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Traffic Control Device Analysis, Testing, and Evaluation Program: FY 2025 Activities

Technical Report 0-7198-R2

Cooperative Research Program

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16. Abstract

Traffic control devices are a primary means of communicating highway information to road users and play a key role in highway automation. The design, application, and maintenance of traffic control devices are under constant transformation as new technologies, methodologies, and policies are introduced. In addition, vehicle technologies and the roadway infrastructure industry are rapidly evolving, spurred by technology advancements, customer demand, changes in the vehicle fleet, and changes in national and state policies. This project provides the Texas Department of Transportation with a mechanism to conduct high-priority, limited-scope evaluations of issues related to traffic control devices.

Researchers conducted five activities during the 2025 fiscal year. Two of which were considered internal in nature, so those findings are not included herein. The remaining activities are ongoing and will be documented in future reports, as deemed appropriate. Research activities included in this report are:

- Evaluation of driveway assistance devices in lane closures on two-lane, two-way roads.
- Evaluation of motorist understanding of wait time display options for portable traffic signals.

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TRAFFIC CONTROL DEVICE ANALYSIS, TESTING, AND EVALUATION PROGRAM: FY 2025 ACTIVITIES

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DISCLAIMER

This research was sponsored by 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 FHWA or TxDOT. This report does not constitute a standard, specification, or regulation.

This report is not intended for construction, bidding, or permitting purposes. The engineer in charge of this project was Melisa D. Finley, P.E. #TX-90937.

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TABLE OF CONTENTS

LIST OF FIGURES

Page

LIST OF TABLES

Page

CHAPTER 1: INTRODUCTION

Traffic control devices are essential for conveying critical highway information to road users and serve as a foundational element in advancing highway automation. Their design, implementation, and maintenance are continually evolving in response to emerging technologies, innovative methodologies, and shifting policies. At the same time, rapid developments in vehicle technology and roadway infrastructure—driven by technological progress, customer expectations, fleet composition changes, and policy updates at both state and national levels—are reshaping the transportation landscape. This project equips the Texas Department of Transportation (TxDOT) with a flexible framework to conduct high-priority, targeted evaluations of traffic control device-related issues. Research activities conducted during the 2025 fiscal year (September 2024–August 2025) included:

- Evaluating driveway assistance devices (DADs) in lane closures on two-lane, two-way roads.
- Surveying TxDOT districts about their practices to deter pedestrians from crossing freeways.
- Reviewing existing guidance on raised crosswalks for pedestrian crossings with a focus on markings and other traffic control device treatments.
- Updating the TxDOT Pavement Marking Handbook.
- Investigating the possible use of milled transverse rumble strips in Texas.

The findings from the first activity are documented in this report. The synthesis of practices used by TxDOT districts to deter pedestrians from crossing freeways and the review of existing guidance on raised crosswalks for pedestrian crossings were considered internal in nature, so those findings are not included herein. The remaining activities are ongoing and will be documented in future reports, as deemed appropriate.

This report also documents a study on wait time display options for portable traffic signals that was completed in August 2023 under the previous Traffic Control Device Analysis, Testing, and Evaluation Program project (0-7096). During the 2025 fiscal year, the research team used unpublished findings from this study to help TxDOT develop policies regarding the use of wait time displays.

In addition to these activities, the research team finalized and published technical briefs documenting the safety effects of centerline buffers on two-lane and four-lane undivided roadways (0-7198-TB2 and 0-7198-TB1, respectively). The research team also developed and published a technical brief documenting a synthesis of practices to deter pedestrians from crossing freeways (0-7198-TB3).

CHAPTER 2: EVALUATION OF DRIVEWAY ASSISTANCE DEVICES

INTRODUCTION

In 2012, TxDOT and the Texas A&M Transportation Institute (TTI) developed DADs to control traffic entering from low-volume driveways when a lane is closed on a two-lane, two-way road for construction or maintenance activities (*1*). DADs work in synchronization with portable traffic signals (PTSs) placed at each end of the lane closure on the main road. TxDOT received approval to experiment with DADs from the Federal Highway Administration (FHWA) on June 27, 2013.

As of March 2024, TxDOT had approved the use of DADs on 26 projects, of which 12 projects have been completed, five projects are ongoing, five projects have not started, and four projects have decided not to use DADs. To date, TTI has collected and analyzed data for 11 projects. This chapter documents the findings from field studies conducted between June 2024 to September 2024. Background on the development and application of DADs by TxDOT and results from prior studies conducted from March 2019 to December 2023 can be found in previous research reports (*2*, *3*, *4*).

On January 8, 2025, FHWA published the MUTCD—Interim Approval for Optional Use of Residential Driveway Temporary Signal (IA-23) (*5*). A residential driveway temporary signal (RDTS) is similar in design to the three-section doghouse DADs evaluated in Texas with a few exceptions. The most notable difference is the addition of a steady yellow change interval following the flashing yellow arrow. In addition, the interim approval requires the use of a NO TURN ON RED sign (R10-11b) with a regulatory plaque displaying the legend TURN ONLY IN DIRECTION OF ARROW. The interim approval also limits RDTS applications to residential driveways.

Since this report documents the implementation and evaluation of DADs prior to the publication of IA-23, the term DAD is still used herein.

FIELD STUDY SITES

Between June 2024 and September 2024, TTI researchers documented and evaluated the use of DADs on four projects in Texas. This section contains information about the projects and data collection methodology.

Project 9 FM 2688 CSJ 2660-01-012

Project 9 involved rehabilitating FM 2688 in Dimmit County from about 4.5 miles west of US 83 to 8.7 miles west of US 83 (approximately 4 miles). TTI began discussions with local TxDOT staff and the contractor in July 2023 but were not able to collect data until June 2024. The DAD design for this project was the four-head stacked DAD, which included two 12-inch steady red arrow indications and two 12-inch flashing yellow indications. The steady red arrows indicated which direction a driver could not turn, while the flashing yellow arrows indicated which direction a driver could turn. During the all-red phase, both steady red arrows were illuminated. Since the four-section stacked DAD displayed steady red arrow indications, a modified R10-11 sign was included with a second supplemental sign (WAIT TURN ONLY IN DIRECTION OF FLASHING YELLOW ARROW) (see Figure 1).

Figure 1. Four-Section Stacked DAD Deployed on FM 2688 at D9.

Figure 2 shows the section of roadway under construction in June 2024. The one-lane section was approximately 1.7 miles long and controlled by PTSs (see white pins with squares in Figure 2). DADs were used at two locations for three driveways, with one of the DADs serving two of those driveways (see pink pins with circle and aqua pin with diamond in Figure 2). The three driveways provided access to oil and gas operations, as well as industry and businesses. TTI collected data at D9 (aqua pin with diamond in Figure 2), which had highly variable cycle times for both eastbound and westbound, but overall, both cycles averaged approximately 4 minutes and 36 seconds. The average red time was 3 minutes and 53 seconds, and the average green time was 43 seconds.

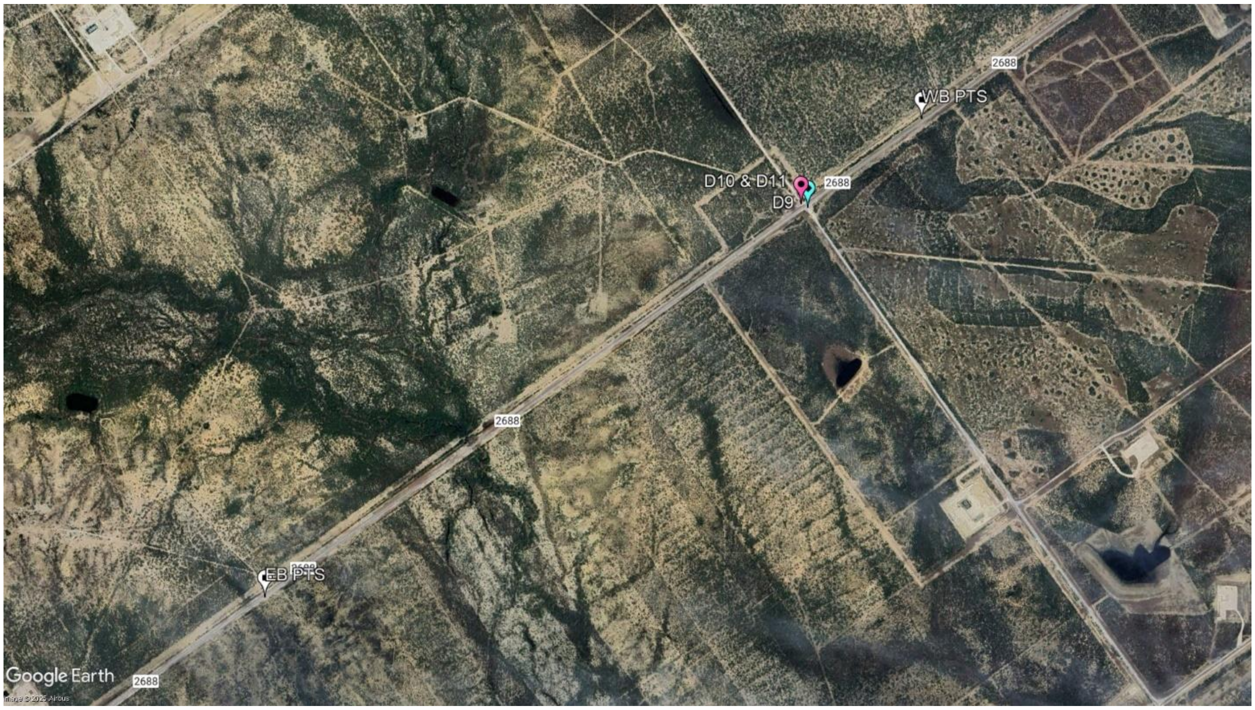

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Figure 2. Project 9 FM 2688 June 2024 One-Lane Study Section.

On June 4–6, 2024, TTI researchers observed traffic approaching FM 2688 from D9. The driveway was located approximately 0.3 miles from the westbound PTS and approximately 1.4 miles from the eastbound PTS. Although D9 was located near the westbound PTS, drivers approaching FM 2866 from D9 could not see the westbound PTS. At D9, the DAD was located on the nearside of the intersection, and construction was occurring in the eastbound lane (see Figure 3). Data collection began at 11:06 a.m. on Tuesday and ended at 10:05 a.m. on Thursday.

Figure 3. DAD at D9 Looking Westbound.

Project 15 FM 730 CSJ 0312-04-022

Project 15 involved the rehabilitation of existing sections of FM 730 in Wise County from SH 114 in Boyd, Texas, to just south of the intersection of FM 730 with CR 4384 (approximately 3.5 miles). The DAD design for this project was the three-section doghouse design, which includes two 12-inch flashing yellow indications, a single 12-inch solid red indication, a R10-11a sign, and a second supplemental sign (WAIT TURN ONLY IN DIRECTION OF FLASHING YELLOW ARROW) (see Figure 4).

Figure 4. Three-Section Doghouse DAD Deployed on FM 730 at D18.

TTI researchers collected data at two different DADs (D21 and D18) in July and September 2024, respectively. Figure 5 shows the section of roadway under construction in July 2024 and the location of D21 (see aqua pin with diamond). The one-lane section was controlled by PTSs and was approximately 0.54 miles (see white pins with squares in Figure 5). This section included five DADs deployed at five private driveways (see pink pins with circles and aqua pin with diamond in Figure 5). Four of the driveways served residences (see pink pins with circles in Figure 5). The DAD deployed at D21 served a driveway that led to multiple oil and gas pads (see aqua pin with diamond in Figure 5). The intersection of FM 730 and CR 4460, in the middle of the one-way section, was closed and CR 4460 traffic was detoured. For the D21 DAD, the eastbound and westbound cycle times were approximately the same at 2 minutes and 4 seconds. The red time was 1 minute and 20 seconds, while the green time was 44 seconds.

On July 9–11, 2024, TTI researchers observed traffic approaching FM 730 from D21. The driveway was located approximately 545 feet from the southbound PTS and approximately 2,257 feet from the northbound PTS. Vehicles entering FM 730 from D21 could see the southbound PTS and queue associated with it, if any. At D21, the DAD was located on the nearside of the driveway, and construction was occurring in the northbound lane (see Figure 6). Data collection began at 10:24 a.m. on Tuesday and ended at 10:09 a.m. on Thursday.

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Figure 5. Project 15 FM 730 July 2024 One-Lane Study Section.

Figure 6. DAD at D21 Looking Southbound.

Figure 7 shows the section of roadway under construction in September 2024 and the location of D18 (see aqua pin with diamond). The one-lane section was controlled by PTSs and was approximately 0.48 miles (see white pins with squares in Figure 7). This section included four DADs deployed at four private driveways (see pink pins with circles and aqua pin with diamond in Figure 7). The DAD deployed at D18 served a driveway that led to multiple oil and gas pads and private residences. The intersection of FM 730 and CR 4360, in the middle of the one-way section, was closed and CR 4360 traffic was detoured. For the D18 DAD, the eastbound and westbound cycle times were approximately the same at 2 minutes and 4 seconds. The red time was 1 minute and 20 seconds, while the green time was 44 seconds.

(Source: © 2025 Google Earth Pro)

Figure 7. Project 15 FM 730 September 2024 One-Lane Study Section.

On September 24–26, 2024, TTI researchers observed traffic approaching FM 730 from D18. The driveway was located approximately 2,328 feet from the southbound PTS and approximately 235 feet from the northbound PTS. Vehicles entering FM 730 from D18 could clearly see the northbound PTS and any queue that might be associated with it. At D18, the DAD was located on the nearside of the driveway, and construction was occurring in the southbound lane (see Figure 8). Data collection began at 1:40 p.m. on Tuesday and ended at 4:27 p.m. on Thursday.

Figure 8. DAD at D18 Looking Southbound.

Project 16 FM 46 CSJ 0540-02-027

Project 16 entailed a bridge replacement taking place at a section of FM 46 that intersects with Cedar Creek in Franklin County just southeast of Franklin, Texas. The work zone and one-lane section spanned the bridge plus additional space around the bridge for an approximate total length of 0.2 miles. The DAD design for this project was the three-section doghouse, which included two 12-inch flashing yellow indications, a single 12-inch solid red indication, a R10-11a sign, and a second supplemental sign (TURN ONLY IN DIRETION OF ARROW) (see Figure 9). However, the red ball graphic on the R10-11a sign was covered by the second supplemental sign (see Figure 9).

Figure 10 shows the section of roadway under construction in September 2024. The one-lane section was controlled by PTSs and was approximately 955 feet long (see white pins with squares in Figure 10). Two DADs were used for this project, one on each side of the bridge (see pink pin with circle and aqua pin with diamond in Figure 10). The DAD deployed at the southern end of the bridge (D2) provided access to a single oil pad, while the DAD deployed on the northern end of the bridge (D1) serviced multiple oil pads and residences. TTI collected data at D1 (see aqua pin with diamond in Figure 10), and the northbound and southbound cycle times were both approximately 1 minute and 8 seconds. The average red time was approximately 39 seconds, and the average green time was approximately 30 seconds.

Figure 9. DAD at D1.

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Figure 10. Project 16 FM 46 September 2024 One-Lane Study Section.

On September 17–19, 2024, TTI researchers observed traffic approaching FM 46 from D1. This driveway was located approximately 55 feet from the southbound PTS and approximately 900 feet from the northbound PTS. The DAD located at D1 was on the nearside of the intersection with FM 46, with construction occurring south of the DAD's location in the southbound lane (see Figure 11 and Figure 12). Vehicles entering FM 46 from D1 could see the southbound PTS and associated queue (if present) with ease due to the proximity of the PTS in relation to the driveway. However, vehicles entering FM 46 from D1 could not see the northbound PTS due to the presence of vegetation and a slight horizontal curve in the southbound direction on the south side of the bridge. Data collection began at 2:15 p.m. on Tuesday and ended at 2:08 p.m. on Thursday.

Figure 11. DAD at D1 from Approaching Traffic Viewpoint.

Figure 12. DAD at D1 Looking Southbound.

Project 25 RM 1376 CSJ 1899-02-021

Project 25 involved several safety improvement projects along a north-south stretch of RM 1376 in Kendall County from RM 473 to 0.8 miles south of Upper Sisterdale Road (approximately 3 miles). TTI began discussions with TxDOT staff and the contractor in April 2024 but were unable to collect data until September 2024 during Phase 4 of the project. The DAD design used for this project was the three-section doghouse, which included two 12-inch flashing yellow indications, a single 12-inch solid red indication, a modified R10-11 sign, and a second supplemental sign (YIELD IN DIRECTION OF FLASHING YELLOW ARROW) (see Figure 13).

Figure 13. DAD Deployed on RM 1376 at D3.

Figure 14 shows the section of roadway under construction in September 2024. The one-lane section was approximately 1 mile long and controlled by PTSs (see white pins with squares in Figure 14). Three DADs were used at three driveways, all serving private residences (see pink pins with circles and aqua pin with diamond in Figure 14). TTI collected data at the southernmost DAD (D3) (see aqua pin with diamond in Figure 14). High variability was present in the cycle times both for the southbound and northbound cycles. On average, a total cycle lasted approximately 3 minutes and 26 seconds. The average red time was approximately 2 minutes and 52 seconds, while average green time was 29 seconds.

(Source: © 2025 Google Earth Pro)

Figure 14. Project 25 RM 1376 September 2024 One-Lane Study Section.

On September 10–12, 2024, TTI researchers observed traffic approaching RM 1376 from D3. The driveway was located approximately 0.25 miles from the northbound PTS and approximately 0.75 miles from the southbound PTS. Vehicles entering RM 1376 from the driveway could not see either PTS due to horizontal curvature, vegetation, and distance from the driveway to either PTS. At D3, the DAD was located on the nearside of the driveway's intersection with RM 1376, and construction was occurring in the southbound lane (see Figure 15). Data collection began at 10:42 a.m. on Tuesday and ended at 6:14 a.m. on Thursday.

Figure 15. DAD at D3 from Approaching Traffic Viewpoint.

FIELD STUDY RESULTS

For each site, researchers computed the hours of study, number of minor approaches vehicles, number of stop cycles, number of violations, and a violation rate (i.e., number of violations per 100 stop cycles). Researchers also described each violation in detail and then categorized the violation into one of the following categories:

- *Turned on Red Prior to Flashing Yellow Arrow—Same Direction.* Driver arrived when the DAD displayed a flashing yellow arrow or just as the DAD displayed the red indication. Driver wanted to turn in the opposite direction of travel from the last flashing yellow arrow. After the DAD turned red and the vehicles on the main road passed by, the driver turned in the desired direction of travel prior to the display of the flashing yellow arrow for that direction. Researchers did not consider this maneuver to be an unsafe driving action.
- *Turned on Red to Join Main Road Traffic—Same Direction.* Driver arrived when the DAD displayed a flashing yellow arrow or just as the DAD displayed the red indication. After the DAD displayed the red indication, the driver turned in the direction of the last flashing yellow arrow. In most cases, the driver was waiting for a gap in the main road traffic or to join the end of the platoon. Researchers did not consider this maneuver to be an unsafe driving action.
- *Turned on Red—Opposite Direction.* Driver arrived when the DAD displayed the red indication. Driver turned either right or left on red in the opposite direction of the subsequent flashing yellow arrow. Researchers considered this maneuver to be an unsafe driving action.
- *Turned in Opposite Direction of Flashing Yellow Arrow.* While the DAD displayed a right or left flashing yellow arrow, the driver turned in the opposite direction of travel. Researchers considered this maneuver to be an unsafe driving action.

Project 9 FM 2688 CSJ 2660-01-012

Over the 46 hours, 52 minutes, and 24 seconds of data collection at D9, 17 vehicles arrived at the DAD, and 15 of those vehicles (88.2 percent) did not comply with the DAD. Of those 15 violations, 10 (67 percent) were related to joining the queue, four (27 percent) were related to "jumping" the left flashing yellow arrow to get ahead of the main lane traffic queue, and one (6 percent) was a flashing yellow arrow violation. Overall, the violation rate for this site was 2.45 violations per 100 stop cycles (15 violations divided by 613 stop cycles multiplied by 100).

Project 15 FM 730 CSJ 0312-04-022

Over 47 hours and 44 minutes of data were collected at D21 on FM 730. During this time, six vehicles arrived at the DAD. Only one driver (17 percent) did not comply with the DAD, and this was due to a red violation (i.e. the driver turned on red in the opposite direction of subsequent/next flashing yellow arrow), which was considered an unsafe driving action. Overall, the violation rate for this site was 0.07 violations per 100 stop cycles (1 violation divided by 1,357 stop cycles multiplied by 100).

Over 50 hours and 46 minutes of data were collected at D18 on FM 730. During this time, 55 vehicles arrived at the DAD. Twenty-eight vehicles (51 percent) did not comply. However, at least 17 of those vehicles were construction-related vehicles with an additional four vehicles potentially being construction-related. Of these 28 violations, 10 (36 percent) were related to “jumping” the flashing yellow arrow, six (21 percent) were related to flashing yellow arrow violations (turning in opposite direction of FYA), and 12 (43 percent) were related to red violations. All the violations may have been attributed to the proximity of the DAD to the northbound PTS, which allowed vehicles at D18 to very clearly see if main lain traffic was coming from the northbound direction (see Figure 8). In addition, a concrete barrier was used to separate the closed lane (work area) from the open travel lane. The end of the concrete barrier terminated at D18, which led to construction workers often using this driveway as an exit from the work area (see Figure 16). Overall, the violation rate for this site was 1.83 violations per 100 stop cycles (28 violations divided by 1,529 stop cycles multiplied by 100).

Figure 16. End of Concrete Barrier and DAD at D18 Looking Southbound.

Project 16 FM 46 CSJ 0540-02-027

Over the 47 hours and 53 minutes of data collection that occurred at FM 46, 13 vehicles arrived at the DAD. Seven drivers (54 percent) did not comply with the DAD. Out of the seven violations that did occur, five (71 percent) were drivers "jumping" the flashing yellow arrows either in anticipation of the next phase and/or to get ahead of the main lane traffic queue. Of the five jumping violations, three of them involved the driver turning left and two of them involved the driver turning right. These violations might be explained by the proximity of the DAD to the PTS, and while these types of maneuvers were considered violations, they were not considered an unsafe driving action.

The remaining two violations (29 percent) were due to drivers that turned on red in the opposite direction of the subsequent flashing yellow arrow (i.e., turning in the direction of oncoming traffic). Both violations were drivers turning left on red when the next phase was a flashing yellow right arrow. These violations may have been influenced by the proximity of the DAD to the southbound PTS, which allowed vehicles at D1 to very clearly see if main lain traffic was coming from the southbound direction (see Figure 10). Overall, the violation rate for this site was 0.27 violations per 100 stop cycles (7 violations divided by 2,570 stop cycles multiplied by 100).

Project 25 RM 1376 CSJ 1899-02-021

Over the 43 hours and 28 minutes of data collection at RM 1376, nine vehicles arrived at the DAD, with four drivers not complying with the DAD (44 percent). All four violations were drivers "jumping" the left flashing yellow arrow to get ahead of the main lane traffic queue. While these types of maneuvers were considered violations, they were not considered an unsafe driving action. Overall, the violation rate for this site was 0.54 violations per 100 stop cycles (4 violations divided by 746 stop cycles multiplied by 100).

SUMMARY AND CONCLUSIONS

Table 1 contains a summary of the DAD characteristics at each site studied to date. Table 2 and Table 3 provide a summary of the violation rates and types, respectively, for all projects to date. The overall violation rate for the three-section doghouse DAD is 2.6 violations per 100 stop cycles and ranges from 0.1 to 10.7 violations per 100 stop cycles. Most of the violations (84 percent) were not considered to be unsafe driving behaviors. The overall violation rate for the four-section stacked DAD is 5.4 violations per 100 stop cycles and ranges from 0.3 to 15.9 violations per 100 stop cycles. In addition, most of the violations (81 percent) were considered to be unsafe driving maneuvers. Based on the study findings analyzed to date, researchers continue to recommend the use of the three-section doghouse DAD with a NO TURN ON RED sign and TURN ONLY IN DIRECTION OF ARROW sign.

Table 1. Summary of DAD Characteristics at Each Site.

Project	Type	Supplemental Sign 1[a]	Supplemental Sign 2	Access Point Number	Access Point Description	Location Relative to Access Point
1	3-head	R10-11	TURN ONLY IN DIRECTION OF ARROW	SB-33	Business driveway	Farside
				NB-12	Business and residential driveway	Nearside
				NB-11	Business and residential driveway	Farside
3	4-head	Modified R10-11	YIELD IN DIRECTION OF FLASHING YELLOW ARROW	FM 1583	Farm-to-Market Road	Nearside
				CR 3800	County Road	Nearside
				CR 3800	County Road	Nearside
4	4-head	Modified R10-11	YIELD IN DIRECTION OF FLASHING YELLOW ARROW	DAD_11	Local Road	Farside
5	4-head	R10-11b	WAIT TURN ONLY IN DIRECTION OF FLASHING YELLOW ARROW	SS_2nd	Business driveway	Nearside
8	3-head	R10-11	WAIT TURN ONLY IN DIRECTION OF ARROW	18	Business driveway	Nearside
				20	Business driveway	Nearside
9	4-head	Modified R10-11	WAIT TURN ONLY IN DIRECTION OF FLASHING YELLOW ARROW	D9	Business driveway	Nearside
13	4-head	Modified R10-11	YIELD IN DIRECTION OF FLASHING YELLOW ARROW	CR 411	County Road	Nearside
14	4-head	Modified R10-11	YIELD IN DIRECTION OF FLASHING YELLOW ARROW	D12	Residential driveway	Farside
15	3-head	R10-11	WAIT TURN ONLY IN DIRECTION OF FLASHING YELLOW ARROW	D21	Business and residential driveway	Nearside
				D18	Business and residential driveway	Nearside
16	3-head	R10-11	TURN ONLY IN DIRETION OF ARROW	D1	Business and residential driveway	Nearside
25	3-head	Modified R10-11	YIELD IN DIRECTION OF FLASHING YELLOW ARROW	D3	Residential driveway	Nearside

[a] R10-11 is "NO TURN ON RED (red ball)," a modified R10-11 is "NO TURN ON RED (two red arrows)," and a R10-11b is "NO TURN ON RED."

Table 2. Summary of Violation Rate Statistics.

Project	Type of DAD	Access Point Number	Hours of Study	Number of Minor Approach Vehicles	Number of Stop Cycles	Number of Violations	Violations per 100 Stop Cycles[a]
1	3-head	SB-33	21.0	17	308	3	1.0
1	3-head	NB-12	47.4	246	696	24	3.4
1	3-head	NB-11	47.1	341	692	69	10.0
1	3-head	Total	115.5	604	1696	96	5.7
8	3-head	18	48.6	97	728	31	4.3
8	3-head	20	48.5	125	727	78	10.7
8	3-head	Total	97.1	222	1455	109	7.5
15	3-head	D21	47.7	6	1357	1	0.1
15	3-head	D18	50.8	55	1529	28	1.8
15	3-head	Total	98.5	61	2886	29	1.0
16	3-head	D1	47.8	13	2570	7	0.3
25	3-head	D3	43.5	9	746	4	0.5
3	4-head	FM 1583	48.0	112	823	19	2.3
3	4-head	CR 3800	48.1	91	475	37	7.8
3	4-head	CR 3800	46.9	79	455	39	8.6
3	4-head	Total	143.0	282	1753	95	5.4
4	4-head	DAD_11	46.0	1254	699	111	15.9
5	4-head	SS_2nd	40.9	123	334	7	2.1
9	4-head	D9	46.9	17	613	15	2.4
13	4-head	CR 411	38.9	74	731	34	4.7
14	4-head	D12	38.9	7	732	2	0.3

[a] Rate computed as violations divided by stop cycles multiplied by 100.

Table 3. Summary of Violation Types.

Project	Type of DAD	Access Point Number	Turned on Red prior to FYA Same Direction	Turned on Red to Join Main Road Traffic Same Direction	Turned on Red Opposite Direction	Turned in Opposite Direction of FYA
1	3-head	SB-33	100%	0%	0%	0%
1	3-head	NB-12	63%	21%	8%	8%
1	3-head	NB-11	56%	41%	3%	0%
1	3-head	Total	60%	34%	4%	2%
8	3-head	18	58%	32%	10%	0%
8	3-head	20	65%	24%	7%	4%
8	3-head	Total	63%	27%	7%	3%
15	3-head	D21	0%	0%	100%	0%
15	3-head	D18	36%	0%	43%	21%
15	3-head	Total	34%	0%	45%	21%
16	3-head	D1	71%	0%	29%	0%
25	3-head	D3	100%	0%	0%	0%
3	4-head	FM 1583	5%	0%	0%	95%
3	4-head	CR 3800	0%	5%	0%	95%
3	4-head	CR 3800	0%	0%	0%	100%
3	4-head	Total	1%	2%	0%	97%
4	4-head	DAD_11	3%	8%	5%	84%
5	4-head	SS_2nd	43%	0%	0%	57%
9	4-head	D9	27%	67%	0%	6%
13	4-head	CR 411	6%	41%	44%	9%
14	4-head	D12	100%	0%	0%	0%

Note: FYA = Flashing Yellow Arrow

CHAPTER 3: DRIVER UNDERSTANDING AND PREFERENCES OF WAIT TIME DISPLAYS ON PORTABLE TRAFFIC SIGNALS

INTRODUCTION

Several TxDOT districts have expanded their use of PTSs to control alternating one-way traffic through work zones on two-lane highways. On lengthier projects, the amount of time that motorists must wait at the signal until a green indication is displayed can be significant. Often, the geometrics of the roadway are such that it is not possible to see the entire length of the alternating one-lane section and so waiting motorists do not see traffic coming towards them in that open lane. In these instances, motorists can become impatient, incorrectly assume that the signal is not operating properly, and enter the work zone when the signal is still displaying a red indication.

Multiple portable signal manufacturers have developed technology that allows the display of the remaining wait time until a green signal indication occurs. The provision of such information is believed to reduce motorist uncertainty about whether the signal is operating correctly and reduce red-light violations. A couple of TxDOT districts have incorporated wait time displays into their PTS specification or added them to an existing project via a change order. In the latter case, the project experienced frequent complaints about energy sector traffic running the red lights, presumably because the long cycle duration gave the drivers the impression that the signals were not functioning properly. After the wait time displays were procured and added to the signals, no additional complaints about drivers running the red signal were received.

Presently, different portable signal manufacturers offer different wait time display designs. Figure 17 through Figure 22 illustrates these different designs. The simplest designs count down the total seconds or minutes:seconds until the red signal indication will change to green (see Figure 17 and Figure 18). Another signal manufacturer uses a WAIT TIME XX MIN display that reduces minute by minute until the green indication appears (see Figure 20). Such designs work for pretimed signal operations but do not work well for actuated signal operations. At least one PTS manufacturer provides actuated signal control. In their system, a static WAIT/UP TO XX MIN message is displayed (representing the maximum possible wait time if the opposite direction green times out) until the signal goes into the clearance interval for opposite direction traffic, at which time the display changes to a WAIT X:XX display (see Figure 21). In addition, one portable signal manufacturer proposed using a bar that gradually decreases in length to suggest that the remaining red time is indeed decreasing (see Figure 22).

Although these various displays are being used by agencies and contractors, there has not been an evaluation to assess how well the various displays are understood and/or preferred by drivers. Consequently, TTI researchers designed and conducted a computer-based survey to investigate these questions.

Figure 17. Example of a Simple Seconds-Only Wait Time Display.

Figure 18. Example of Minutes:Seconds Wait Time Display.

Figure 19. Example of "WAIT X:XX" Wait Time Display.

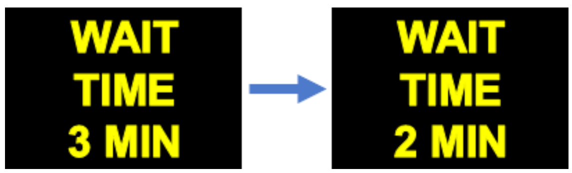

Figure 20. Example of Wait Time Display Including "WAIT" Term and the Time Remaining in Minutes.

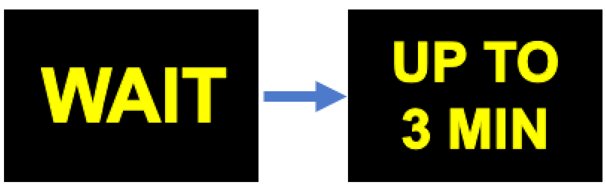

Figure 21. Example of Wait Time Display with "WAIT/UP TO X MIN."

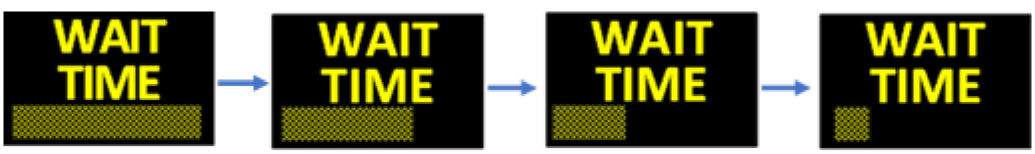

Figure 22. Example of Proposed Wait Time Display Without Numbers.

STUDY METHODOLOGY

Researchers utilized Qualtrics software to develop a survey to investigate driver understanding and opinions of six different wait time displays described in Table 4. The survey protocol was approved by The Texas A&M University System's Human Subjects Protection Program. To improve participation rates, researchers designed the study to be completed in under 10 minutes. Participants were recruited via social media posts on TTI and TxDOT public information accounts. Upon accessing the survey, participants were presented with information about the study's purpose, its approximate length, and the requirements for participation. Requirements included: being 18 years of age or older, being able to read and write in English, having a valid Texas driver's license, and using a desktop/laptop computer or a full-size tablet to complete the survey. Participants were also informed of their ability to terminate the study without any repercussions and that any information collected would remain anonymous (i.e., no names were requested, and any personal information collected was aggregated to ensure that responses to the questions cannot be tracked back to the individual). Those who did not meet the stated requirements or who decided they did not want to participate were thanked for their interest in the study and the session ended. For those who continued to participate, basic information was collected about their gender and age category.

Table 4. Wait Time Display Treatment Descriptions.

Treatment	Example Description	Example Display
1	Display that alternated between a WAIT message and an UP TO 3 MIN message where the 3 value did not change	Figure 21
2	Display where a WAIT 2:45 message was shown and the 2:45 counted down each second	Figure 19
3	Display where a WAIT TIME 3 MIN message was shown, where the 3 value changed to indicate that the message was counting down on a minute-by-minute basis	Figure 20
4	Display where a WAIT TIME message was displayed showing a bar that reduced from right to left to illustrate that time was counting down graphically	Figure 22
5	Display with a 185 message of time that counted down second by second	Figure 17
6	Display with a 3:05 message of time that counted down second by second and minute by minute	Figure 18

Participants who met the requirements and decided to participate were advanced to an explanation screen that showed a PTS with a wait time display board attached (see Figure 23). Text positioned above the image highlighted the message board on top of the signal as the focus of the study.

Please review the image below. It shows an approach to a portable traffic signal that is alternating one-way traffic on a two-lane roadway that is under construction. In addition to the signal, there is a message display that may provide additional information to you. During this survey, you will be asked a few questions about your interpretation of messages that may appear on the display.

Next, you will see an image depicting a possible message display on the portable traffic signal. This image will only be displayed for 10 seconds. You will then be asked to explain what you think the message means.

Figure 23. Study Explanatory Screen.

Once the subject reviewed the introductory text and pressed "continue," they were shown a close-up image of the top signal and message display board with a randomly selected display listed in Table 4. The image was shown for approximately 10 seconds. During that 10-second interval, the display continuously counted down for those displays that count down second by second. For the display that counts down in one-minute intervals, the minute value was changed from 3 minutes to 2 minutes approximately halfway into the 10-second display interval to illustrate that it did count down (albeit much less frequently). After the 10-second display interval concluded, the participant was asked to type their opinion of the meaning of the message display into a response box. After entering their answer to the first question, the following additional text popped up to explain what the display represented:

> *Portable traffic signal message displays can be used to indicate anticipated wait times for the signal to change from red to green. When used in this manner, the message displays are referred to as wait time displays.*

A follow-up question was then posed to the participant, along with three possible answers:

> *If the wait time display reaches ZERO and the signal does not change from red to green, what should you do?*
>
> - *Proceed with caution if you can see that there is no oncoming traffic.*
> - *Continue to wait for the signal to change from red to green.*
> - *Unsure.*

For Treatment 4, the phrase "reaches ZERO" was replaced with "bar disappears." If the participant selected the "proceed with caution" response, they were then asked to explain that selection.

Following the questions about the specific wait time display message presented, participants were then shown the different display formats being evaluated in the survey. Treatments were presented in random order to reduce any recency or order effects upon the rankings. Participants were instructed to rank the displays in order from most easily understood to least easily understood, and then asked to explain what they liked the most about their best choice and what they liked the least about their worst choice.

STUDY RESULTS

Participant Demographics

The survey software automatically deleted records for participants who completed only a portion of the study before deciding to terminate their study session. In addition, the researchers performed a manual check of the collected data, eliminating responses that were apparently generated from web-based chatbots. After cleansing the data, responses from 184 participants remained for analysis. Participant demographics are summarized in Table 5 and compared to recent data on the Texas driving population. Overall, the study sample was slightly skewed toward males but was fairly representative in terms of driver age relative to the Texas driving population.

Participant Understanding of Wait Time Display Alternatives

Researchers reviewed the open-ended participant responses to the question about the meaning of the wait time display they viewed. Researchers categorized their responses as fully correct, partially correct, or incorrect. A fully correct response was one where the participant indicated that it conveyed the time (or approximate time) that they would have to wait at the red signal until it turned green. Partially correct responses were those where the participants indicated that they would need to wait at the red signal, but it was not clear whether they understood that the display was counting down to when a green indication was expected. Incorrect responses were those where the response did not indicate a recognition of the message relating to the signal indications (for example, that the display reflected the current time of day).

Table 5. Participant Demographics.

Demographic	Study Sample (%)	Texas Driving Population (%)
Gender:		
Male	60	49
Female	39	51
Prefer not to answer	1	0
Age:		
18–24	4	15
25–34	33	22
35–44	29	23
45–54	17	18
55–64	9	11
65–74	8	7
75–84	0	3
85+	0	1

Figure 24 presents driver understanding of the wait time display alternatives. All the treatment alternatives were well understood, with 84 to 97 percent of participant responses correct or partially correct, exceeding the commonly used 85 percent threshold for acceptable comprehension. The percentages of completely correct responses for treatments that counted down second-by-second (Treatments 2, 5, and 6) were also found to not differ significantly from the 85 percent threshold. Likewise, Treatment 3 that counted down minute-by-minute (which participants saw the number change while they were viewing the display) was also well interpreted. Conversely, the percent of completely correct responses for Treatment 1 and Treatment 4, which did not have numerals counting down in their displays, were significantly lower than the 85 percent threshold. Clearly, the ability of participants to see numerals in the display decreasing over time provides a strong indication that the display represents a countdown and is usually associated with the red signal indication.

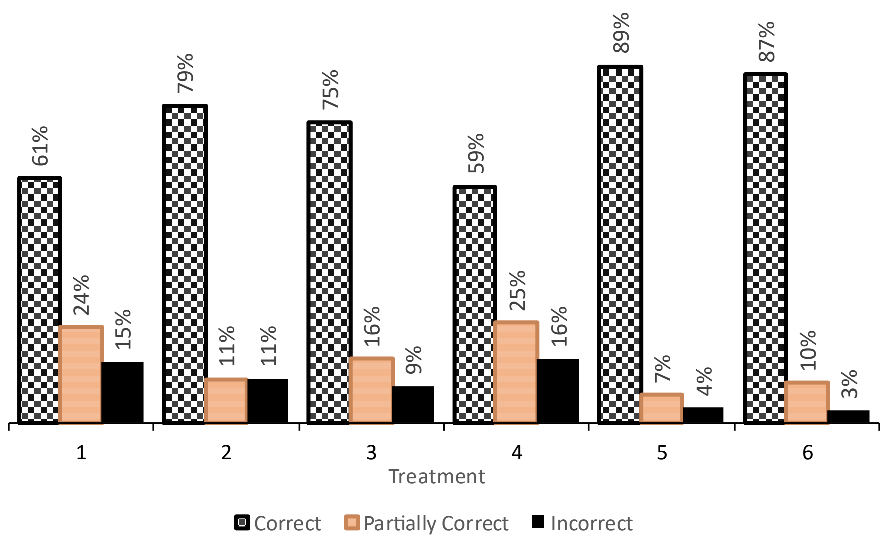

Figure 24. Participant Interpretations of the Meaning of the Wait Time Display.

Participant responses to the question concerning the appropriate action to take if the wait time display counted down to zero but a red indication was still showing are presented in Figure 25. Overall, most participants correctly indicated that they would continue to wait until the signal turned green (none of the "continue to wait" percentages differed significantly from the 85 percent acceptable threshold value). However, over one-quarter (28 percent) of participants viewing Treatment 5 indicated that they would either proceed with caution into the work zone or were unsure what to do if the wait time indication displayed a zero while the red signal indication was still showing. Similarly, 22 percent of participants viewing Treatment 3 responded the same way. When those participants were asked why they would proceed with caution or were unsure what to do if the wait time display was at zero but the signal indication was still red, all of them stated that the signal could be malfunctioning. These participants apparently assumed that since the wait time display was actively counting down, it must be operating correctly rather than the signal itself.

Although very few participants (3 percent) viewing Treatment 1 or Treatment 6 indicated they would proceed with caution, 15 percent and 13 percent of the participants viewing those treatments, respectively, were unsure what they would do in that situation. The researchers hypothesize that this question may have confused participants viewing Treatment 1 since it displayed a static number (WAIT UP TO 3 MIN) that did not change. It is unclear why participants viewing Treatment 6 were unsure since none of them entered an explanation in the survey.

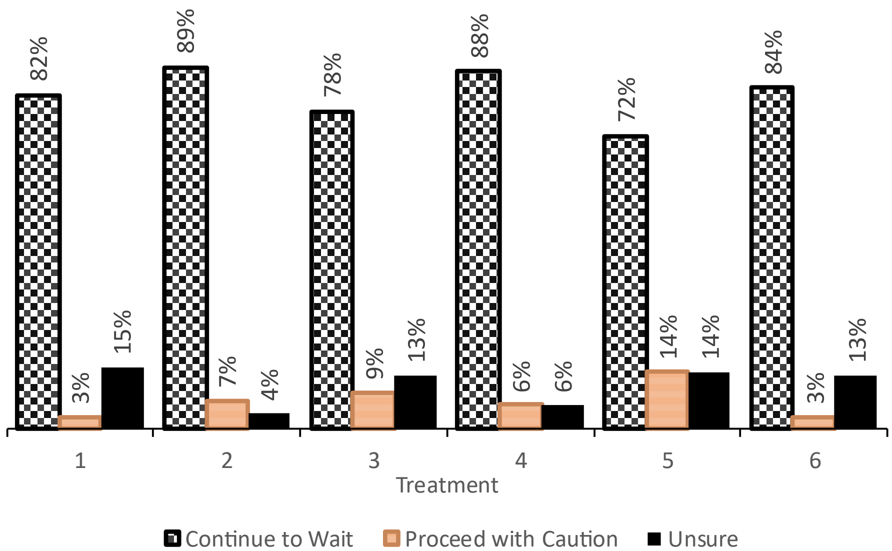

Figure 25. Participant Responses to Question About Proper Action to Take If Wait Time Display Reaches Zero and Signal Indication Is Still Red.

Interestingly, only 11 percent of participants viewing Treatment 2 indicated that they would proceed with caution or were unsure what to do, even though the wait time display for that treatment also included a minutes:seconds message that counted down second by second. Researchers hypothesize that the WAIT statement included in the display may have heightened participants' wariness about the display and resulted in a higher percentage of "continue to wait" responses. Conversely, while only 12 percent of participants viewing Treatment 4 said they would proceed with caution or were unsure what to do, researchers hypothesized that this was due more to the fact that several participants did not associate the decreasing bar display as a traffic signal countdown and so only considered how they would respond to the red indication when answering that question.

Participant Wait Time Display Preferences

Next, researchers analyzed the wait time display rankings. Figure 26 presents the average participant rankings of each treatment (with 1 indicating the best treatment and 6 indicating the worst treatment). On average, participants ranked Treatment 2 as the best (2.3) and Treatments 1 and 4 as the worst (4.3 and 4.2, respectively).

The percentage of participants ranking each treatment as best or as worst is provided in Figure 27. Treatments 1, 4, and 5 received the greatest percentage of "worst" rankings, whereas Treatments 2 and 5 received the greatest percentage of "best" rankings. The lack of a changing time on Treatment 1 was cited as a main reason by several participants for ranking it worst (e.g., "no real time information, I have no idea if the light just changed or how long you will be waiting"). Several participants noted that the use of a decreasing bar to indicate the wait time in

Treatment 4 was not intuitive but rather confusing. The fact that it did not present a specific time was also cited as reasons for ranking it as worst.

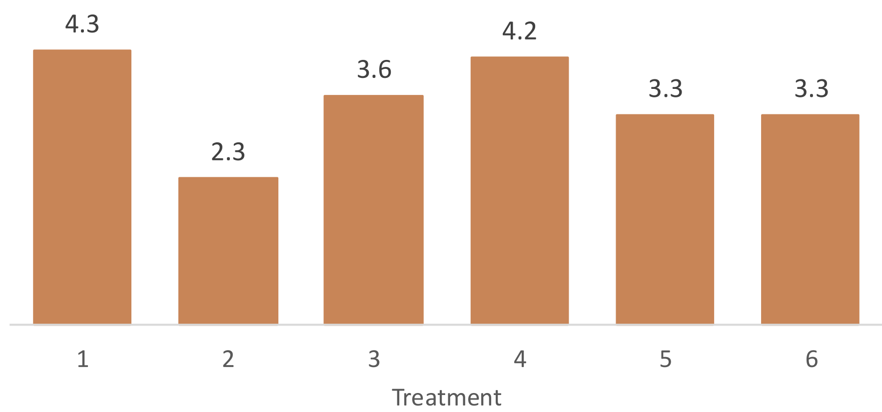

Figure 26. Average Treatment Ratings by Participants (1 = Best, 6 = Worst).

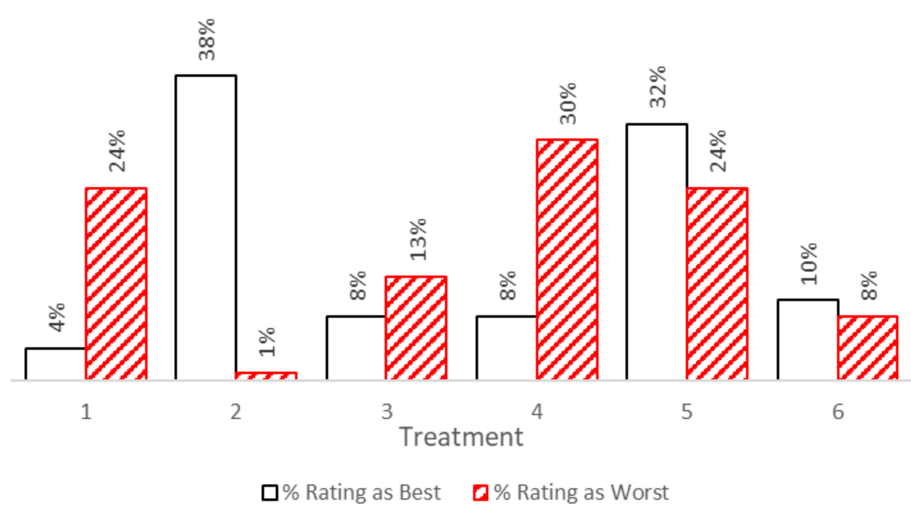

Figure 27. Percent of Participants Rating Each Treatment as "Best" or "Worst."

Interestingly, Treatment 5 received significant numbers of both "best" and "worst" rankings, indicating that participants were highly opinionated regarding that treatment. Some of the reasons offered by participants for rating this treatment as best or worst are shown in Table 6. Whereas some participants focused on the larger font that this type of display allows (since no text is included in the display) as the reason for their preference, other participants perceived the simple numerical display as possibly confusing, especially since it lacked context. The fact that Treatment 5 only displayed seconds rather than minutes:seconds was disconcerting for some of the participants.

Table 6. Reasons for Treatment 5 "Best" and "Worst" Rankings.

Reasons for Ranking as "Best"	Reasons for Ranking as "Worst"
• The numbers are big and clear and simple. • Eye-catching, more intuitive. • Big numbers, clear to see. • I can understand the meaning very quickly.	• Too vague with just a number, no explanation or directive. • Some people may not understand that the number represents seconds, and they may not understand what the countdown is for. • It doesn't provide clear direction. • We are used to HH:MM:SS format. Don't like numbers without units, or without context. • Numbers mean nothing without an explanation. Are they seconds? Number of oncoming cars left to pass? I would not like a random countdown.

CONCLUSIONS AND RECOMMENDATIONS

The results of this computer-based study of driver understanding and preference of alternative wait time displays indicate the following:

- A simple display stating WAIT along with a minutes:seconds time indication (Treatment 2) was ranked as the best display alternative and was well understood by participants.
- Displays of seconds remaining (Treatment 5) or minutes:seconds counting down without a WAIT indication (Treatment 6) were also ranked favorably. However, over one-quarter of participants viewing Treatment 5 indicated that they would either proceed with caution into the work zone or were unsure what to do if the wait time indication displayed a zero while the red signal indication was still showing. Similarly, 13 percent of the participants viewing Treatment 6 were unsure what they would do in that situation.
- The display counting down in minutes only (Treatment 3) was also ranked well. However, researchers ensured that the participants saw that the indication did change after a few seconds while viewing the display. Whether participants would have ranked the display as highly if they had not seen the number change is unknown.
- Displays that did not periodically change a numeric time value while being viewed by the participants (either second by second or minute by minute) were not well understood (i.e., Treatments 1 and 4).
- None of the displays tested resulted in significant numbers of participants assuming they could enter the work zone once the display reached zero if the signal indication was still red. However, there was a small portion of participants (regardless of which treatment was viewed) who were unsure whether they would or would not enter on the red signal indication.

Based on these conclusions, researchers do not recommend using a display with a bar or other graphic to convey wait time until a green indication since it was not perceived as particularly useful to drivers. Rather, researchers recommended that a wait time display incorporates text indicating WAIT or WAIT TIME in addition to displaying minutes:seconds to increase driver understanding that it is counting down until a green signal indication will be displayed. Finally, for actuated signal operations, it is recommended that the display indicates not only the maximum possible wait time that could occur but rather periodically change the time to reflect the remaining maximum expected wait time. This could be done at 15- or 30-second intervals so that drivers waiting in the queue see the numerals change occasionally and associate it with a countdown to green.

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