanta District US 59 Interior Sound.

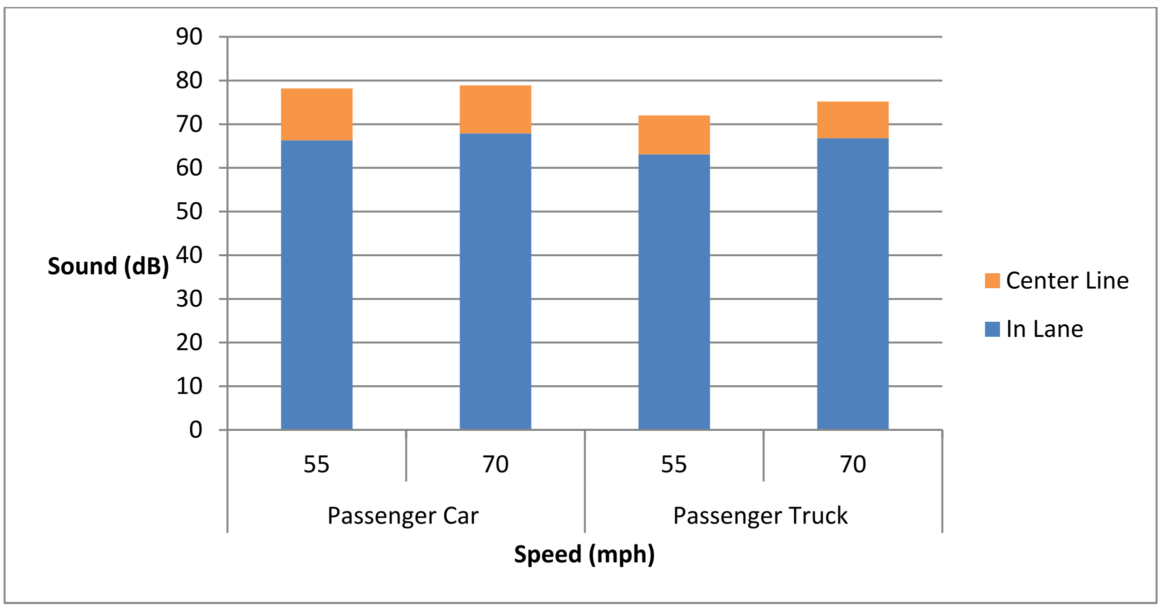


Figure 20. Atlanta District SH 43 Interior Sound.

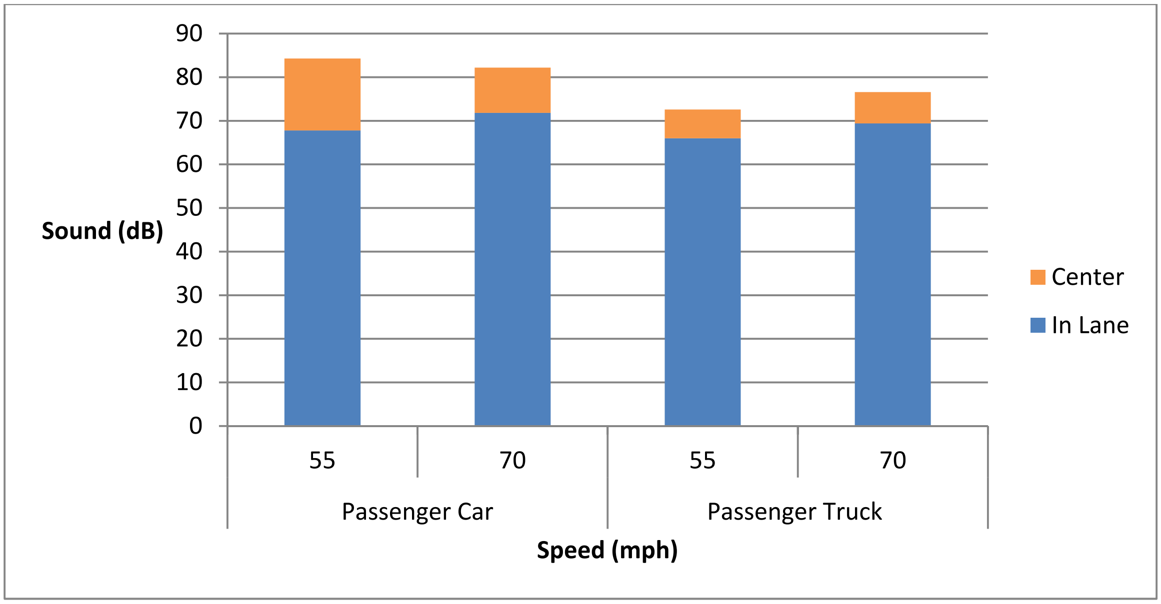


Figure 21. Atlanta District FM 2328 Interior Sound.

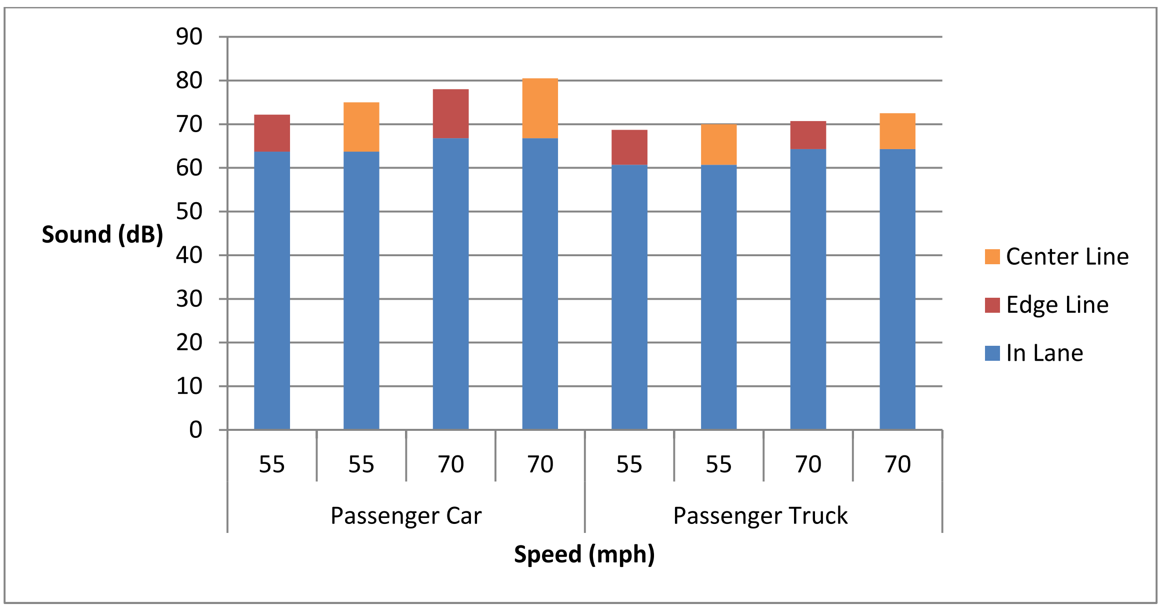


Figure 22. Atlanta District FM 3129 Interior Sound.

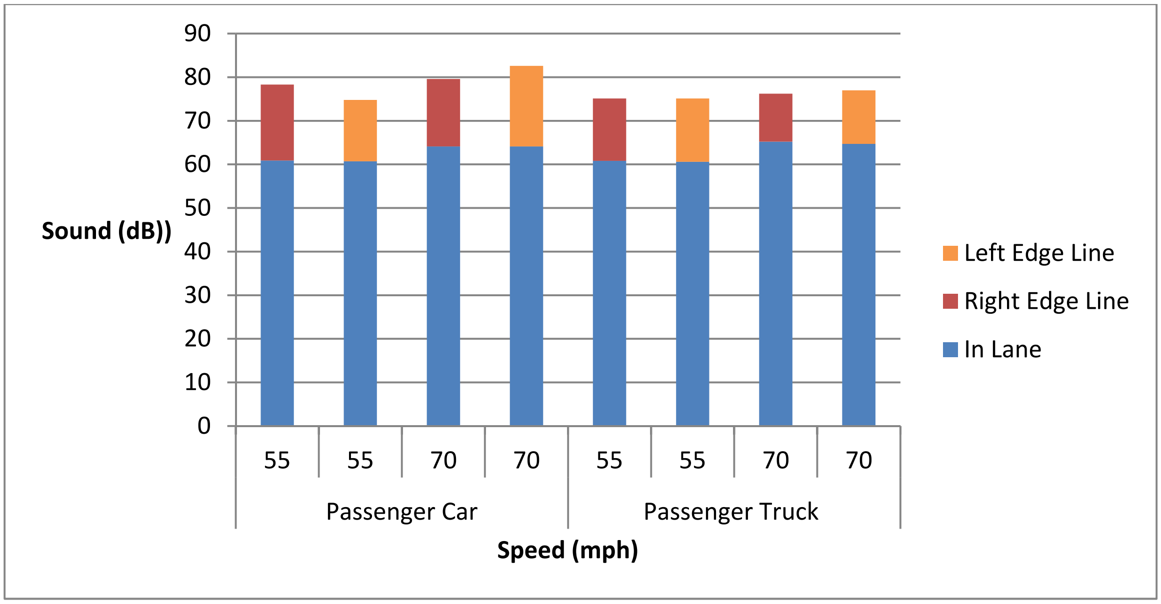


Figure 23. Austin District US 290 Asphalt Interior Sound.

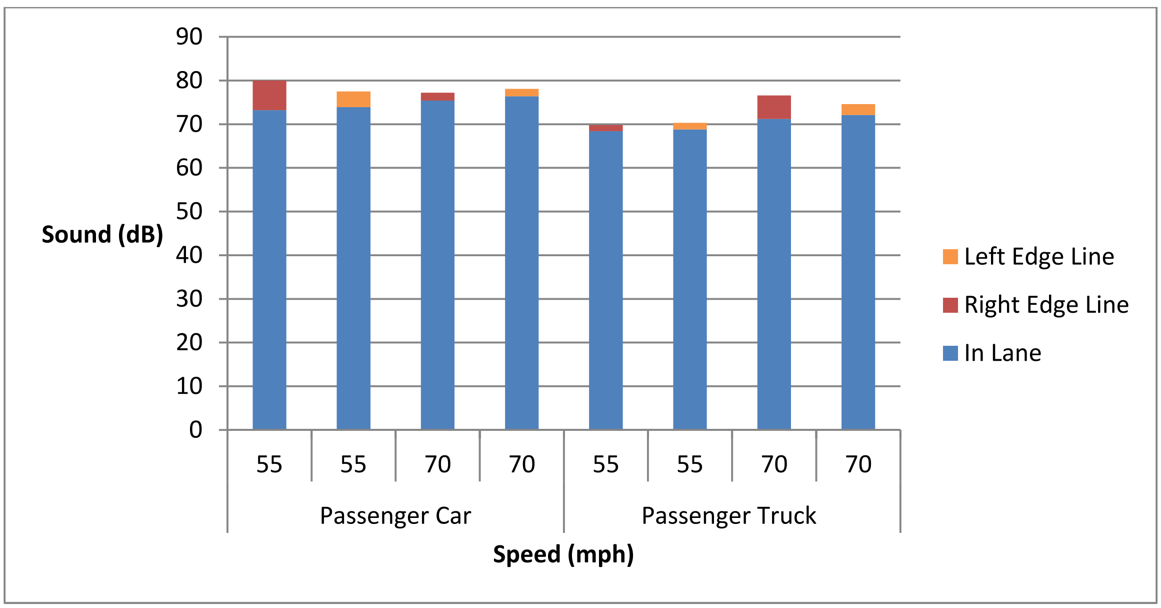


Figure 24. Austin District US 290 Seal Coat Interior Sound.

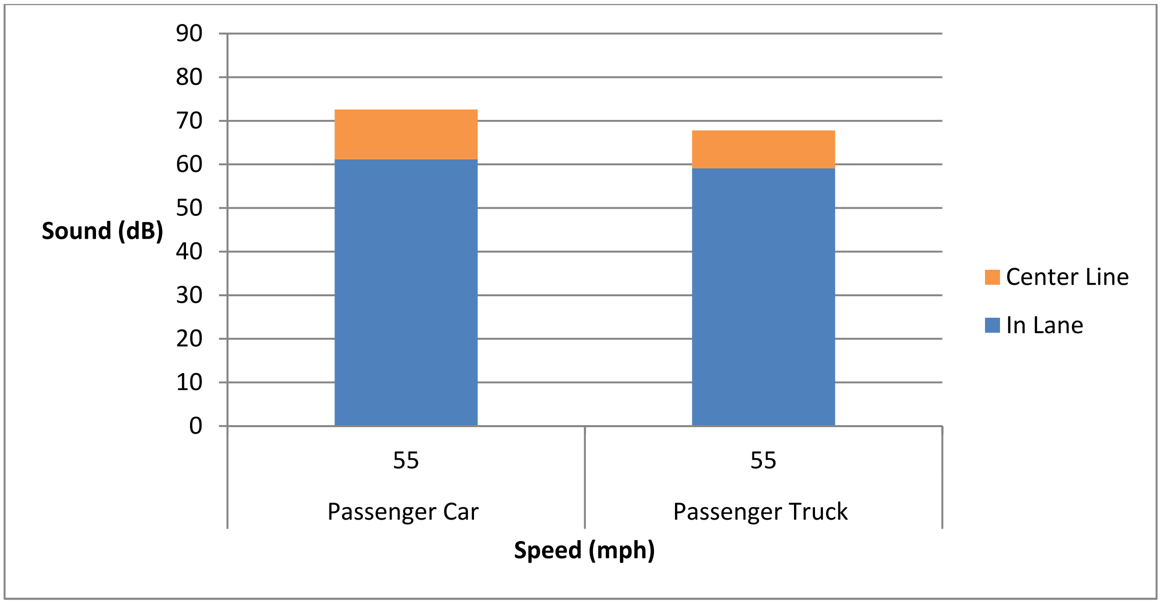


Figure 25. Austin District FM 12 North Interior Sound.

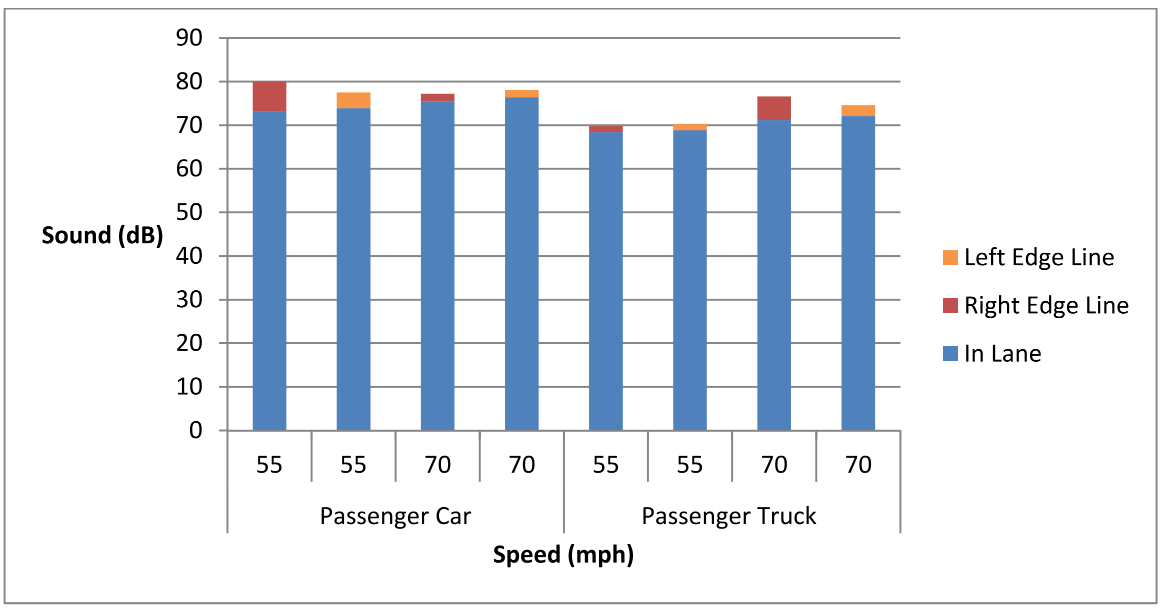


Figure 26. Austin District FM 12 South Interior Sound.

Table 9. Summary of Interior Sound Data.

	Treatment Type	Passenger Car		Passenger Truck	
		55 mph	70 mph	55 mph	70 mph
Average Ambient In Lane	Asphalt	60.4	63.9	59.3	63.5
	PCC	64.4	66.2	62.6	66.7
	Seal Coat	69.3	71.7	65.5	68.8
Average Increase Over Ambient	SRS	16.4	12.3	12.9	17.3
	CLRS	10.2	16.2	7.6	5.5
	4" Profile (Center Line, Square Shape)	11.4	-	8.7	-
	4" Profile (Center Line/Left Edge, Circular Shape)	10.2	11.0	10.1	10.7
	4" Inverted Profile w/ Audible (Center Line)	1.3	-	1.3	-
	4" Profile (Right Edge, Circular Shape)	13.4	9.9	8.8	9.8
	4" Inverted Profile w/ Audible (Edge Line)	8.5	11.2	8.0	6.4
	6" Inverted Profile w/ Audible (Edge Line)	8.4	13.3	10.2	7.3
	48" Spaced Rumble Bars (Center Line)	16.5	10.4	6.6	7.2
	60" Spaced Rumble Bars (Center Line)	9.2	7.9	4.6	4.7
	55" Spaced Rumble Bars (Shoulder)	6.8	8.7	4.9	4.3
	4" Profile (Center Line) + 30" Spaced Rumble Bars	11.9	11.0	8.9	8.4
	4" Inverted Profile w/ Audible (Center Line) + 60" Spaced Rumble Bars	11.3	13.7	9.3	8.2
	ELRS + 60" Spaced Rumble Bars	24.8	23.6	16.2	20.5
	CLRS + 48" Spaced Rumble Bars	21.9	20.9	13.6	14.5

-Shaded cells indicate no data collected.
All values in dB.

Interior Vibration

Figure 27 through Figure 37 present the interior vibration data. The data presented are the average value along the test section. Each individual figure represents a different study site. The data, ambient or on the rumble device, are for the indicated vehicles at the indicated speeds. Each site has the in lane ambient condition represented in blue. The data for the rumble devices are provided in various colors depending on the treatment location/type. The data for the rumble device are indicated at the top of the associated ambient condition to represent the increase in vibration produced by the device. A large colored band for the treatment represents a large increase in the vibration produced inside the vehicle. Table 10 indicates the ambient interior vibration levels and the increase in vibration provided by each type of rumble device. The vibration increase was averaged for treatments that were on more than one test area. The specific treatments at each site can be found in Appendix D.

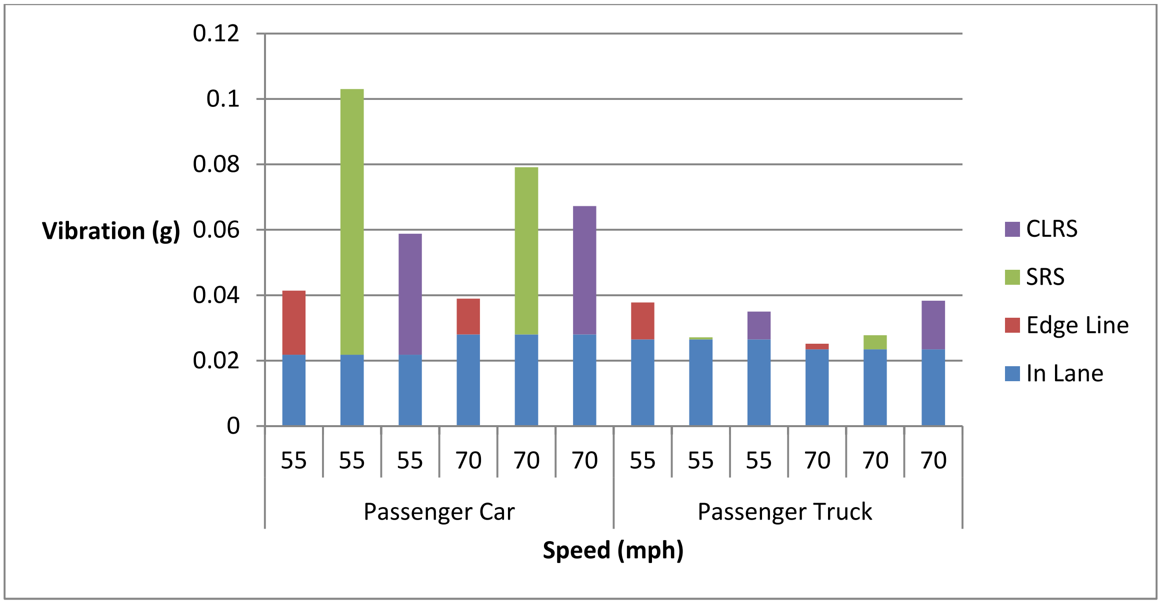


Figure 27. Atlanta District US 79 Carthage Vibration.

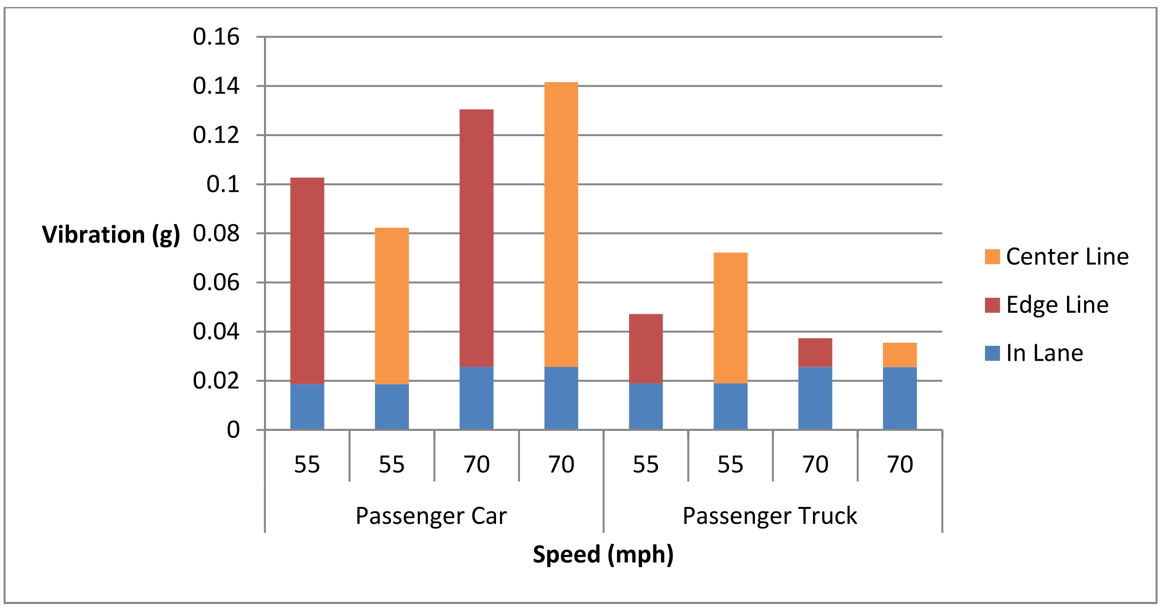


Figure 28. Atlanta District US 79 DeBerry Vibration.

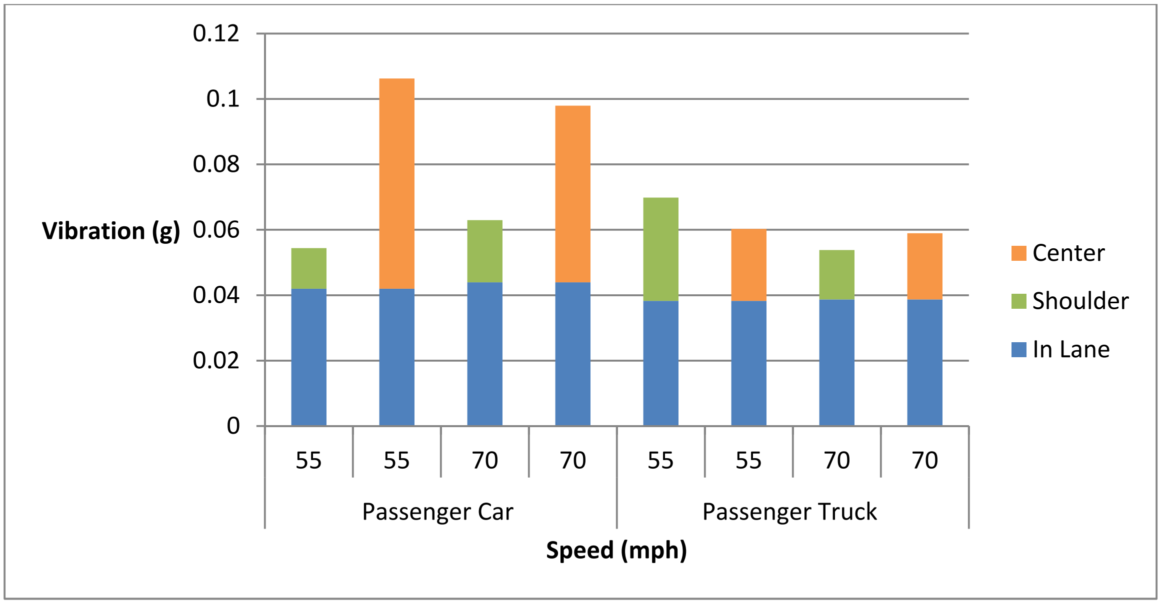


Figure 29. Atlanta District US 80 Vibration.

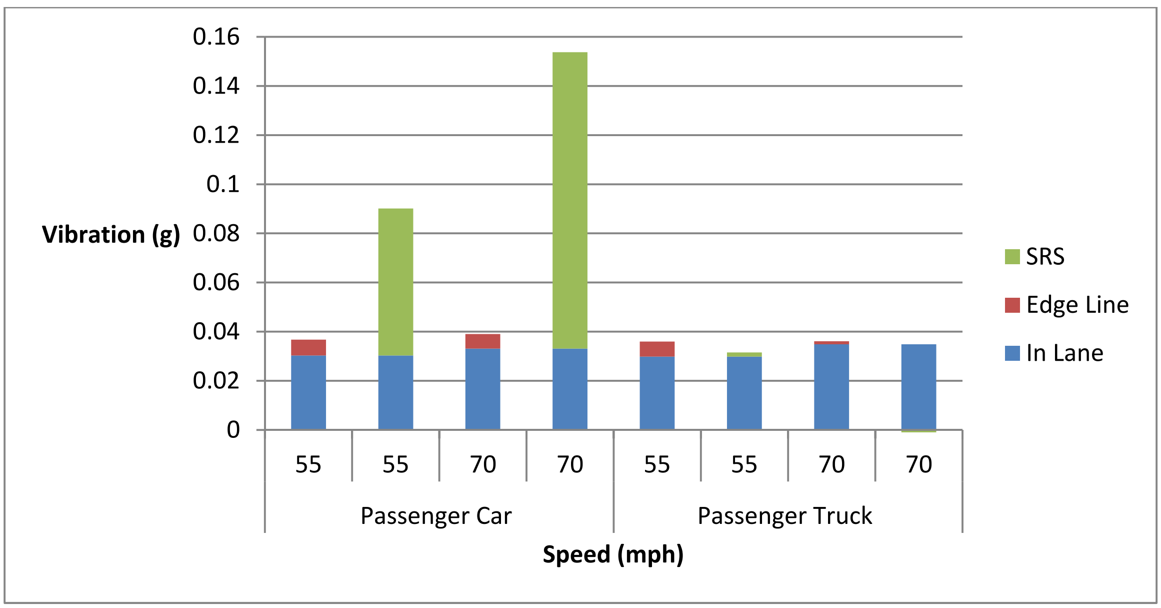


Figure 30. Atlanta District US 59 Vibration.

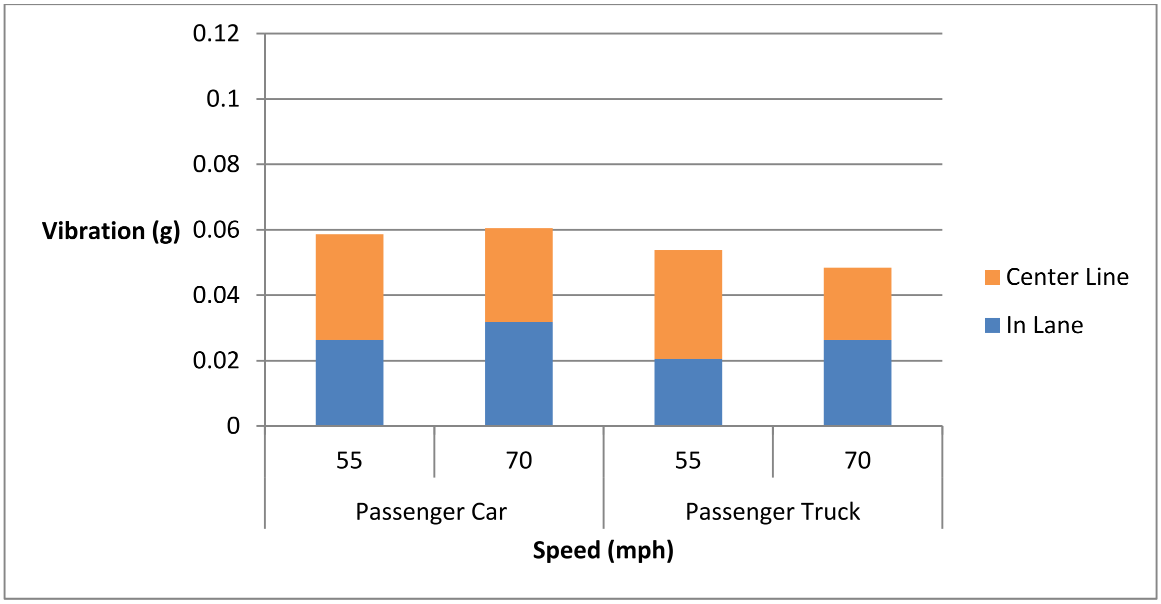


Figure 31. Atlanta District SH 43 Vibration.

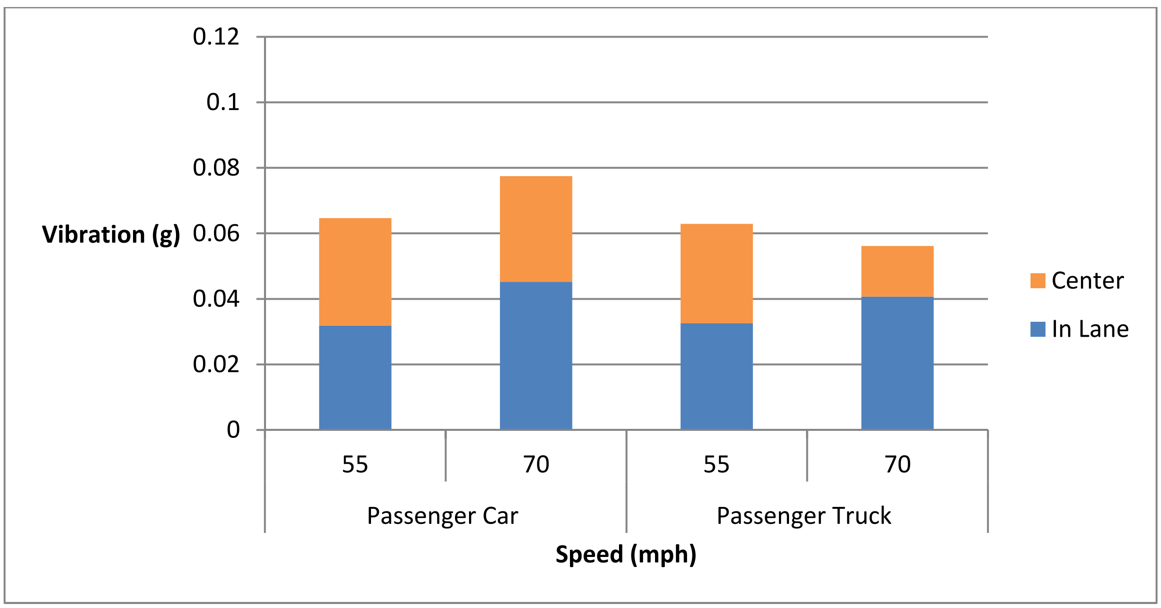


Figure 32. Atlanta District FM 2328 Vibration.

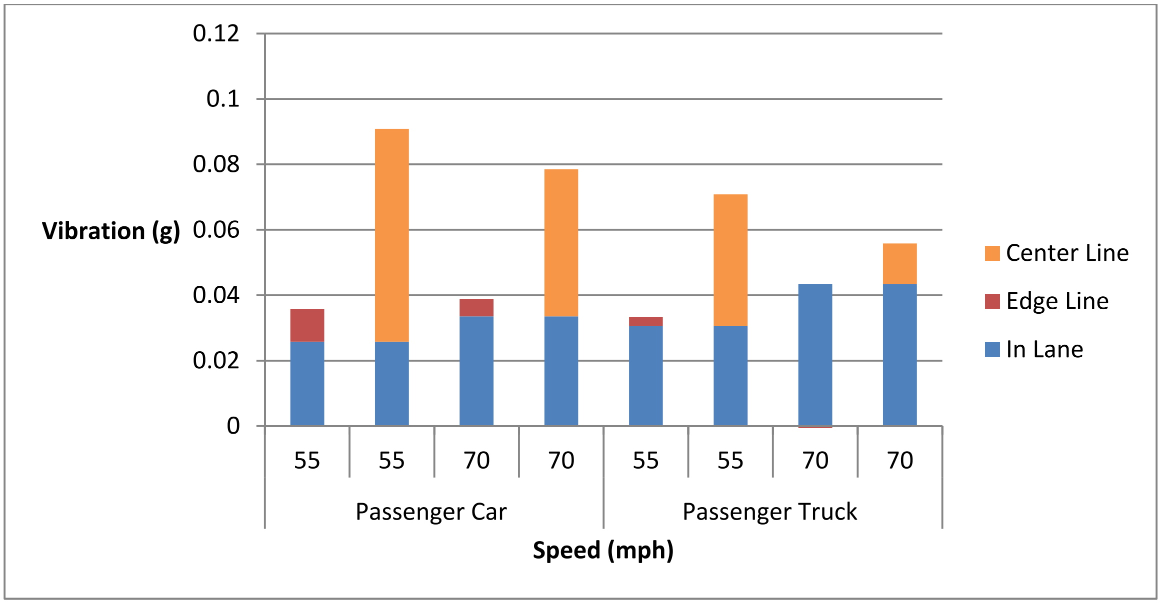


Figure 33. Atlanta District FM 3129 Vibration.

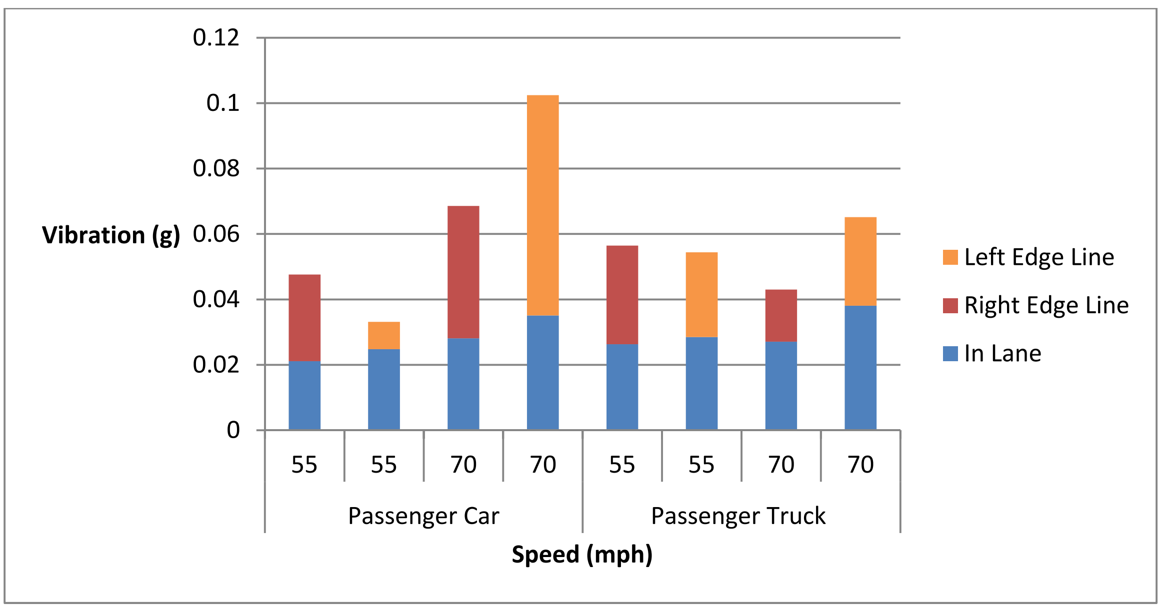


Figure 34. Austin District US 290 Asphalt Vibration.

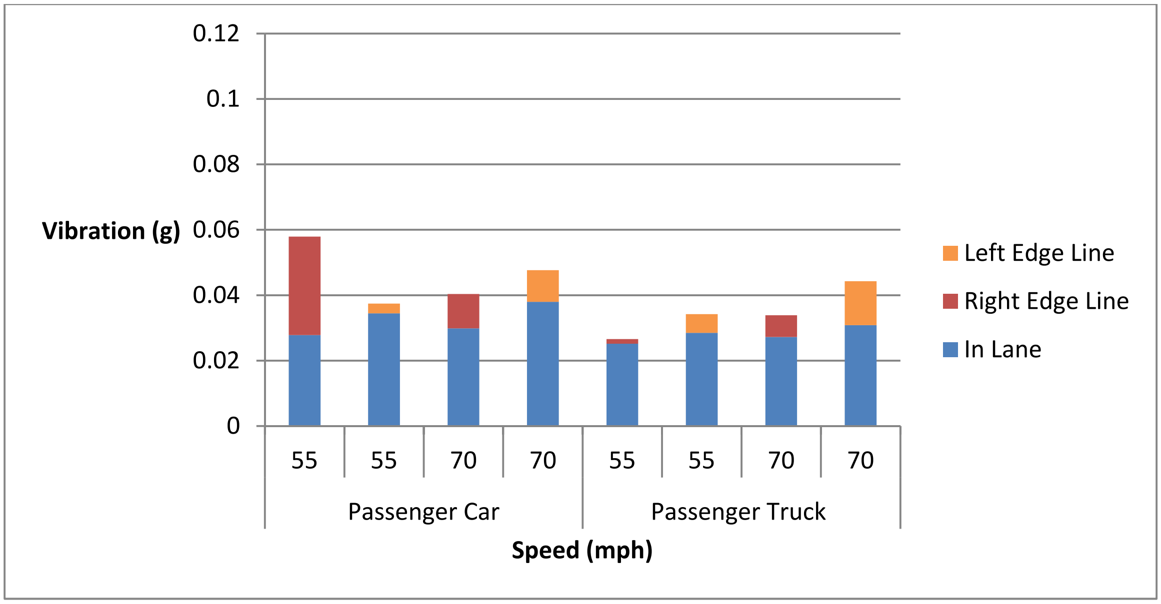


Figure 35. Austin District US 290 Seal Coat Vibration.

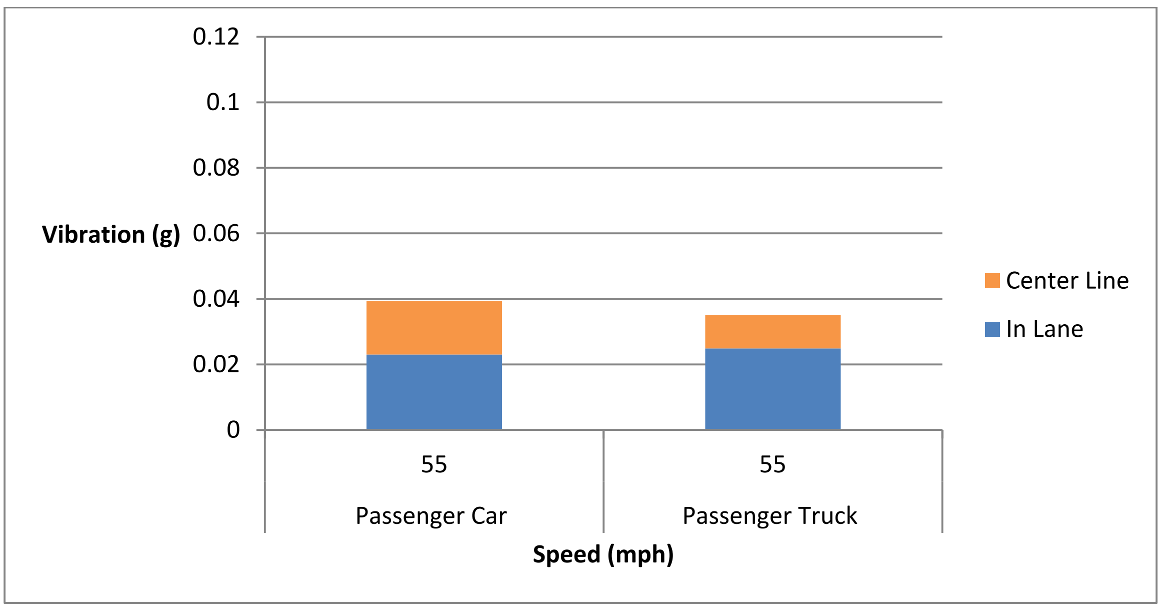


Figure 36. Austin District FM 12 North Vibration.

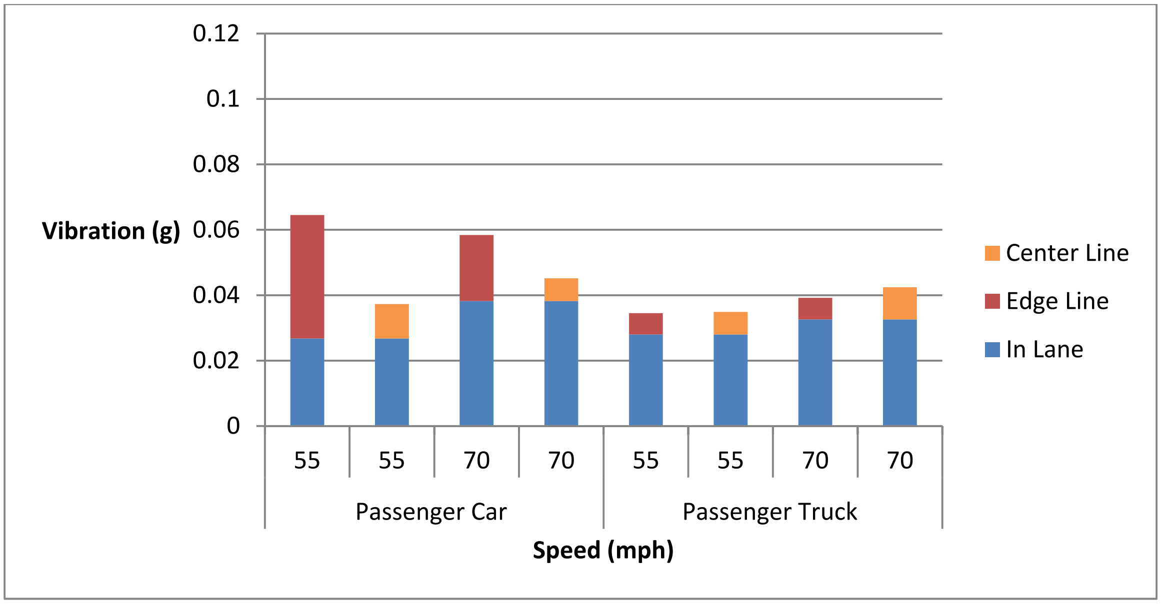


Figure 37. Austin District FM 12 South Vibration.

Table 10. Summary of Interior Vibration Data.

	Treatment Type	Passenger Car		Passenger Truck	
		55 mph	70 mph	55 mph	70 mph
Average Ambient In Lane	Asphalt	0.0229	0.0318	0.0253	0.0308
	PCC	0.0303	0.0331	0.0298	0.0348
	Seal Coat	0.0300	0.0358	0.0289	0.0330
Average Increase Over Ambient	SRS	0.0706	0.0859	0.0012	0.0043
	CLRS	0.0370	0.0393	0.0085	0.0149
	4" Profiled (Center Line, Square Shape)	0.0164	-	0.0102	-
	4" Profiled (Center Line/Left Edge, Circular Shape)	0.0073	0.0280	0.0128	0.0168
	4" Profiled (Right Edge, Circular Shape)	0.0315	0.0237	0.0127	0.0097
	4" Inverted Profile w/ Audible (Edge Line)	0.0100	0.0054	0.0027	0.0000
	6" Inverted Profile w/ Audible (Edge Line)	0.0130	0.0085	0.0087	0.0015
	48" Spaced Rumble Bars (Center Line)	0.0329	0.0323	0.0303	0.0155
	60" Spaced Rumble Bars (Center Line)	0.0643	0.0540	0.0220	0.0203
	55" Spaced Rumble Bars (Shoulder)	0.0124	0.0190	0.0316	0.0151
	4" Profiled Center Line + 30" Spaced Rumble Bars	0.0323	0.0287	0.0333	0.0222
	4" Inverted Profile w/ Audible (Center Line) + 60" Spaced Rumble Bars	0.0651	0.0450	0.0403	0.0124
	ELRS + 60" Spaced Rumble Bars	0.0841	0.1049	0.0282	0.0118
	CLRS + 48" Spaced Rumble Bars	0.0637	0.1159	0.0533	0.0099

-Shaded cells indicate no data collected.
All values in g-force.

Exterior Sound

Figure 38 through Figure 44 present the exterior sound data. The data presented are the maximum value along the test section. Each individual figure represents a different study site. The data, ambient or on the rumble device, are for the indicated vehicles at the indicated speeds. Each site has the in lane ambient condition represented in blue. The data for the rumble devices are provided in various colors depending on the treatment location/type. The data for the rumble device are indicated at the top of the associated ambient condition to represent the increase in exterior sound produced by the device. A large colored band for the treatment represents a large increase in the sound produced outside the vehicle. Table 11 indicates the ambient exterior sound levels and the increase in sound provided by each type of rumble device. The sound increase was averaged for treatments that were on more than one test area. The specific treatments at each site can be found in Appendix D.

The researchers also collected exterior sound data on other vehicles as they drove through the test areas. Of particular interest were large vehicles such as 18-wheelers. These types of vehicles typically produce more noise while driving in the lane than typical passenger vehicles. The researchers wanted to compare the in-lane ambient condition exterior noise for the large vehicles versus the test vehicles while on the rumble devices. The average exterior noise for the 18-wheeler vehicles in the test areas was 82.9 dB. This was the average of all the 18-wheeler data that were collected on each road surface. There was not a substantial difference in the exterior sound for the 18-wheelers on the different road surfaces.

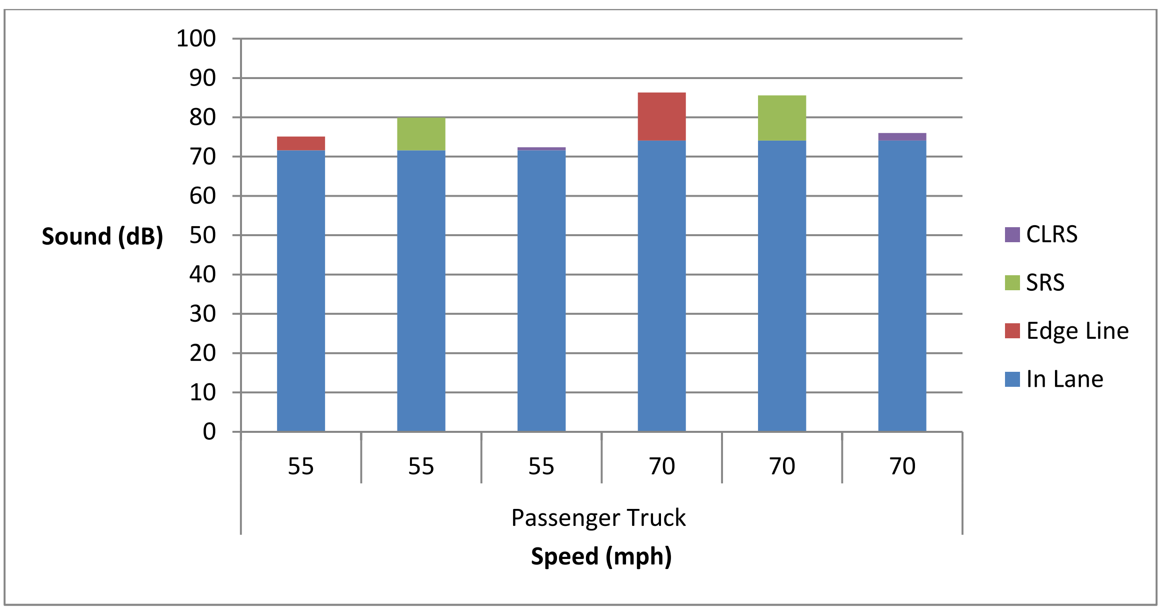


Figure 38. Atlanta District US 79 Carthage Exterior Sound.

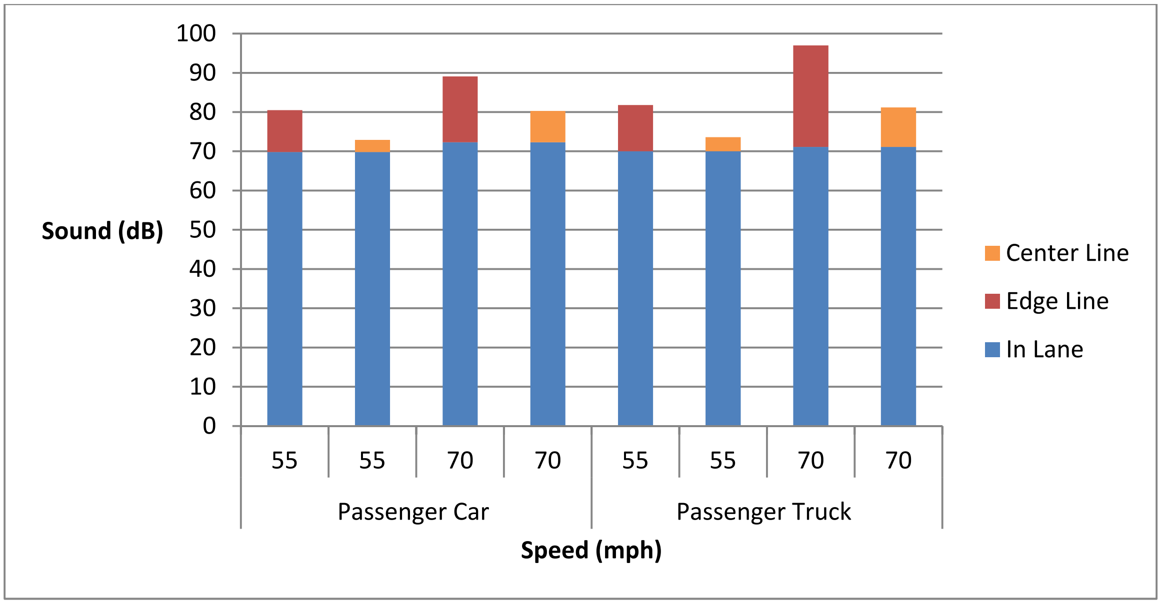


Figure 39. Atlanta District US 79 DeBerry Exterior Sound.

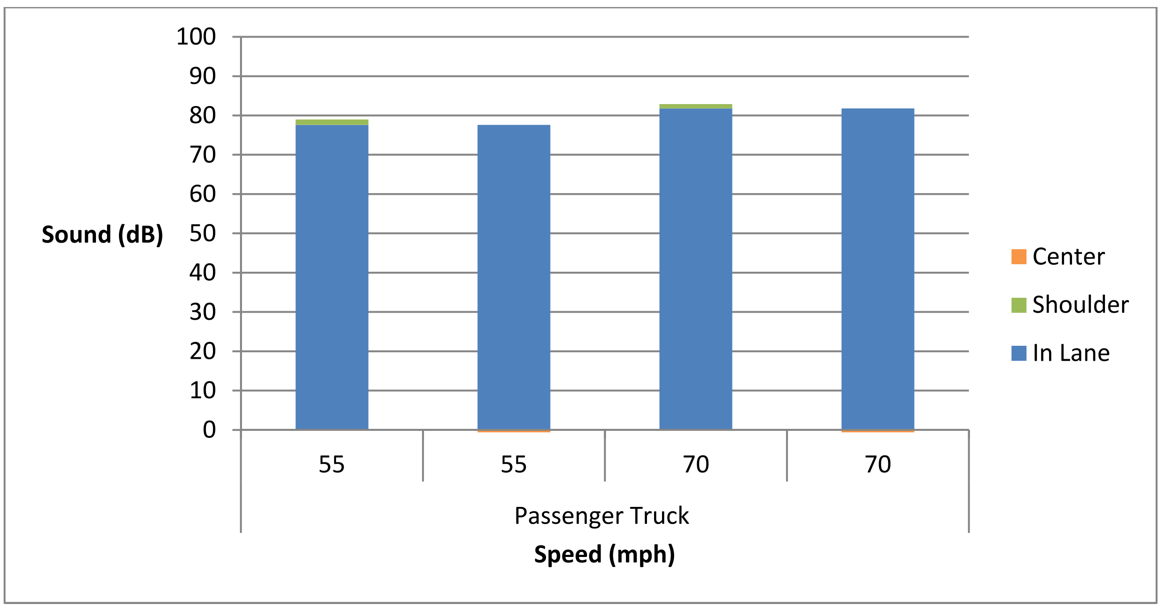


Figure 40. Atlanta District US 80 Exterior Sound.

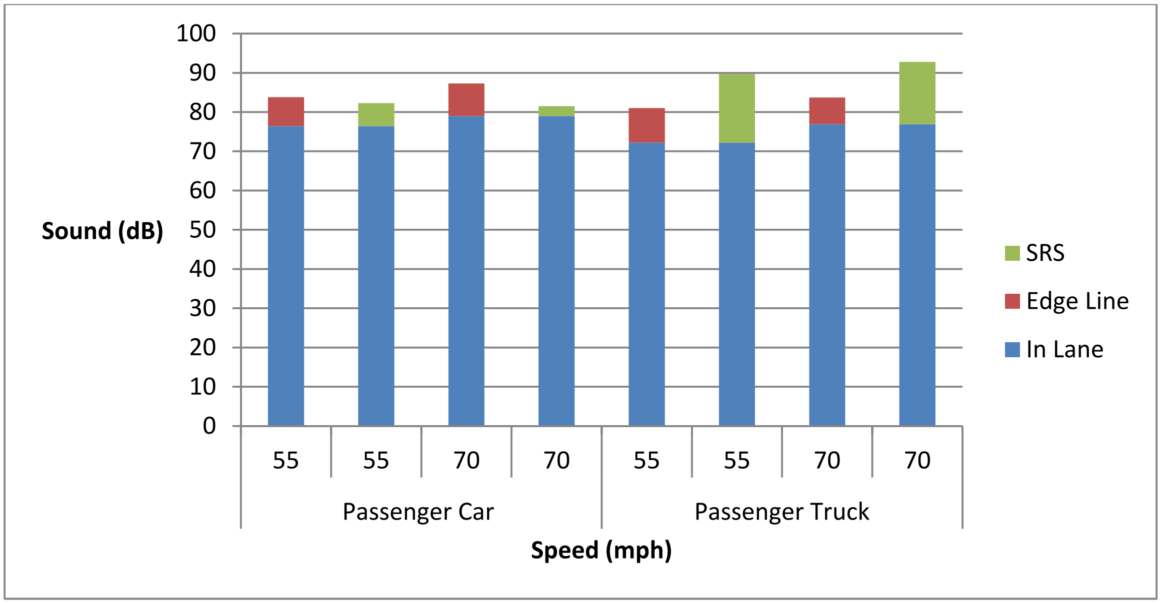


Figure 41. Atlanta District US 59 Exterior Sound.

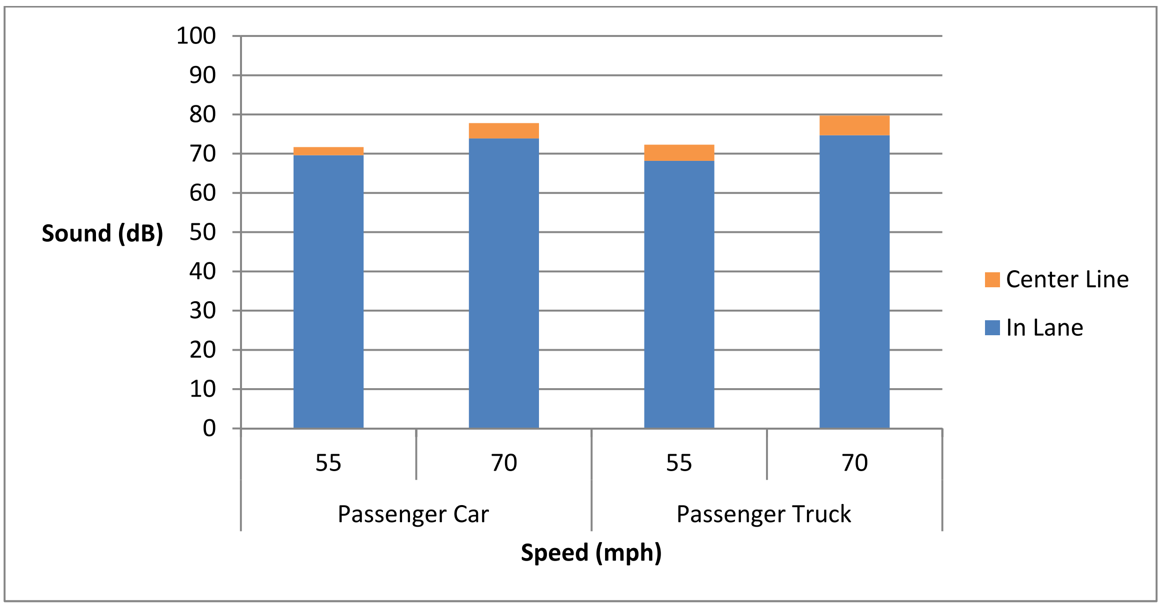


Figure 42. Atlanta District SH 43 Exterior Sound.

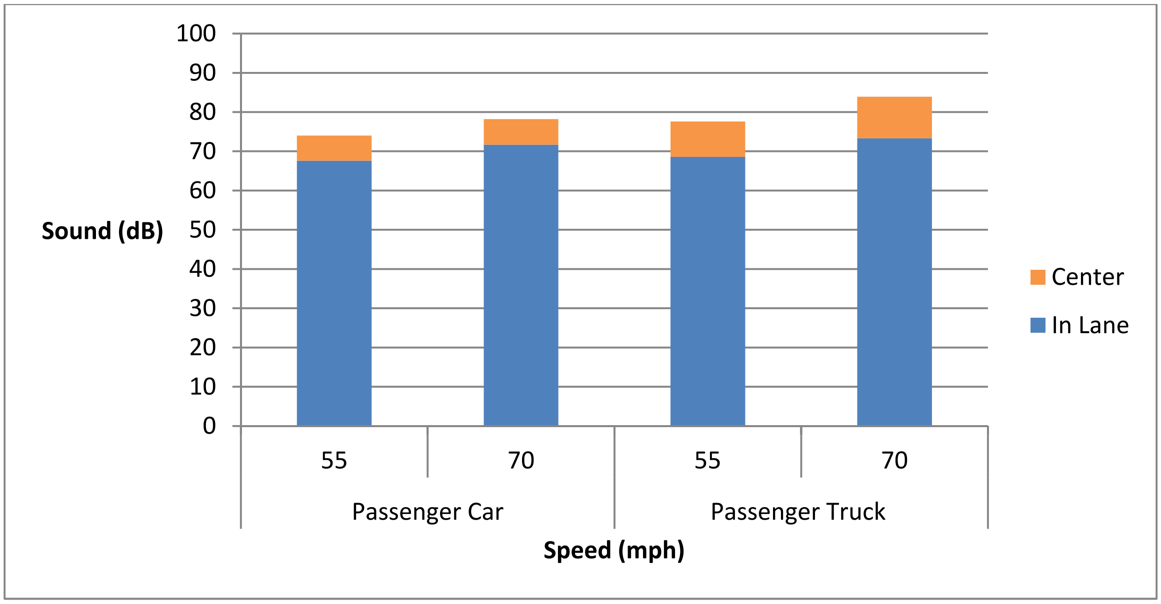


Figure 43. Atlanta District FM 2328 Exterior Sound.

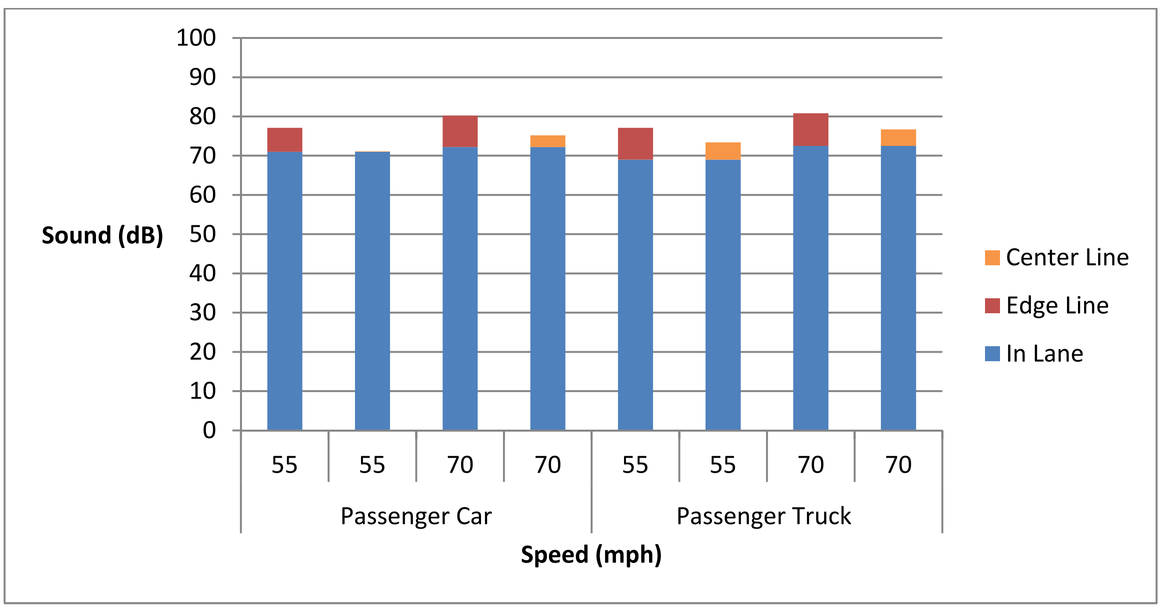


Figure 44. Atlanta District FM 3129 Exterior Sound.

Table 11. Summary of Exterior Sound Data.

	Treatment Type	Passenger Car		Passenger Truck	
		55 mph	70 mph	55 mph	70 mph
Average Ambient In Lane	Asphalt	69.8	72.3	70.0	71.1
	PCC	76.4	79.0	72.2	76.9
	Seal Coat	69.4	72.6	68.6	73.5
Average Increase Over Ambient	SRS	5.9	2.5	17.5	15.9
	CLRS	-	-	0.8	1.9
	4" Inverted Profile w/ Audible (Edge Line)	6.1	8.0	8.1	8.3
	6" Inverted Profile w/ Audible (Edge Line)	7.4	8.3	6.2	9.5
	48" Spaced Rumble Bars (Center Line)	6.4	6.5	9.0	10.6
	60" Spaced Rumble Bars (Center Line)	-	-	0.0	0.0
	55" Spaced Rumble Bars (Shoulder)	-	-	1.4	1.1
	4" Profiled Center Line + 30" Spaced Rumble Bars	2.1	3.9	4.1	5.0
	4" Inverted Profile w/ Audible (Center Line) + 60" Spaced Rumble Bars	0.1	3.0	4.4	4.2
	ELRS + 60" Spaced Rumble Bars	10.7	16.8	11.8	25.9
	CLRS + 48" Spaced Rumble Bars	3.1	8.0	3.6	10.1

-Shaded cells indicate no data collected.
All values in dB.

FINDINGS

The sound and vibration data were collected and summarized as described in the previous sections. From the data, several observations can be made of the varying rumble device designs and their impact on the sound and vibration data produced by the vehicles used in the study.

The interior sound levels were consistently higher at higher speeds in the ambient condition. While on the rumble devices the increase in interior sound was not consistent based on speed nor was it consistent based on vehicle type. The vehicle dynamics coupled with the varying designs of the rumble devices are reasons for the differences in the interior sound level increases. In general, the car had higher increases in interior sound while on the rumble devices than the truck. The closer spaced rumble bars resulted in higher interior sound level increases. The profile and inverted profile markings generated similar interior sound level increases. The rumble bars evaluated produced similar interior sound level increases to the two pavement marking systems. The center line rumble bars, profile and inverted profile markings, and marking bar combinations produced similar interior sound level increases compared to the CLRS. Overall the alternate systems were not able to produce the same interior sound level increase on the right side shoulder as the SRS. The standard rumble strips with the rumble bars produced the largest interior sound level increases.

The vibration levels were consistently higher at higher speeds in the ambient condition. While on the rumble devices, the increase in vibration was not consistent based on speed nor was it consistent based on vehicle type. The vehicle dynamics coupled with the varying designs of the rumble devices are reasons for the differences in the vibration level increases. In general, the car had higher increases in vibration while on the rumble devices than the truck. The impact of spacing of the rumble bars on vibration levels was inconclusive. The profile markings produced a greater increase in vibration than the inverted profile markings. The rumble bars evaluated produced higher vibration level increases than the two pavement marking systems. In most cases, the center line rumble bars and center line markings and bar combinations produced similar or greater vibration level increases compared to the CLRS. For the car, the alternate systems were not able to produce the same vibration level increase on the right side shoulder as the SRS. For the truck the alternate systems were able to produce similar or greater vibration level increase on the right side shoulder as the SRS. The standard rumble strips with the rumble bars produced the largest vibration level increases for the car and some of the largest increases for the truck.

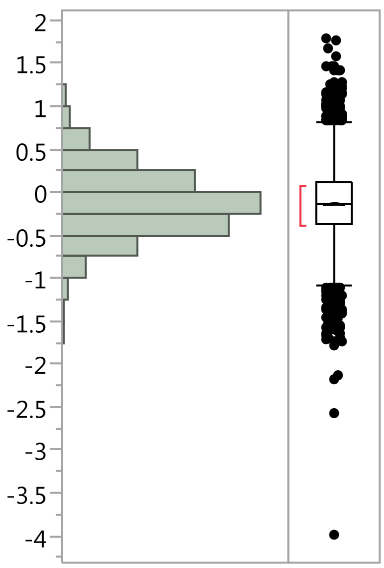
The exterior sound levels were consistently higher at higher speeds in the ambient condition. While on the rumble devices, the increase in exterior sound typically increased with speed. In general, the truck had higher increases in exterior sound while on the rumble devices than the car. The closer spaced rumble bars resulted in higher exterior sound level increases. The 48-in. spaced rumble bars produced similar exterior sound level increases to the inverted profile with audible hump pavement marking systems. Only the truck was tested for exterior sound on the CLRS. Each of the alternate systems produced higher exterior sound levels compared to the standard CLRS except for the rumble bars spaced at 60 in. The alternate systems produced similar or higher exterior sound level increases on the right side edge line as the SRS for the car but lower for the truck. The standard ELRS with the rumble bars produced the largest exterior sound level increases. The average exterior noise for the 18-wheeler vehicles in the test areas was 82.9 dB while driving in the lane. The test vehicles exceeded 82.9 dB while on the rumble devices in 10 of the 66 scenarios evaluated.

Overall the alternate rumble strip devices were able to produce similar results for the center line condition as compared to the CLRS. In general, the alternate rumble strip devices were not able to produce similar performance to the SRS. The alternate markings and bars were able to produce similar results in some conditions as compared to the standard rumble strips. The use of the alternate systems to produce audible and vibratory alerts to drivers is a valid option for instances where standard rumble strips cannot be used. Closer spaced rumble bars will generate higher interior noise levels, but also generate higher exterior noise levels and may sacrifice the vibration produced. The pavement marking systems produced similar sound levels to the rumble bars, but had lower vibration levels.

With the increased cost of profile markings and rumble bars compared to standard markings and rumble strips, the added cost may need to be justified with increased performance from an operations or safety perspective. The researchers recommend future studies be conducted to evaluate the safety impact of the alternate rumble devices to determine if their impact on safety is comparable to the standard milled rumble strips. An advantage of the profile markings and ELRS that was not evaluated in this project is the possible visibility improvement in inclement conditions that the structured markings can provide (rumble bars provide no additional visibility improvements). Studying the visibility improvement and safety impact of these markings are areas for future research. Future research should also include more sites and a wider variety of designs (i.e., different spacing and heights of the devices). Another area to evaluate in the future is the specific impact on sound and vibration for profile markings that are either square or circular. This study did not have enough sections to compare the shape of the design. An increased number of study sections would allow researchers to see if there is a performance difference. The difference in performance coupled with the cost differences and installation requirements could allow for a specific design to be required to improve performance and consistency.

APPENDIX A. DETAILED RESULTS AND ANALYSIS FOR LANE DEVIATION AND ENCROACHMENT

Laneoffset(meter)
(Blank: lane change)



Quantiles

100.0%	maximum	1.78332
99.5%		1.03199
97.5%		0.67811
90.0%		0.37072
75.0%	quartile	0.10756
50.0%	median	-0.1478
25.0%	quartile	-0.3708
10.0%		-0.5967
2.5%		-0.8656
0.5%		-1.3022
0.0%	minimum	-3.9843

Summary Statistics

Mean	-0.130253
Std Dev	0.3939016
Std Err Mean	0.0040071
Upper 95% Mean	-0.122399
Lower 95% Mean	-0.138108
N	9663

Table 12. Mixed Effects ANOVA for Testing the Effects of Logo Presence and Other Factors on Variability of Lane Offset.

Response Abs_std_cond_residuals

Summary of Fit

RSquare	0.101427
RSquare Adj	0.100496
Root Mean Square Error	0.580867
Mean of Response	0.691479
Observations (or Sum Wgts)	9663

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Participant_ID	0.0932024	0.0314471	0.0075525	0.0166445	0.0462497	8.526
Residual		0.3374067	0.0048665	0.3280681	0.3471518	91.474
Total		0.3688538	0.008973	0.35188	0.3870923	100.000

-2 LogLikelihood = 17123.282563

Note: Total is the sum of the positive variance components.

Total including negative estimates = 0.3688538

Fixed Effect Tests

Source	**Nparm**	**DF**	**DFDen**	**F Ratio**	**Prob > F**
Logo_Presence	1	1	9615	0.1043	0.7467
Sign_Type	1	1	9615	0.0681	0.7941
Age Group	1	1	38.39	9.9323	0.0031*
Gender	1	1	38.39	0.0415	0.8396
Logo_Presence*Sign_Type	1	1	9615	9.4928	0.0021*
Logo_Presence*Age Group	1	1	9615	0.0509	0.8214
Logo_Presence*Gender	1	1	9615	0.3913	0.5316
Sign_Type*Age Group	1	1	9615	0.8734	0.3500
Sign_Type*Gender	1	1	9615	0.8470	0.3574
Age Group*Gender	1	1	37.99	0.0206	0.8868

Effect Details

Logo_Presence

Least Squares Means Table

Level	Least Sq Mean	Std Error
0	0.69417754	0.02923272
1	0.69013113	0.02834163

Sign_Type

Least Squares Means Table

Level	Least Sq Mean	Std Error
S	0.69051981	0.02878965
T	0.69378885	0.02879129

Age Group

Least Squares Means Table

Level	Least Sq Mean	Std Error
Old	0.78071546	0.03974973
Young	0.60359320	0.03973157

LS Means Plot

Gender

Least Squares Means Table

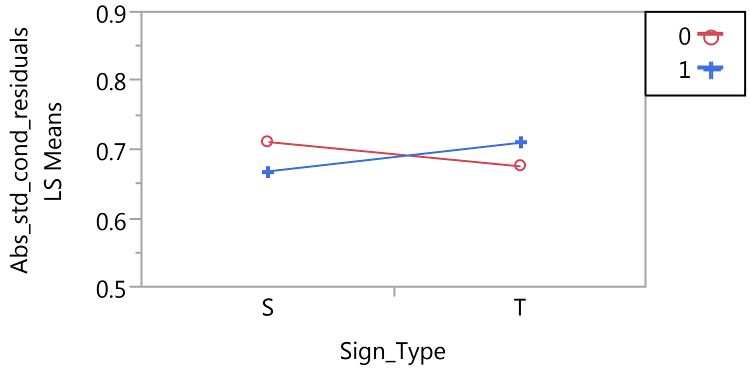
Level	Least Sq Mean	Std Error
0	0.69788194	0.03878335
1	0.68642673	0.04067574

Logo_Presence*Sign_Type

Least Squares Means Table

Level	Least Sq Mean	Std Error
0,S	0.71181923	0.03096156
0,T	0.67653585	0.03095790
1,S	0.66922040	0.02925296
1,T	0.71104186	0.02926312

LS Means Plot



LSMeans Differences Tukey HSD

α=0.050

Level			Least Sq Mean
0,S	A	B	0.71181923
1,T	A		0.71104186
0,T	A	B	0.67653585
1,S		B	0.66922040

Levels not connected by same letter are significantly different.

Logo_Presence*Age Group

Least Squares Means Table

Level	Least Sq Mean	Std Error
0,Old	0.78415076	0.04136066
0,Young	0.60420431	0.04131811
1,Old	0.77728016	0.04009547
1,Young	0.60298210	0.04006581

Logo_Presence*Gender

Least Squares Means Table

Level	Least Sq Mean	Std Error
0,0	0.70382321	0.04034397
0,1	0.68453186	0.04231521
1,0	0.69194067	0.03911733
1,1	0.68832159	0.04102224

Sign_Type*Age Group
Least Squares Means Table

Level	Least Sq Mean	Std Error
S,Old	0.78460738	0.04067383
S,Young	0.59643224	0.04064986
T,Old	0.77682354	0.04068817
T,Young	0.61075416	0.04064187

Sign_Type*Gender
Least Squares Means Table

Level	Least Sq Mean	Std Error
S,0	0.69079939	0.03968492
S,1	0.69024023	0.04161821
T,0	0.70496449	0.03969079
T,1	0.68261322	0.04161828

Age Group*Gender
Least Squares Means Table

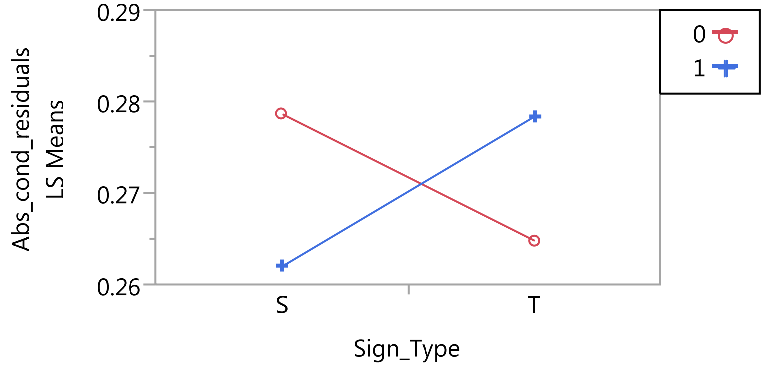
Level	Least Sq Mean	Std Error
Old,0	0.79046080	0.05482807
Old,1	0.77097013	0.05749442
Young,0	0.60530308	0.05479878
Young,1	0.60188332	0.05747357

LM means plot for the interaction effect of Logo Presence*Sign Type in terms of absolute residuals in meter
Response Abs_cond_residuals
Summary of Fit

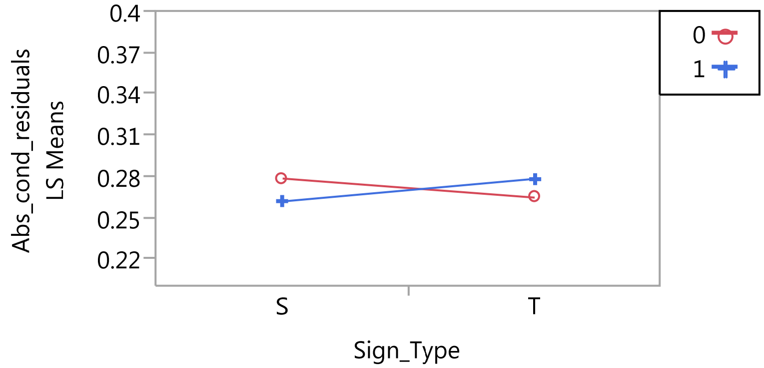
Logo_Presence*Sign_Type
Least Squares Means Table

Level	Least Sq Mean	Std Error
0,S	0.27870869	0.01212258
0,T	0.26488892	0.01212114
1,S	0.26209195	0.01145338
1,T	0.27847537	0.01145735

LS Means Plot



LS Means Plot (Same plot as the above one on a different scale)



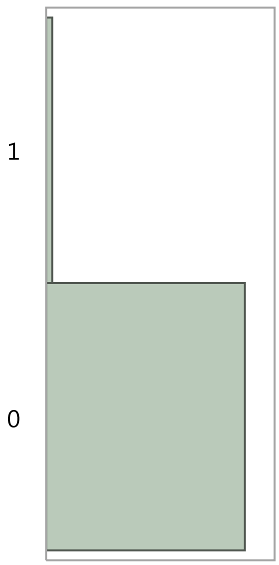
LSMeans Differences Tukey HSD

α=0.050

Level			**Least Sq Mean**
0,S	A	B	0.27870869
1,T	A		0.27847537
0,T	A	B	0.26488892
1,S		B	0.26209195

Levels not connected by same letter are significantly different.

LaneEncroachment
(1: Yes, 0: No)



Frequencies

Level	Count	Prob
0	9523	0.97114
1	283	0.02886
Total	9806	1.00000

N Missing
0
2 Levels

Logo_Presence

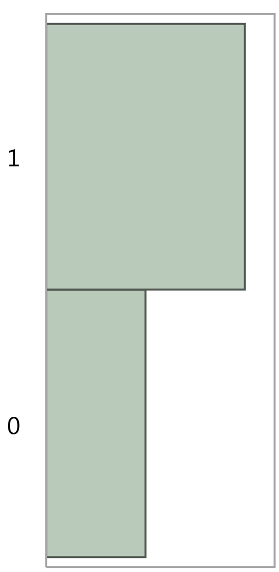


Table 13. Logistic Regression Model for Testing the Effects of Logo Presence and Other Factors on Lane Encroachment.

The GENMOD Procedure

Model Information	
Data Set	WORK.LANE_ENCROACHEMENT
Distribution	Binomial
Link Function	Logit
Dependent Variable	Lane_Encroachment

Number of Observations Read	9806
Number of Observations Used	9806
Number of Events	283
Number of Trials	9806

Class Level Information		
Class	**Levels**	**Values**
Participant_ID	42	2 3 4 5 6 8 9 10 11 12 13 14 15 16 17 18 19 20 21 23 24 22 26 27 28 29 31 32 33 34 35 36 37 38 39 40 41 42 43 47 48 50
Logo_Presence	2	0 1
Sign_Type	2	S T
Age_Group	2	Old Young
Gender	2	1 0

Response Profile		
Ordered Value	**Lane_Encroachment**	**Total Frequency**
1	1	283
2	0	9523

PROC GENMOD is modeling the probability that Lane_Encroachment='1'.

Parameter Information

Parameter	Effect	Logo_Presence	Sign_Type	Age_Group	Gender
Prm1	Intercept				
Prm2	Logo_Presence	0			
Prm3	Logo_Presence	1			
Prm4	Sign_Type		S		
Prm5	Sign_Type		T		
Prm6	Age_Group			Old	
Prm7	Age_Group			Young	
Prm8	Gender				1
Prm9	Gender				0
Prm10	PSL				

Algorithm converged.

GEE Model Information

Correlation Structure	Independent
Subject Effect	Participant_ID (42 levels)
Number of Clusters	42
Correlation Matrix Dimension	234
Maximum Cluster Size	234
Minimum Cluster Size	221

Algorithm converged.

GEE Fit Criteria

QIC	2528.1857
QICu	2477.7623

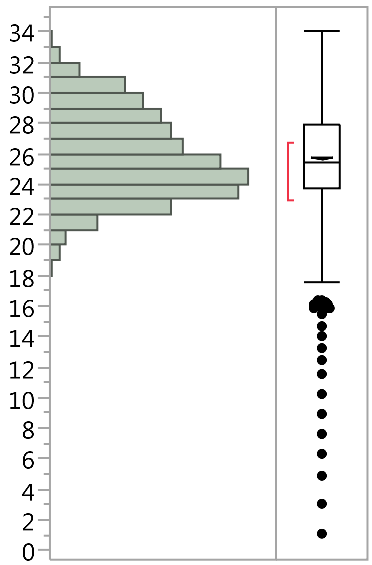
Analysis Of GEE Parameter Estimates							
Empirical Standard Error Estimates							
Parameter		**Estimate**	**Standard Error**	**95% Confidence Limits**		**Z**	**Pr > |Z|**
Intercept		-5.2801	0.6736	-6.6003	-3.9598	-7.84	<.0001
Logo_Presence	0	0.0667	0.1941	-0.3137	0.4471	0.34	0.7311
Logo_Presence	1	0.0000	0.0000	0.0000	0.0000	.	.
Sign_Type	S	0.1141	0.2052	-0.2882	0.5163	0.56	0.5784
Sign_Type	T	0.0000	0.0000	0.0000	0.0000	.	.
Age_Group	Old	1.1462	0.3365	0.4866	1.8057	3.41	0.0007
Age_Group	Young	0.0000	0.0000	0.0000	0.0000	.	.
Gender	1	0.4826	0.3476	-0.1986	1.1638	1.39	0.1650
Gender	0	0.0000	0.0000	0.0000	0.0000	.	.
PSL		0.0276	0.0210	-0.0135	0.0687	1.32	0.1883

Score Statistics For Type 3 GEE Analysis			
Source	**DF**	**Chi-Square**	**Pr > ChiSq**
Logo_Presence	1	0.11	0.7393
Sign_Type	1	0.30	0.5861
Age_Group	1	6.25	0.0124
Gender	1	1.37	0.2420
PSL	1	1.50	0.2210

APPENDIX B. RESULTS AND ANALYSIS FOR SPEED DATA

Distributions of Speed and Speed Difference by Posted Speed Limit (PSL) (*n*=9,806)

speed(m/s)



Quantiles

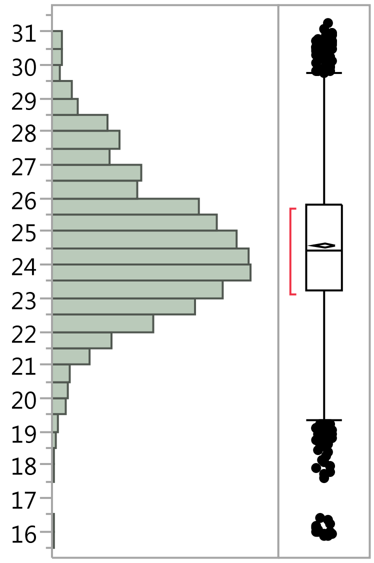
100.0%	maximum	34.0416
99.5%		32.3608
97.5%		31.1958
90.0%		29.8088
75.0%	quartile	27.9058
50.0%	median	25.4388
25.0%	quartile	23.7225
10.0%		22.519
2.5%		21.0034
0.5%		19.015
0.0%	minimum	1.00831

Summary Statistics

Mean	25.786231
Std Dev	2.8496202
Std Err Mean	0.0287767
Upper 95% Mean	25.842639
Lower 95% Mean	25.729823
N	9806

Post_Speed_ Limit(m/s)=50 mph

Speed(m/s)



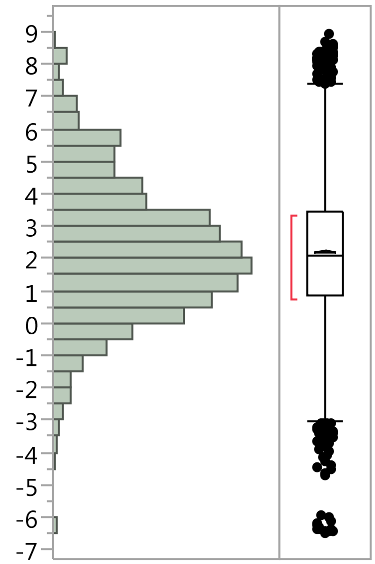
Quantiles

100.0%	maximum	31.2771
99.5%		30.5282
97.5%		29.0433
90.0%		27.5524
75.0%	quartile	25.8176
50.0%	median	24.4385
25.0%	quartile	23.2035
10.0%		22.1688
2.5%		20.4728
0.5%		18.8892
0.0%	minimum	15.8637

Summary Statistics

Mean	24.588956
Std Dev	2.1247734
Std Err Mean	0.0262819
Upper 95% Mean	24.640477
Lower 95% Mean	24.537435
N	6536

Speed-PSL



Quantiles

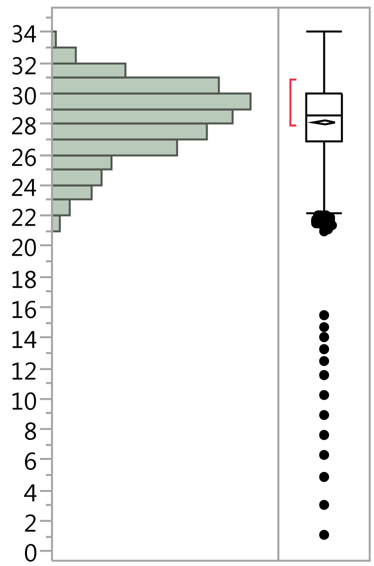
100.0%	maximum	8.92507
99.5%		8.17615
97.5%		6.69129
90.0%		5.20042
75.0%	quartile	3.46558
50.0%	median	2.08646
25.0%	quartile	0.85153
10.0%		-0.1832
2.5%		-1.8792
0.5%		-3.4628
0.0%	minimum	-6.4883

Summary Statistics

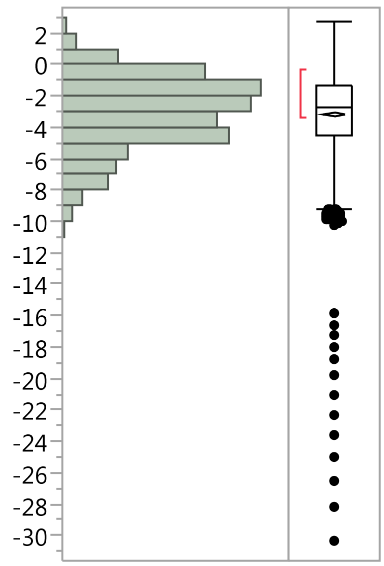
Mean	2.2369557
Std Dev	2.1247734
Std Err Mean	0.0262819
Upper 95% Mean	2.2884768
Lower 95% Mean	2.1854346
N	6536

Post_Speed_ Limit(m/s)=70 mph

Speed(m/s)



Speed-PSL



Quantiles

100.0%	maximum	34.0416
99.5%		32.951
97.5%		32.0091
90.0%		30.9195
75.0%	quartile	29.9565
50.0%	median	28.5225
25.0%	quartile	26.8122
10.0%		24.8652
2.5%		22.9237
0.5%		21.2764
0.0%	minimum	1.00831

Summary Statistics

Mean	28.179317
Std Dev	2.5954158
Std Err Mean	0.0453872
Upper 95% Mean	28.268307
Lower 95% Mean	28.090327
N	3270

Quantiles

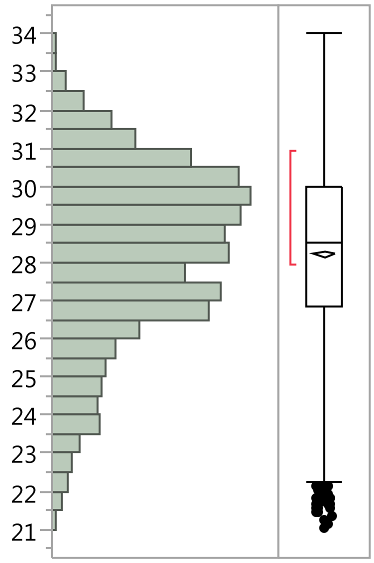
100.0%	maximum	2.74877
99.5%		1.65821
97.5%		0.71631
90.0%		-0.3733
75.0%	quartile	-1.3363
50.0%	median	-2.7703
25.0%	quartile	-4.4806
10.0%		-6.4276
2.5%		-8.3691
0.5%		-10.016
0.0%	minimum	-30.284

Summary Statistics

Mean	-3.113483
Std Dev	2.5954158
Std Err Mean	0.0453872
Upper 95% Mean	-3.024493
Lower 95% Mean	-3.202473
N	3270

Distributions of speed and speed difference without 13 extreme outliers when PSL=70 mph

Speed(m/s)



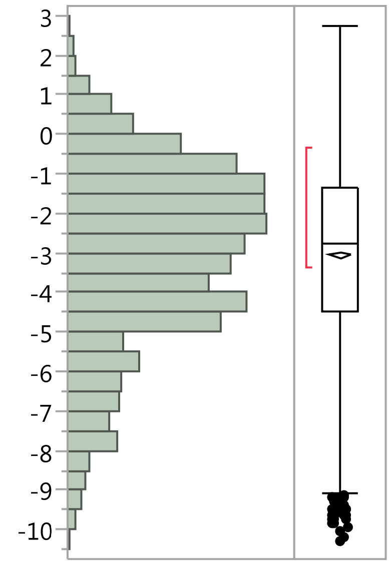
Quantiles

100.0%	maximum	34.0416
99.5%		32.9521
97.5%		32.0098
90.0%		30.9212
75.0%	quartile	29.964
50.0%	median	28.5317
25.0%	quartile	26.8353
10.0%		24.9418
2.5%		23.083
0.5%		21.8047
0.0%	minimum	21.0178

Summary Statistics

Mean	28.253833
Std Dev	2.2991218
Std Err Mean	0.0402859
Upper 95% Mean	28.332821
Lower 95% Mean	28.174844
N	3257

Speed-PSL



Quantiles

100.0%	maximum	2.74877
99.5%		1.65925
97.5%		0.71699
90.0%		-0.3716
75.0%	quartile	-1.3288
50.0%	median	-2.7611
25.0%	quartile	-4.4575
10.0%		-6.351
2.5%		-8.2098
0.5%		-9.4881
0.0%	minimum	-10.275

Summary Statistics

Mean	-3.038967
Std Dev	2.2991218
Std Err Mean	0.0402859
Upper 95% Mean	-2.959979
Lower 95% Mean	-3.117956
N	3257

Table 14. Mixed Effects ANOVA for Testing the Effects of Logo Presence and Other Factors on Speed Compliance when the Posted Speed Limit Is 50 mph.

Response Speed-PSL when PSL(m/s)=50 mph
Summary of Fit

RSquare	0.376473
RSquare Adj	0.375518
Root Mean Square Error	1.683934
Mean of Response	2.236956
Observations (or Sum Wgts)	6536

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Participant_ID	0.5061428	1.4352356	0.3334366	0.7817119	2.0887593	33.605
Residual		2.8356337	0.0497901	2.7405223	2.9358079	66.395
Total		4.2708693	0.3370865	3.6801752	5.0169491	100.000

-2 LogLikelihood =
25580.477207
Note: Total is the sum of the positive variance components.

Total including negative estimates =
4.2708693

Fixed Effect Tests

Source	Nparm	DF	DFDen	F Ratio	Prob > F
Logo_Presence	1	1	6487	4.4990	0.0340*
Sign_Type	1	1	6487	3.4465	0.0634
Age Group	1	1	38.12	9.6299	0.0036*
Gender	1	1	38.12	0.7147	0.4032
Logo_Presence*Sign_Type	1	1	6487	21.2368	<.0001*
Logo_Presence*Age Group	1	1	6487	4.8278	0.0280*
Logo_Presence*Gender	1	1	6487	0.7163	0.3974
Sign_Type*Age Group	1	1	6487	11.5973	0.0007*
Sign_Type*Gender	1	1	6487	13.2557	0.0003*
Age Group*Gender	1	1	38	0.1091	0.7430

Effect Details

Logo_Presence

Least Squares Means Table

Level	Least Sq Mean	Std Error
0	2.1662981	0.18857565
1	2.2602503	0.18681836

Sign_Type

Least Squares Means Table

Level	Least Sq Mean	Std Error
S	2.2543818	0.18771035
T	2.1721666	0.18768675

Age Group

Least Squares Means Table

Level	Least Sq Mean	Std Error
Old	2.7916732	0.26360029
Young	1.6348752	0.26358349

Gender

Least Squares Means Table

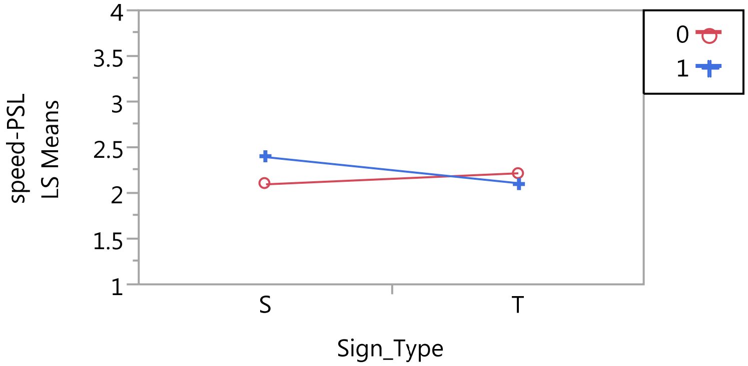
Level	Least Sq Mean	Std Error
0	2.3708459	0.25723043
1	2.0557024	0.26980411

Logo_Presence*Sign_Type

Least Squares Means Table

Level	Least Sq Mean	Std Error
0,S	2.1054833	0.19206116
0,T	2.2271128	0.19196515
1,S	2.4032802	0.18854911
1,T	2.1172204	0.18855436

LS Means Plot



LSMeans Differences Tukey HSD

α=0.050

Level		Least Sq Mean
1,S	A	2.4032802
0,T	B	2.2271128
1,T	B	2.1172204
0,S	B	2.1054833

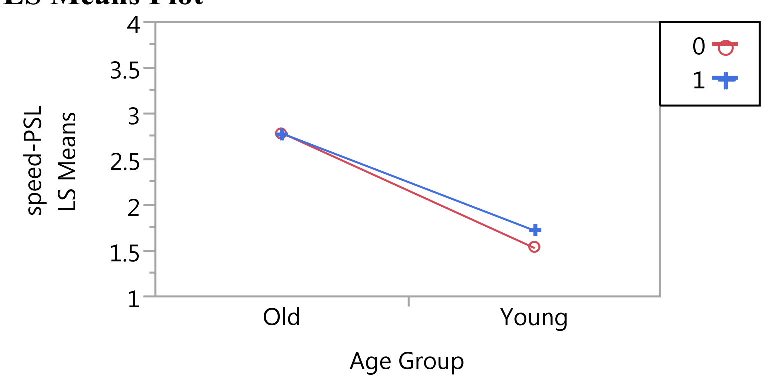
Levels not connected by same letter are significantly different.

Logo_Presence*Age Group

Least Squares Means Table

Level	Least Sq Mean	Std Error
0,Old	2.7932930	0.26671601
0,Young	1.5393031	0.26664688
1,Old	2.7900534	0.26419824
1,Young	1.7304472	0.26420198

LS Means Plot



LSMeans Differences Tukey HSD
α=0.050

Level				Least Sq Mean
0,Old	A			2.7932930
1,Old	A			2.7900534
1,Young		B		1.7304472
0,Young			C	1.5393031

Levels not connected by same letter are significantly different.

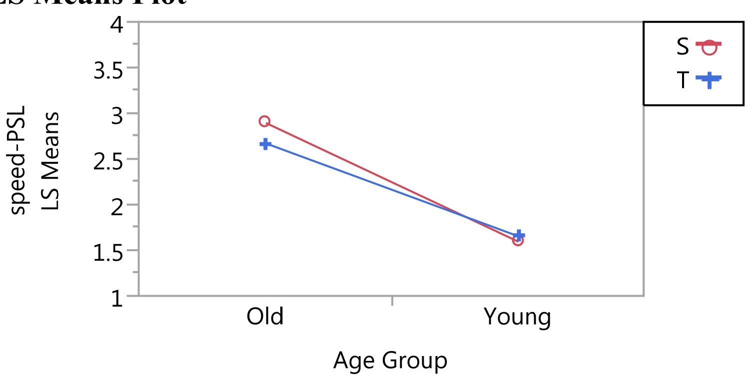
Logo_Presence*Gender
Least Squares Means Table

Level	Least Sq Mean	Std Error
0,0	2.3051252	0.26022429
0,1	2.0274709	0.27299529
1,0	2.4365667	0.25783198
1,1	2.0839339	0.27042018

Sign_Type*Age Group
Least Squares Means Table

Level	Least Sq Mean	Std Error
S,Old	2.9037219	0.26538144
S,Young	1.6050416	0.26532383
T,Old	2.6796245	0.26532383
T,Young	1.6647088	0.26532809

LS Means Plot



LSMeans Differences Tukey HSD
α=0.050

Level				Least Sq Mean
S,Old	A			2.9037219
T,Old		B		2.6796245
T,Young			C	1.6647088
S,Young			C	1.6050416

Levels not connected by same letter are significantly different.

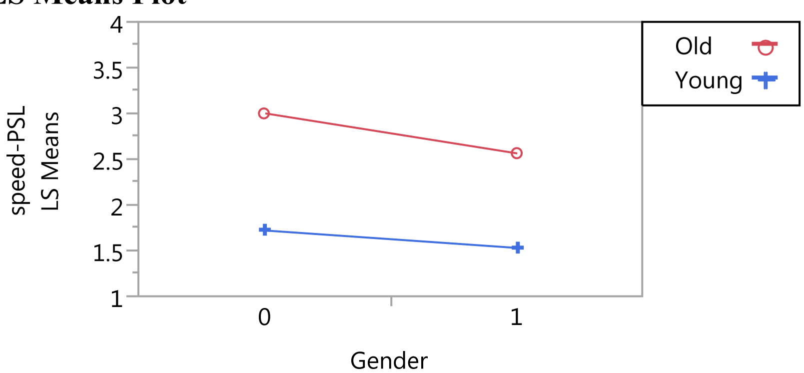
Sign_Type*Gender
Least Squares Means Table

Level	Least Sq Mean	Std Error
S,0	2.4878941	0.25893644
S,1	2.0208694	0.27162278
T,0	2.2537978	0.25893644
T,1	2.0905354	0.27156926

Age Group*Gender
Least Squares Means Table

Level	Least Sq Mean	Std Error
Old,0	3.0107595	0.36371151
Old,1	2.5725869	0.38149799
Young,0	1.7309324	0.36371151
Young,1	1.5388180	0.38145988

LS Means Plot



LSMeans Differences Tukey HSD
α=0.050

Level			Least Sq Mean
Old,0	A		3.0107595
Old,1	A	B	2.5725869
Young,0	A	B	1.7309324
Young,1		B	1.5388180

Levels not connected by same letter are significantly different.

Table 15. Mixed Effects ANOVA for Testing the Effects of Logo Presence and Other Factors on Speed Compliance when the Posted Speed Limit Is 70 mph.

Response speed-PSL when PSL(m/s)=70 mph
Summary of Fit

RSquare	0.523532
RSquare Adj	0.522064
Root Mean Square Error	1.598668
Mean of Response	-3.03897
Observations (or Sum Wgts)	3257

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Participant_ID	0.7124369	1.8208027	0.425272	0.987285	2.6543205	41.604
Residual		2.555739	0.0638137	2.4351371	2.6855725	58.396
Total		4.3765418	0.4299114	3.6425672	5.3583741	100.000

-2 LogLikelihood =
12499.191066
Note: Total is the sum of the positive variance components.

Total including negative estimates =
4.3765418

Fixed Effect Tests

Source	Nparm	DF	DFDen	F Ratio	Prob > F
Logo_Presence	1	1	3208	5.6051	0.0180*
Sign_Type	1	1	3208	23.5774	<.0001*
Age Group	1	1	38.18	24.4462	<.0001*
Gender	1	1	38.18	0.0277	0.8688
Logo_Presence*Sign_Type	1	1	3208	10.2216	0.0014*
Logo_Presence*Age Group	1	1	3208	2.1272	0.1448
Logo_Presence*Gender	1	1	3208	1.7578	0.1850
Sign_Type*Age Group	1	1	3208	8.0952	0.0045*
Sign_Type*Gender	1	1	3208	2.4257	0.1195
Age Group*Gender	1	1	38	0.0049	0.9444

Effect Details

Logo_Presence

Least Squares Means Table

Level	Least Sq Mean	Std Error
0	-2.951508	0.21407644
1	-3.092658	0.21125274

Sign_Type

Least Squares Means Table

Level	Least Sq Mean	Std Error
S	-3.166833	0.21262657
T	-2.877333	0.21271211

Age Group

Least Squares Means Table

Level	Least Sq Mean	Std Error
Old	-4.063205	0.29781462
Young	-1.980961	0.29776664

Gender

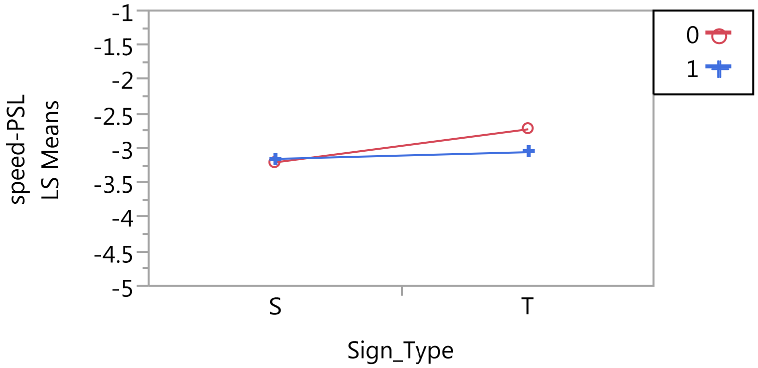
Least Squares Means Table

Level	Least Sq Mean	Std Error
0	-2.987053	0.29063946
1	-3.057113	0.30477384

Logo_Presence*Sign_Type
Least Squares Means Table

Level	Least Sq Mean	Std Error
0,S	-3.191494	0.21940589
0,T	-2.711521	0.21970670
1,S	-3.142172	0.21399962
1,T	-3.043145	0.21403526

LS Means Plot



LSMeans Differences Tukey HSD
α=0.050

Level			Least Sq Mean
0,T	A		-2.711521
1,T		B	-3.043145
1,S		B	-3.142172
0,S		B	-3.191494

Levels not connected by same letter are significantly different.

Logo_Presence*Age Group
Least Squares Means Table

Level	Least Sq Mean	Std Error
0,Old	-4.036075	0.30285643
0,Young	-1.866941	0.30263826
1,Old	-4.090336	0.29874205
1,Young	-2.094981	0.29876757

Logo_Presence*Gender

Least Squares Means Table

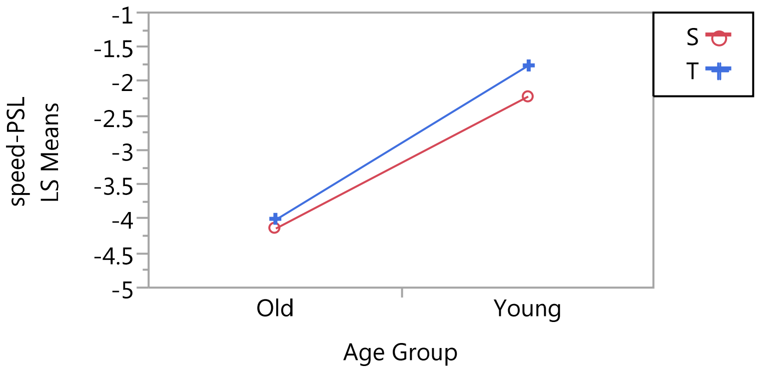
Level	Least Sq Mean	Std Error
0,0	-2.876956	0.29556702
0,1	-3.026060	0.30976607
1,0	-3.097151	0.29154382
1,1	-3.088166	0.30579908

Sign_Type*Age Group

Least Squares Means Table

Level	Least Sq Mean	Std Error
S,Old	-4.128207	0.30053516
S,Young	-2.205459	0.30053546
T,Old	-3.998204	0.30071919
T,Young	-1.756463	0.30056486

LS Means Plot



LSMeans Differences Tukey HSD

α=0.050

Level				Least Sq Mean
T,Young	A			-1.756463
S,Young		B		-2.205459
T,Old			C	-3.998204
S,Old			C	-4.128207

Levels not connected by same letter are significantly different.

Sign_Type*Gender
Least Squares Means Table

Level	Least Sq Mean	Std Error
S,0	-3.175501	0.29330371
S,1	-3.158164	0.30760384
T,0	-2.798606	0.29348730
T,1	-2.956061	0.30763339

Age Group*Gender
Least Squares Means Table

Level	Least Sq Mean	Std Error
Old,0	-4.013403	0.41097265
Old,1	-4.113008	0.43088312
Young,0	-1.960704	0.41084161
Young,1	-2.001217	0.43090427

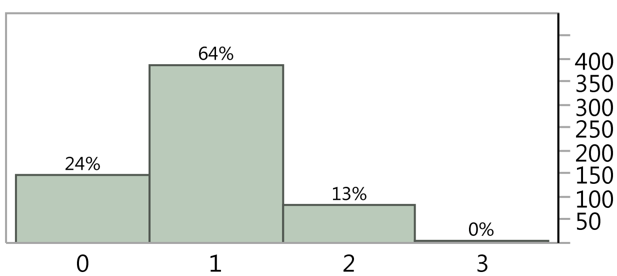
APPENDIX C. EYE TRACKING DATA AND ANALYSIS

The dependent variable is 'Glance_Count>=2sec' (Total Eyes Off Road Time of 2 sec, i.e., how many single glances exceed 2 seconds). Because researchers were mainly interested in determining whether the presence of a sponsored logo (regardless of whether logo changes in phasing) significantly impact the dependent variable, the Logo Presence variable defined previously was utilized again:

Logo Presence = 1 when Logo_Count=1 or 2,
= 0 when Logo_Count=0.

In addition to the main study factor, Logo Presence (with values 0, 1), other factors of interest in the analysis are Sign Type (with 2 levels S or T), Age Group (Old: 55 years of age and older, Young: 18 to 35 years of age), and Gender (1: Male, 0: Female). Only the observations with Sign_Blocked=No were included in the data for this analysis. The sample size of the data for the analysis was *n*=604. Figure 45 contains the distribution of Glance_Count>=2sec regardless of Logo Presence.

Distributions
Glance_Count>=2sec



Frequencies

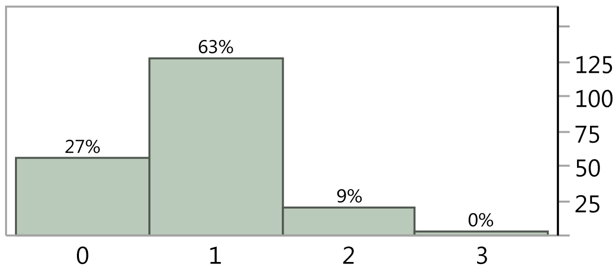
Level	Count	Prob
0	143	0.23675
1	384	0.63576
2	76	0.12583
3	1	0.00166
Total	604	1.00000

N Missing
0
4 Levels

Figure 45. Distribution of Glance_Count ≥ 2sec regardless of Logo Presence.

Figure 46 contains the distribution of Glance_Count>=2sec when the logo is present and when the logo is not present. When the logo is present the number of glances exceeding 2 seconds tends to increase (the proportion of total eyes off road time of 2 sec being at least two is larger when the logo is present).

Distributions Logo Presence=0
Glance_Count>=2sec



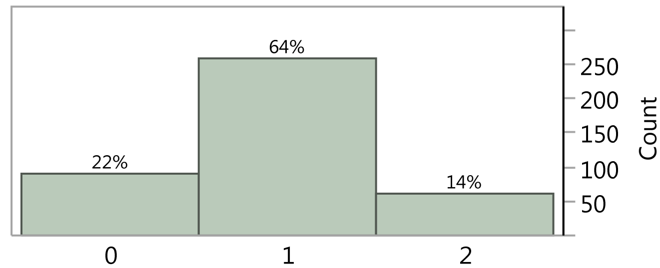
Frequencies

Level	Count	Prob
0	55	0.27228
1	127	0.62871
2	19	0.09406
3	1	0.00495
Total	202	1.00000

N Missing 0
4 Levels

(a)

Distributions Logo Presence=1
Glance_Count>=2sec



Frequencies

Level	Count	Prob
0	88	0.21891
1	257	0.63930
2	57	0.14179
Total	402	1.00000

N Missing 0
3 Levels

(b)

Figure 46. Distribution of Glance_Count>=2sec (a) When Logo Is Not Present, (b) When Logo Is Present.

Because Glance_Count>=2 is a count variable with a small mean (0.89), a Generalized Linear Regression Model (GLM), specifically a Poisson regression model would have been a preferable model for these data. Unfortunately, a GLM platform did allow Participant to be included as a random effect, which would have been a good way to control for driver-to-driver variability.

To employ a mixed effects ANOVA model that allows Participant to be included as a random effect, researchers first transformed the count data using the square-root transformation as follows:

$$z = \left(y + \frac{3}{8} \right)^{1/2}$$

where y is Glance_Count>=2sec and z is Transformed Glance Count.

The mixed effects ANOVA model having Logo Presence, Sign Type, Age group, Gender, and two-way interactions among them as fixed effects and Participant as a random effect was employed to test the effect of Logo Presence on Glance_Count>=2sec. Table 16 contains the results of the mixed effects ANOVA model. As can be observed from Table 16 (see Fixed Effects Tests), none of the two-way interaction effects were statistically significant at the 5 percent significance level.

Table 16. Mixed Effects ANOVA for Testing the Effect of Logo Presence on Glance_Count ≥ 2sec.

Response Transformed Glance Count

Summary of Fit

RSquare	0.225833
RSquare Adj	0.212778
Root Mean Square Error	0.264358
Mean of Response	1.087434
Observations (or Sum Wgts)	604

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Participant	0.2192442	0.0153219	0.0048963	0.0057252	0.0249185	17.982
Residual		0.0698851	0.0041733	0.0623761	0.0788441	82.018
Total		0.085207	0.0062653	0.0741466	0.0989548	100.000

-2 LogLikelihood =
223.99879371
Note: Total is the sum of the positive variance components.

Total including negative estimates =
0.085207

Fixed Effect Tests

Source	Nparm	DF	DFDen	F Ratio	Prob > F
Logo Presence	1	1	561.9	4.1048	0.0432*
Sign_Type	1	1	562.5	5.8014	0.0163*
Age_Group	1	1	33.69	1.4319	0.2398
Gender	1	1	33.67	0.0140	0.9065
Age_Group*Gender	1	1	32	0.6739	0.4178
Age_Group*Sign_Type	1	1	562.9	0.6882	0.4071
Age_Group*Logo Presence	1	1	561.9	0.6719	0.4128
Gender*Sign_Type	1	1	562.7	2.0167	0.1561
Gender*Logo Presence	1	1	561.8	0.0809	0.7761
Sign_Type*Logo Presence	1	1	561.6	1.2559	0.2629

To see whether the removal of the two-way interaction effects from the model will change the results, the two-way interaction effects were removed from the model, and the data were refitted with the model without the interaction effects. Table 17 contains the results of fitting the mixed effects ANOVA model with only main effects to Transformed Glance Count. As can be seen from Table 17, the effects of Logo Presence and Sign Type (S or T) are statistically significant at the 5 percent significance level. The effect of Age Group and Gender are not statistically significant. Table 17 also presents the predicted values (Least Squares Means) for Last Glance Distance from Sign (ft) for each level of factors in the model along with their standard errors (in Effect Details). It can be seen that the predicted Transformed Glance Count is statistically larger when the logo is present compared to when the logo is not present. Table 17 also shows that Sign Type=S leads to larger Transformed Glance Count compared to Sign Type=T. Note that the predicted values of the untransformed variable 'Glance_Count>=2sec' can be obtained by back-transforming the predicted values in Table 17. For instance, the predicted value of Glance_Count>=2sec is 0.7455 when Logo Presence=0 and 0.8512 when Logo Presence=1.

Table 17. Mixed Effects ANOVA Model with Only Main Effects for Testing the Effect of Logo Presence on Glance_Count ≥ 2sec.

Response Transformed Glance Count

Summary of Fit

RSquare	0.218318
RSquare Adj	0.213098
Root Mean Square Error	0.26441
Mean of Response	1.087434
Observations (or Sum Wgts)	604

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Participant	0.2163619	0.0151264	0.0047716	0.0057743	0.0244786	17.788
Residual		0.0699127	0.0041564	0.0624313	0.0788316	82.212
Total		0.0850391	0.0061591	0.0741499	0.0985299	100.000

-2 LogLikelihood =
188.6012229
Note: Total is the sum of the positive variance components.

Total including negative estimates =
0.0850391

Fixed Effect Tests

Source	Nparm	DF	DFDen	F Ratio	Prob > F
Logo Presence	1	1	566.6	4.5689	0.0330*
Sign_Type	1	1	567.4	4.6722	0.0311*
Age_Group	1	1	32.98	1.5115	0.2276
Gender	1	1	32.95	0.0840	0.7738

Effect Details

Logo Presence

Least Squares Means Table

Level	Least Sq Mean	Std Error
0	1.0585401	0.02798106
1	1.1073501	0.02471243

Sign_Type

Least Squares Means Table

Level	Least Sq Mean	Std Error
S	1.1062623	0.02612777
T	1.0596279	0.02613416

Age_Group

Least Squares Means Table

Level	Least Sq Mean	Std Error
Young	1.0540336	0.03128086
Old	1.1118566	0.03550279

Gender

Least Squares Means Table

Level	Least Sq Mean	Std Error
0	1.0761319	0.03130920
1	1.0897583	0.03547047

Statistical Analysis of Last Glance Distance from Sign (ft)

The objective of this analysis is to test whether the sponsored logo CMS continues to attract the driver's attention beyond the traditional last look distance (i.e., to answer Question 3 in the list Sue provided). The dependent variable is 'Last Glance Distance from Sign (ft)'. Because researchers were mainly interested in determining whether the presence of a sponsored logo (regardless of whether logo changes in phasing) significantly impact the dependent variable, the Logo Presence variable defined previously was utilized again:

Logo Presence = 1 when Logo_Count=1 or 2, = 0 when Logo_Count=0.

In addition to the main study factor, Logo Presence (with values 0, 1), other factors of interest in the analysis are Sign Type (with 2 levels S or T), Age Group (Old: 55 years of age and older, Young: 18 to 35 years of age), and Gender (1: Male, 0: Female). To control for driver-to-driver variability, Participant was included as a random block in the analysis. The sample size used for this analysis was *n*=603 (there was one missing measurement for Participant 17, which reduced the sample size by 1 from *n*=604).

The mixed effects ANOVA model having Logo Presence, Sign Type, Age group, Gender, and two-way interactions among them as fixed effects and Participant as a random effect was employed to test the effect of Logo Presence on Last Glance Distance from Sign (ft). Table 18 contains the results of the mixed effects ANOVA model. As can be observed from Table 18 (see Fixed Effects Tests), none of the two-way interaction effects were statistically significant at the 5 percent significance level.

Table 18. Mixed Effects ANOVA for Testing the Effect of Logo Presence on Last Glance Distance from Sign (ft).

Response Last_Glance_Distance_from_Sign_(ft)

Summary of Fit

RSquare	0.340821
RSquare Adj	0.329686
Root Mean Square Error	60.12794
Mean of Response	92.13947
Observations (or Sum Wgts)	603

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Participant	0.3102006	1121.4898	336.41944	462.11986	1780.8598	23.676
Residual		3615.3694	216.11474	3226.5479	4079.3547	76.324
Total		4736.8593	392.38427	4052.9113	5610.8149	100.000

-2 LogLikelihood =
6658.2663358
Note: Total is the sum of the positive variance components.

Total including negative estimates =
4736.8593

Fixed Effect Tests

Source	Nparm	DF	DFDen	F Ratio	Prob > F
Logo Presence	1	1	560.5	43.9112	<.0001*
Sign_Type	1	1	561	16.7316	<.0001*
Age_Group	1	1	33.09	6.8763	0.0131*
Gender	1	1	33.08	0.0205	0.8869
Age_Group*Gender	1	1	31.83	0.0774	0.7827
Age_Group*Sign_Type	1	1	561.3	1.0966	0.2955
Age_Group*Logo Presence	1	1	560.6	1.1268	0.2889
Gender*Sign_Type	1	1	561.2	0.0195	0.8890
Gender*Logo Presence	1	1	560.5	0.0129	0.9095
Sign_Type*Logo Presence	1	1	560.3	0.9534	0.3293

Effect Details

Logo Presence

Least Squares Means Table

Level	Least Sq Mean	Std Error
0	114.16926	7.1722999
1	79.15852	6.5012539

Sign_Type

Least Squares Means Table

Level	Least Sq Mean	Std Error
S	85.86089	6.8338254
T	107.46690	6.8556614

Age_Group

Least Squares Means Table

Level	Least Sq Mean	Std Error
Old	80.10286	9.5575683
Young	113.22492	8.2568608

Gender

Least Squares Means Table

Level	Least Sq Mean	Std Error
0	97.568955	8.2621485
1	95.758829	9.5521273

Age_Group*Gender
Least Squares Means Table

Level	Least Sq Mean	Std Error
Old,0	79.26794	11.641531
Old,1	80.93779	15.096686
Young,0	115.86997	11.678873
Young,1	110.57987	11.627562

Age_Group*Sign_Type
Least Squares Means Table

Level	Least Sq Mean	Std Error
Old,S	71.92351	10.288927
Old,T	88.28222	10.338599
Young,S	99.79827	8.933170
Young,T	126.65157	8.916506

Age_Group*Logo Presence
Least Squares Means Table

Level	Least Sq Mean	Std Error
Old,0	94.79491	10.852520
Old,1	65.41082	9.841771
Young,0	133.54361	9.390941
Young,1	92.90623	8.498747

Gender*Sign_Type
Least Squares Means Table

Level	Least Sq Mean	Std Error
0,S	87.11528	8.929303
0,T	108.02263	8.941261
1,S	84.60650	10.292115
1,T	106.91116	10.312208

Gender*Logo Presence
Least Squares Means Table

Level	Least Sq Mean	Std Error
0,0	114.77355	9.406833
0,1	80.36436	8.503121
1,0	113.56497	10.833761
1,1	77.95269	9.837159

Sign_Type*Logo Presence
Least Squares Means Table

Level	Least Sq Mean	Std Error
S,0	100.82841	8.2834401
S,1	70.89336	7.2100358
T,0	127.51011	8.4041888
T,1	87.42368	7.1490089

To see whether the removal of the two-way interaction effects from the model will change the results, the two-way interaction effects were removed from the model, and the data were refitted with the model without the interaction effects. Table 19 contains the results of fitting the mixed effects ANOVA model with main effects only to Last Glance Distance from Sign (ft). As can be seen from Table 19, the effects of Logo Presence, Sign Type (S or T), and Age Group are statistically significant at the 5 percent significance level. The effect of Gender is not statistically significant. Table 19 also presents the predicted values (Least Squares Means) for Last Glance Distance from Sign (ft) for each level of factors in the model along with their standard errors (in Effect Details). The predicted Last Glance Distance from Sign (ft) is significantly lower when the logo is present compared to when the logo is not present, which suggests that the sponsored logo CMS continues to attract the driver's attention beyond the traditional last look distance. Table 19 also shows that Sign Type=S leads to lower predicted Last Glance Distance from Sign (ft) compared to Sign Type=T, and Old drivers are also associated with lower predicted Last Glance Distance from Sign (ft) compared to Young drivers. The predicted values in Table 19 may be compared to those in Table 18 for the main effects. It can be noted that, for Last Glance Distance from Sign (ft), the predicted values for the main effects are not really affected whether or not the interaction effects are included in the model.

Table 19. Mixed Effects ANOVA for Last Glance Distance from Sign (ft) with Only Main Effects including Logo Presence.

Response Last_Glance_Distance_from_Sign_(ft)

Summary of Fit

RSquare	0.336604
RSquare Adj	0.332167
Root Mean Square Error	60.03914
Mean of Response	92.13947
Observations (or Sum Wgts)	603

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Participant	0.3008043	1084.3089	321.91128	453.37438	1715.2434	23.124
Residual		3604.6984	214.52238	3218.5998	4065.0731	76.876
Total		4689.0073	379.24489	4026.2016	5531.0375	100.000

-2 LogLikelihood =
6685.7710824
Note: Total is the sum of the positive variance components.

Total including negative estimates =
4689.0073

Fixed Effect Tests

Source	Nparm	DF	DFDen	F Ratio	Prob > F
Logo Presence	1	1	565.3	47.4142	<.0001*
Sign_Type	1	1	566	17.7026	<.0001*
Age_Group	1	1	32.79	6.8367	0.0134*
Gender	1	1	32.78	0.0437	0.8357

Effect Details
Logo Presence
Least Squares Means Table

Level	Least Sq Mean	Std Error
0	114.32592	7.0048773
1	78.60340	6.3412081

Sign_Type
Least Squares Means Table

Level	Least Sq Mean	Std Error
S	86.14753	6.6256016
T	106.78179	6.6294368

Age_Group
Least Squares Means Table

Level	Least Sq Mean	Std Error
Old	80.51328	9.1955701
Young	112.41604	8.1055091

Gender
Least Squares Means Table

Level	Least Sq Mean	Std Error
0	97.740061	8.1097152
1	95.189259	9.1909355

Researchers also refitted the models in Table 18 and Table 19 after eliminating three apparent outliers from the data. The results did not change noticeably, however. The statistical significance of the factors and predicted values stayed materially the same as those in Table 18 and Table 19.

APPENDIX D. DETAILED TREATMENT INFORMATION

Appendix D provides additional details on the treatments at each of the study site locations. A separate table is provided for the Atlanta (Table 20) and Austin Districts (Table 21).

Table 20. Atlanta District Detailed Treatment Information.

Roadway	Location	Road Surface	Rumble Design					
			Location	Style	Spacing (in.)	Length (in.)	Width (in.)	Height (in.)
US79	West of Carthage	Seal coat in good shape	Edge Line	Inverted Profile w/ Audible	16	2	6	0.3
			Shoulder	SRS	12	7.5	16	0.375
			Center	CLRS	24	7.5	16	0.375
US79	East of DeBerry	New Asphalt	Edge Line	ELRS + Rumble Bars	Rumble @ 12, Bars @ 60	Rumble @ 7.5, Bars @ 2	Rumble @ 16, Bars @ 10	Rumble @ 0.375, Bars @ 0.5
			Center	CLRS + Rumble Bars	Rumble @ 24, Bars @ 48	Rumble @ 7.5, Bars @ 2	Rumble @ 16, Bars @ 10	Rumble @ 0.375, Bars @ 0.5
US80	East of Marshall	Seal coat in good shape	Shoulder	Rumble Bars	55	2	10.75	0.5
			Center	Rumble Bars	60	2	10.75	0.5
			Center Line	Inverted Profile w/ Audible	16	2	4	0.3
US59	South of Atlanta	PCC	Edge Line	Inverted Profile w/ Audible	16	2	6	0.3
			Shoulder	SRS	12	7.5	16	0.375
SH43	South of Atlanta	Seal coat in good shape	Center Line	Profile Marking + Rumble Bars (Rumble Bars Only in Two-Way Passing Areas)	Marking @ 18, Bars @ 30	Marking @ 2.5, Bars @ 2	Marking @ 4, Bars @ 10.5	Marking @ 0.4, Bars @ 0.5
FM2328	Between US59 and SH43	Seal coat in good shape	Center	Rumble Bars	48	2.25	11	0.5
FM3129	North of Atlanta	Seal coat in good shape	Edge Line	Inverted Profile w/ Audible	16	2	4	0.3
			Center Line	Inverted Profile w/ Audible + Rumble Bars	Marking @ 16, Bars @ 60	Marking @ 2, Bars @ 2.25	Marking @ 4, Bars @ 11	Marking @ 0.25, Bars @ 0.5

Table 21. Austin District Detailed Treatment Information.

Roadway	Location	Road Surface	Rumble Design					
			Location	Style	Spacing (in.)	Length (in.)	Width (in.)	Height (in.)
US290	By Manor	New Asphalt	Edge Line (Right)	Circular Profile Humps	14	5	4	0.4
			Edge Line (Left)	Circular Profile Humps	14	5	4	0.4
US290	By Manor	Sealcoat	Edge Line (Right)	Circular Profile Humps	12	5	4	0.3
			Edge Line (Left)	Circular Profile Humps	12	5	4	0.3
FM12	North of Dripping Springs	Old Asphalt	Center Line	Square Profile Humps	12	3.5	3.5	0.3
FM12	South of Dripping Springs	New Asphalt	Edge Line	Circular Profile Humps	12	5	4	0.35
			Center Line	Circular Profile Humps	12	4	3.5	0.35

APPENDIX E. DETAILED DATA SUMMARY

Appendix E provides additional details on the data collected at each of the study site locations. Separate tables are provided for the Atlanta (Table 22–Table 27) and Austin Districts (Table 28–Table 30).

Table 22. Atlanta District US 79 Carthage Site.

Roadway	Road Surface	Rumble Design		Vehicle		Interior Sound (dB)			Interior Vibration (g)			Exterior Sound (dB)
		Location	Style	Type	Speed (mph)	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum
US 79 West of Carthage	Seal coat in good shape	In Lane	N/A	Ford Fusion	55	74.0	66.0	69.0	0.07181	0.00149	0.02179	-
		Edge Line	Inverted Profile w/ Audible	Ford Fusion	55	80.9	74.0	77.2	0.12359	0.00049	0.04142	-
		Shoulder	SRS	Ford Fusion	55	85.7	84.0	84.7	0.23730	0.00290	0.10304	-
		Center	CLRS	Ford Fusion	55	81.2	77.3	79.2	0.17093	0.00093	0.05881	-
		In Lane	N/A	Ford Fusion	70	71.2	68.2	69.7	0.11457	0.00037	0.02798	-
		Edge Line	Inverted Profile w/ Audible	Ford Fusion	70	85.5	79.4	83.2	0.15607	0.00077	0.03895	-
		Shoulder	SRS	Ford Fusion	70	83.0	80.5	82.3	0.17695	0.00105	0.07915	-
		Center	CLRS	Ford Fusion	70	91.2	78.4	85.9	0.19880	0.00040	0.06728	-
		In Lane	N/A	Ford F150	55	65.2	61.8	63.6	0.08630	0.00140	0.02650	71.6
		Edge Line	Inverted Profile w/ Audible	Ford F150	55	76.2	68.2	73.7	0.12066	0.00056	0.03777	75.1
		Shoulder	SRS	Ford F150	55	74.6	71.9	73.3	0.11011	0.00119	0.02714	79.9
		Center	CLRS	Ford F150	55	72.4	69.1	71.2	0.14569	0.00081	0.03500	72.4
		In Lane	N/A	Ford F150	70	67.6	65.3	67.0	0.16489	0.00079	0.02348	74.1
		Edge Line	Inverted Profile w/ Audible	Ford F150	70	76.2	69.6	73.1	0.08894	0.00104	0.02517	86.3
		Shoulder	SRS	Ford F150	70	84.4	77.0	82.0	0.10498	0.00052	0.02775	85.6
		Center	CLRS	Ford F150	70	75.1	70.0	72.5	0.16338	0.00072	0.03833	76.0

Table 23. Atlanta District US 79 DeBerry Site.

Roadway	Road Surface	Rumble Design		Vehicle		Interior Sound (dB)			Interior Vibration (g)			Exterior Sound (dB)
		Location	Style	Type	Speed (mph)	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum
US 79 East of DeBerry	New Asphalt	In Lane	N/A	Ford Fusion	55	61.1	59.0	60.0	0.07068	0.00038	0.01860	69.8
		Edge Line	ELRS + Rumble Bars	Ford Fusion	55	85.9	83.6	84.8	0.32018	0.00213	0.10273	80.5
		Center	CLRS + Rumble Bars	Ford Fusion	55	83.5	79.7	81.9	0.27646	0.00106	0.08234	72.9
		In Lane	N/A	Ford Fusion	70	65.1	62.1	63.3	0.10402	0.00142	0.02564	72.3
		Edge Line	ELRS + Rumble Bars	Ford Fusion	70	88.4	85.1	86.9	0.35221	0.00239	0.13049	89.1
		Center	CLRS + Rumble Bars	Ford Fusion	70	86.7	80.6	84.2	0.44778	0.00228	0.14157	80.3
		In Lane	N/A	Ford F150	55	61.6	58.5	60.0	0.07368	0.00038	0.01893	70.0
		Edge Line	ELRS + Rumble Bars	Ford F150	55	77.5	74.1	76.2	0.16750	0.00050	0.04716	81.8
		Center	CLRS + Rumble Bars	Ford F150	55	75.0	71.1	73.6	0.19770	0.00140	0.07219	73.6
		In Lane	N/A	Ford F150	70	63.7	61.9	62.8	0.08143	0.00067	0.02562	71.1
		Edge Line	ELRS + Rumble Bars	Ford F150	70	84.4	81.3	83.3	0.14581	0.00069	0.03737	97.0
		Center	CLRS + Rumble Bars	Ford F150	70	79.1	74.5	77.3	0.12450	0.00140	0.03553	81.2

Table 24. Atlanta District US 80 Site.

Roadway	Road Surface	Rumble Design		Vehicle		Interior Sound (dB)			Interior Vibration (g)			Exterior Sound (dB)
		Location	Style	Type	Speed (mph)	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum
US 80 East of Marshall	Seal coat in good shape	In Lane	N/A	Ford Fusion	55	72.4	69.6	70.9	0.16550	0.00140	0.04198	-
		Shoulder	Rumble Bars	Ford Fusion	55	82.7	73.3	77.7	0.28348	0.00072	0.05438	-
		Center	Rumble Bars	Ford Fusion	55	87.4	75.9	80.1	0.25702	0.00212	0.10627	-
		Center Line	Inverted Profile w/ Audible	Ford Fusion	55	74.0	70.1	72.2	0.10043	0.00083	0.02776	-
		In Lane	N/A	Ford Fusion	70	77.3	71.8	73.6	0.21064	0.00036	0.04395	-
		Shoulder	Rumble Bars	Ford Fusion	70	86.1	79.9	82.3	0.27519	0.00022	0.06297	-
		Center	Rumble Bars	Ford Fusion	70	86.5	75.4	81.5	0.27700	0.00160	0.09798	-
		In Lane	N/A	Ford F150	55	68.3	67.1	67.7	0.17159	0.00131	0.03827	77.6
		Shoulder	Rumble Bars	Ford F150	55	75.1	70.8	72.6	0.24224	0.00096	0.06986	79.0
		Center	Rumble Bars	Ford F150	55	74.4	70.4	72.3	0.23142	0.00008	0.06026	75.7
		Center Line	Inverted Profile w/ Audible	Ford F150	55	71.8	66.9	69.0	0.08738	0.00052	0.02384	-
		In Lane	N/A	Ford F150	70	71.4	70.0	70.7	0.16363	0.00047	0.03870	81.8
		Shoulder	Rumble Bars	Ford F150	70	76.2	72.9	75.0	0.20721	0.00079	0.05383	82.9
		Center	Rumble Bars	Ford F150	70	76.4	73.8	75.4	0.26791	0.01213	0.05897	79.8

Table 25. Atlanta District US 59 Site.

Roadway	Road Surface	Rumble Design		Vehicle		Interior Sound (dB)			Interior Vibration (g)			Exterior Sound (dB)
		Location	Style	Type	Speed (mph)	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum
US 59 South of Atlanta	PCC	In Lane	N/A	Ford Fusion	55	66.9	63.2	64.5	0.08729	0.00071	0.03027	76.4
		Edge Line	Inverted Profile w/ Audible	Ford Fusion	55	75.7	71.2	73.0	0.11418	0.00016	0.03673	83.8
		Shoulder	SRS	Ford Fusion	55	83.6	80.0	81.5	0.25458	0.00258	0.09012	82.3
		In Lane	N/A	Ford Fusion	70	67.7	64.4	66.2	0.12584	0.00016	0.03307	79.0
		Edge Line	Inverted Profile w/ Audible	Ford Fusion	70	82.7	76.1	79.3	0.14196	0.00164	0.03900	87.3
		Shoulder	SRS	Ford Fusion	70	80.1	75.2	78.2	0.38968	0.00012	0.15375	81.5
		In Lane	N/A	Ford F150	55	63.6	61.0	62.6	0.12057	0.00047	0.02984	72.2
		Edge Line	Inverted Profile w/ Audible	Ford F150	55	74.1	71.2	72.8	0.12691	0.00091	0.03596	81.0
		Shoulder	SRS	Ford F150	55	80.5	76.1	78.6	0.10237	0.00013	0.03154	89.7
		In Lane	N/A	Ford F150	70	68.5	65.0	66.7	0.12097	0.00077	0.03484	76.9
		Edge Line	Inverted Profile w/ Audible	Ford F150	70	77.0	72.6	75.3	0.13629	0.00149	0.03609	83.7
		Shoulder	SRS	Ford F150	70	86.8	85.2	86.2	0.14326	0.00024	0.03239	92.8

Table 26. Atlanta District SH 43 and FM 2328 Sites.

Roadway	Road Surface	Rumble Design		Vehicle		Interior Sound (dB)			Interior Vibration (g)			Exterior Sound (dB)
		Location	Style	Type	Speed (mph)	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum
SH 43 South of Atlanta	Seal coat in good shape	In Lane	N/A	Ford Fusion	55	69.5	64.6	66.3	0.09457	0.00077	0.02632	69.6
		Center Line	Profile Marking + Rumble Bars	Ford Fusion	55	82.7	75.5	78.2	0.20823	0.00013	0.05862	71.7
		In Lane	N/A	Ford Fusion	70	70.0	65.6	67.9	0.15348	0.00118	0.03178	73.9
		Center Line	Profile Marking + Rumble Bars	Ford Fusion	70	82.9	74.5	78.9	0.20846	0.00036	0.06044	77.8
		In Lane	N/A	Ford F150	55	64.3	60.8	63.1	0.07435	0.00115	0.02054	68.2
		Center Line	Profile Marking + Rumble Bars	Ford F150	55	74.5	69.6	72.0	0.17393	0.00103	0.05385	72.3
		In Lane	N/A	Ford F150	70	68.4	65.5	66.8	0.09158	0.00078	0.02628	74.7
		Center Line	Profile Marking + Rumble Bars	Ford F150	70	76.7	72.6	75.2	0.20211	0.00281	0.04844	79.7
FM 2328 Between US 59 and SH 43	Seal coat in good shape	In Lane	N/A	Ford Fusion	55	69.7	66.3	67.8	0.09949	0.00011	0.03183	67.6
		Center	Rumble Bars	Ford Fusion	55	88.4	80.1	84.3	0.22542	0.00018	0.06468	74.0
		In Lane	N/A	Ford Fusion	70	73.3	70.0	71.8	0.17580	0.00010	0.04520	71.7
		Center	Rumble Bars	Ford Fusion	70	86.3	79.1	82.2	0.22997	0.00137	0.07748	78.2
		In Lane	N/A	Ford F150	55	66.8	63.7	66.0	0.13071	0.00119	0.03259	68.6
		Center	Rumble Bars	Ford F150	55	74.0	70.7	72.6	0.21828	0.00148	0.06291	77.6
		In Lane	N/A	Ford F150	70	70.1	68.2	69.4	0.16227	0.00117	0.04073	73.3
		Center	Rumble Bars	Ford F150	70	77.9	74.5	76.6	0.18781	0.00031	0.05618	83.9

Table 27. Atlanta District FM 3129 Site.

Roadway	Road Surface	Rumble Design		Vehicle		Interior Sound (dB)			Interior Vibration (g)			Exterior Sound (dB)
		Location	Style	Type	Speed (mph)	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum
FM 3129 North of Atlanta	Seal coat in good shape	In Lane	N/A	Ford Fusion	55	65.2	62.3	63.7	0.12163	0.00147	0.02578	71.0
		Edge Line	Inverted Profile w/ Audible	Ford Fusion	55	73.4	70.9	72.2	0.13263	0.00083	0.03573	77.1
		Center Line	Inverted Profile w/ Audible + Rumble Bars	Ford Fusion	55	77.1	73.9	75.0	0.27641	0.00391	0.09088	71.1
		In Lane	N/A	Ford Fusion	70	67.9	65.7	66.8	0.10372	0.00112	0.03354	72.2
		Edge Line	Inverted Profile w/ Audible	Ford Fusion	70	80.2	74.8	78.0	0.11560	0.00130	0.03890	80.2
		Center Line	Inverted Profile w/ Audible + Rumble Bars	Ford Fusion	70	84.6	76.8	80.5	0.26899	0.00061	0.07852	75.2
		In Lane	N/A	Ford F150	55	62.5	59.8	60.7	0.09123	0.00257	0.03058	69.0
		Edge Line	Inverted Profile w/ Audible	Ford F150	55	70.6	67.2	68.7	0.12815	0.00075	0.03328	77.1
		Center Line	Inverted Profile w/ Audible + Rumble Bars	Ford F150	55	71.8	68.8	70.0	0.19676	0.00036	0.07083	73.4
		In Lane	N/A	Ford F150	70	64.9	63.5	64.3	0.17658	0.00078	0.04344	72.5
		Edge Line	Inverted Profile w/ Audible	Ford F150	70	71.5	70.2	70.7	0.13510	0.00030	0.03683	80.8
		Center Line	Inverted Profile w/ Audible + Rumble Bars	Ford F150	70	74.1	71.1	72.5	0.21818	0.00152	0.05580	76.7

Table 28. Austin District US 290 Asphalt Site.

Roadway	Road Surface	Rumble Design		Vehicle		Interior Sound (dB)			Interior Vibration (g)		
		Location	Style	Type	Speed (mph)	Maximum	Minimum	Average	Maximum	Minimum	Average
US 290 by Manor	New Asphalt	In Lane (Right)	N/A	Ford Fusion	55	62.3	59.9	60.9	0.08846	0.00056	0.02110
		Edge Line (Right)	Circular Profile Humps	Ford Fusion	55	88.2	71.9	78.3	0.23855	0.00125	0.04762
		In Lane (Left)	N/A	Ford Fusion	55	62.3	60.1	60.7	0.10472	0.00078	0.02477
		Edge Line (Left)	Circular Profile Humps	Ford Fusion	55	80.0	69.8	74.8	0.12184	0.00126	0.03313
		In Lane (Right)	N/A	Ford Fusion	70	65.1	62.8	64.1	0.09892	0.00068	0.02811
		Edge Line (Right)	Circular Profile Humps	Ford Fusion	70	83.1	70.9	79.6	0.19764	0.00134	0.06860
		In Lane (Left)	N/A	Ford Fusion	70	65.2	63.0	64.1	0.13537	0.00057	0.03511
		Edge Line (Left)	Circular Profile Humps	Ford Fusion	70	84.6	78.7	82.6	0.28657	0.00527	0.10245
		In Lane (Right)	N/A	Ford F150	55	61.6	60.0	60.8	0.14789	0.00139	0.02628
		Edge Line (Right)	Circular Profile Humps	Ford F150	55	78.8	70.7	75.1	0.20383	0.00129	0.05645
		In Lane (Left)	N/A	Ford F150	55	61.8	59.5	60.6	0.16408	0.00002	0.02851
		Edge Line (Left)	Circular Profile Humps	Ford F150	55	77.6	71.9	75.1	0.20907	0.00097	0.05441
		In Lane (Right)	N/A	Ford F150	70	66.6	64.2	65.2	0.10520	0.00030	0.02710
		Edge Line (Right)	Circular Profile Humps	Ford F150	70	82.3	73.0	76.2	0.14887	0.00063	0.04300
		In Lane (Left)	N/A	Ford F150	70	66.0	63.5	64.7	0.18182	0.00022	0.03805
		Edge Line (Left)	Circular Profile Humps	Ford F150	70	80.0	71.6	77.0	0.23100	0.00050	0.06517

Table 29. Austin District US 290 Seal Coat Site.

Roadway	Road Surface	Rumble Design		Vehicle		Interior Sound (dB)			Interior Vibration (g)		
		Location	Style	Type	Speed (mph)	Maximum	Minimum	Average	Maximum	Minimum	Average
US 290 by Manor	Seal Coat	In Lane (Right)	N/A	Ford Fusion	55	74.2	71.7	73.2	0.10694	0.00144	0.02781
		Edge Line (Right)	Circular Profile Humps	Ford Fusion	55	81.9	78.8	80.0	0.15680	0.00141	0.05792
		In Lane (Left)	N/A	Ford Fusion	55	74.6	72.8	73.9	0.14062	0.00008	0.03447
		Edge Line (Left)	Circular Profile Humps	Ford Fusion	55	78.6	76.6	77.5	0.13103	0.00087	0.03742
		In Lane (Right)	N/A	Ford Fusion	70	76.1	74.8	75.4	0.09744	0.00074	0.02986
		Edge Line (Right)	Circular Profile Humps	Ford Fusion	70	78.1	75.7	77.2	0.15788	0.00032	0.04037
		In Lane (Left)	N/A	Ford Fusion	70	78.0	75.5	76.4	0.12982	0.00092	0.03797
		Edge Line (Left)	Circular Profile Humps	Ford Fusion	70	79.2	75.9	78.1	0.18735	0.00025	0.04764
		In Lane (Right)	N/A	Ford F150	55	69.9	67.4	68.4	0.07924	0.00014	0.02517
		Edge Line (Right)	Circular Profile Humps	Ford F150	55	71.7	67.9	69.8	0.10550	0.00000	0.02659
		In Lane (Left)	N/A	Ford F150	55	69.7	68.4	68.8	0.11501	0.00071	0.02849
		Edge Line (Left)	Circular Profile Humps	Ford F150	55	71.2	69.4	70.3	0.11365	0.00065	0.03420
		In Lane (Right)	N/A	Ford F150	70	72.0	70.5	71.2	0.10050	0.00090	0.02722
		Edge Line (Right)	Circular Profile Humps	Ford F150	70	77.9	74.7	76.6	0.11734	0.00014	0.03385
		In Lane (Left)	N/A	Ford F150	70	73.1	71.0	72.1	0.09825	0.00135	0.03084
		Edge Line (Left)	Circular Profile Humps	Ford F150	70	77.0	72.5	74.6	0.17882	0.00012	0.04431

Table 30. Austin District FM 12 Sites.

Roadway	Road Surface	Rumble Design		Vehicle		Interior Sound (dB)			Interior Vibration (g)		
		Location	Style	Type	Speed (mph)	Maximum	Minimum	Average	Maximum	Minimum	Average
FM 12 North of Dripping Springs	Old Asphalt	In Lane	N/A	Ford Fusion	55	62.8	60.3	61.2	0.08829	0.00039	0.02302
		Center Line	Square Profile Humps	Ford Fusion	55	75.0	70.6	72.6	0.11030	0.00100	0.03939
		In Lane	N/A	Ford F150	55	61.2	57.9	59.1	0.11294	0.00136	0.02488
		Center Line	Square Profile Humps	Ford F150	55	70.0	64.2	67.8	0.10635	0.00085	0.03510
FM 12 South of Dripping Springs	New Asphalt	In Lane	N/A	Ford Fusion	55	60.8	59.5	60.2	0.09827	0.00134	0.02676
		Edgeline	Circular Profile Humps	Ford Fusion	55	80.0	72.0	76.1	0.16849	0.00149	0.06452
		Center line	Circular Profile Humps	Ford Fusion	55	75.9	71.3	73.1	0.10037	0.00077	0.03729
		In Lane	N/A	Ford Fusion	70	65.3	63.0	63.9	0.15612	0.00082	0.03824
		Edgeline	Circular Profile Humps	Ford Fusion	70	81.1	73.1	76.4	0.17526	0.00054	0.05841
		Center line	Circular Profile Humps	Ford Fusion	70	77.5	74.9	76.6	0.17612	0.00032	0.04517
		In Lane	N/A	Ford F150	55	57.1	54.6	55.8	0.09734	0.00064	0.02800
		Edgeline	Circular Profile Humps	Ford F150	55	69.5	64.4	66.4	0.12158	0.00138	0.03452
		Center line	Circular Profile Humps	Ford F150	55	72.0	65.7	70.0	0.12636	0.00036	0.03488
		In Lane	N/A	Ford F150	70	62.5	59.6	61.3	0.13515	0.00035	0.03260
		Edgeline	Circular Profile Humps	Ford F150	70	77.3	72.5	74.3	0.11892	0.00118	0.03920
		Center line	Circular Profile Humps	Ford F150	70	79.7	75.7	78.6	0.18957	0.00093	0.04243

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