1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FHWA/TX-08/5-5113-01-1		

4. Title and Subtitle	5. Report Date
IMPLEMENTATION OF ADVANCE WARNING OF END OF GREEN SYSTEM (AWEGS): IMPLEMENTATION REPORT	October 2008
	6. Performing Organization Code
7. Author(s)	8. Performing Organization Report No.
Srinivasa R. Sunkari, Hassan A. Charara, and Jeremy D. Johnson	Report 5-5113-01-1
9. Performing Organization Name and Address	10. Work Unit No. (TRAIS)
Texas Transportation Institute The Texas A&M University System College Station, Texas 77843-3135	11. Contract or Grant No. Project 5-5113-01
12. Sponsoring Agency Name and Address	13. Type of Report and Period Covered
Texas Department of Transportation Research and Technology Implementation Office P.O. Box 5080 Austin, Texas 78763-5080	Technical Report: March 2007-August 2008
	14. Sponsoring Agency Code

15. Supplementary Notes

Project performed in cooperation with the Texas Department of Transportation and the Federal Highway Administration.
Project Title: Implementation of Advance Warning of End of Green Systems (AWEGS)
URL: http://tti.tamu.edu/documents/5-5113-01-1.pdf

16. Abstract

The objective of this implementation project was to implement four AWEGS across Texas at intersections appropriate for the installation of AWEGS. After a survey across Texas, four sites were chosen in the Atlanta District, Pharr District, Odessa District, and San Antonio District. The AWEGS design plans were prepared for these four sites and submitted to the districts. These plans were prepared for an intersection with high-speed approaches having the required dilemma zone detection design. The Atlanta District implementation was typical of the earlier implementation and used the TS2 TS 1 conversion panel. However the remaining implementations were configured for using enhanced BIUs. AWEGS software was also modified to account for rail preemption as the site in Odessa District was being preempted by between 15 to 25 trains per day. Finally the implementation in San Antonio District was redesigned to use radar detection for both dilemma zone and advance detection. AWEGS at the Atlanta, Pharr, and Odessa Districts have been implemented and an evaluation of the system showed that AWEGS was performing satisfactorily at all sites. TTI researchers are awaiting the San Antonio District to install the radar detectors to implement the system there.

17. Key Words	18. Distribution Statement
Advance Warning Flashers, AWEGS, W3-4 Signs, Advance Traffic Warning Devices, Traffic Actuated Control , Enhanced BIU, TS 2 Conversion Panel	No restrictions. This document is available to the public through NTIS: National Technical Information Service Springfield, Virginia 22161 http://www.ntis.gov

19. Security Classif.(of this report)	20. Security Classif.(of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	26	

IMPLEMENTATION OF ADVANCE WARNING OF END OF GREEN SYSTEM (AWEGS): IMPLEMENTATION REPORT

by

Srinivasa R. Sunkari, P.E.
Research Engineer
Texas Transportation Institute

Hassan A. Charara
Research Scientist
Texas Transportation Institute

and

Jeremy D. Johnson
Associate Research Specialist
Texas Transportation Institute

Report 5-5113-01-1
Project 5-5113-01
Project Title: Implementation of Advance Warning of End of Green Systems (AWEGS)

Performed in cooperation with the
Texas Department of Transportation
and the
Federal Highway Administration

October 2008

TEXAS TRANSPORTATION INSTITUTE
The Texas A&M University System
College Station, Texas 77843-3135

DISCLAIMER

This implementation 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.

This report is not intended for construction, bidding, or permit purposes. The engineer in charge of the project was Srinivasa Sunkari, P.E. #87591. The United States Government and the State of Texas do not endorse products or manufacturers. Trade or manufacturers' names appear herein solely because they are considered essential to the object of this report.

ACKNOWLEDGMENTS

This implementation was conducted during a one and half-year project under a cooperative research program with TxDOT and FHWA. Michael Jedlicka of the TxDOT Bryan District was the implementation director. Other TxDOT members of the project monitoring committee included Carlos Ibarra, Jeśus Leal, Kelli Williams, Rick Castaneda, Henry Wickes, and Wade Odell.

TTI researchers specifically thank signal technicians from the Pharr, Atlanta, Odessa, and San Antonio Districts for assisting us in the installation of the equipment for this project. This project would not have been implemented without their dedicated assistance.

TABLE OF CONTENTS

LIST OF FIGURES

Page

LIST OF TABLES

Page

ADVANCE WARNING OF END OF GREEN SYSTEM (AWEGS)

AWEGS is a dilemma zone protection system designed to minimize vehicles from being trapped in their respective dilemma zones at the onset of yellow (*1*). The objective is achieved by providing advance warning to motorists approaching the intersection with the help of advance warning signs coupled with flashing beacons. Advance warning about the end of green is provided by the activation of the beacons on the warning sign. Figure 1 illustrates the functionality and the various components of AWEGS.

Typically dilemma zone detection is provided on high-speed approaches to minimize vehicles caught in their dilemma zone at the onset of the yellow indication in the traffic signal. However dilemma zone detection is usually designed to protect passenger cars up to the 85th percentile approach speed. This means that passengers above the 85th percentile approach speed and trucks are not provided the same level of dilemma zone protection. The objective of AWEGS is to provide protection to trucks and passenger cars up to the 99th percentile approach speeds. Figure 2 illustrates the typical approach layout of AWEGS.

SITE SELECTION

AWEGS is typically applicable at locations that meet the following characteristics:

- High-speed approaches should have a speed limit of 55 mph or greater.
- The intersection should have dilemma zone detection that conforms to TxDOT's practice of using inductive loops.
- The intersection should be operating in a fully actuated mode.
- The intersection should have detection for all non-arterial phases (arterial left turns and cross streets), preferably at the stop bar.
- The location should have an ADT of preferably not greater than 15,000 vehicles.
- There should be minimum driveways between the intersection and the advance detectors.
- The percentage of turning traffic at the intersection should not be unusually high.

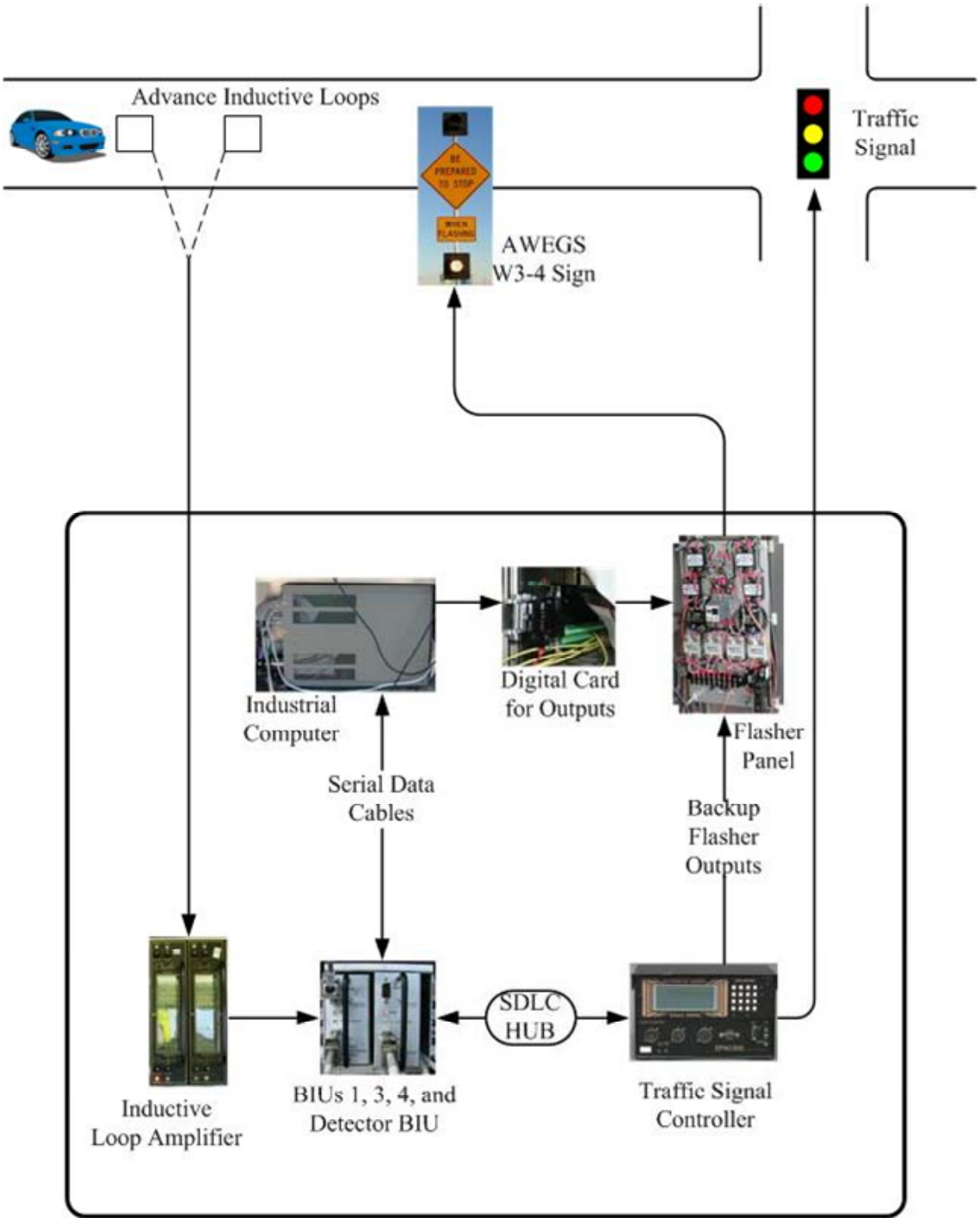

Figure 1. Layout of a Typical Advance Warning for End-of-Green System (AWEGS).

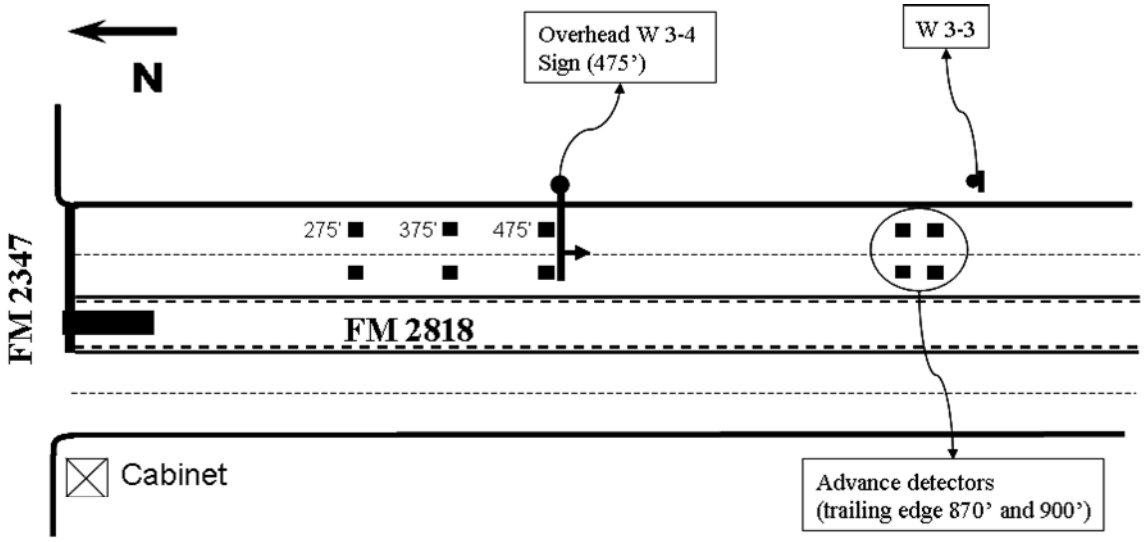

Figure 2. Typical Layout for an Intersection Approach Having AWEGS.

The project personnel started contacting the individual districts immediately after the project was awarded in March 2007. The objective of the site selection was to select three four-lane highways and one two-lane highway sites that met the site selection requirements. It was desirable to select sites in all parts of the state to ensure the implementations were spread across the state.

TTI researchers contacted 23 out of 25 TxDOT districts. The Bryan District and El Paso District were not contacted. The Bryan District currently has two AWEGS deployed in the district and TTI researchers in consultation with the implementation director decided to look at other districts. The El Paso District was not contacted as TTI researchers already had received a tentative confirmation about a good site in the Odessa District and thus had a representation of a site in West Texas.

After getting preliminary site information, TTI researchers visited the sites in the Atlanta District and the Tyler District on April 16 and 17, 2007, and the Pharr District on May 4, 2007. Based on the visits, one site in Atlanta and one site in Pharr District were found suitable for AWEGS implementation. Based on discussions with the district traffic engineers, review of intersection as-built plans, and site photographs, the remaining two AWEGS sites were then selected in the Odessa District and the San Antonio District.

Table 1 illustrates the results of the site selection survey conducted by TTI researchers. A brief description of the four sites selected and the rationale for selection is described next.

Site 1 - Atlanta District: The intersection of US 80 and Page Road is to the east of the city of Longview in the Atlanta District. This site is a T intersection. US 80 is a four-lane

highway in the east-west direction. Page road is northbound approach at the intersection. This intersection is currently un-signalized and is being signalized during the summer of 2007. The following reasons were used for selecting this intersection as an AWEGS site:

- high approach speeds and low ADTs, and
- the district confirmed that they will provide dilemma zone detection at proper location.

Site 2 - Pharr District: The intersection of SH 100 and FM 510 is near the city of Port Isabel in the Pharr District. This site is a T intersection. SH 100 is a four-lane highway in the east-west direction. FM 510 is northbound approach at the intersection. This intersection was recently signalized and the district currently has some safety concerns about intersection visibility. The following reasons were used for selecting this intersection as an AWEGS site:

- high approach speeds and low ADTs, and
- the district has inductive loops for dilemma zone detection at proper location.

Site 3 - Odessa District: The intersection of BI 20 and Coors Road (CR 1290) is between the city of Midland and Odessa in the Odessa District. This site is a T intersection. BI 20 is a four-lane highway in the east-west direction. Coors Road is northbound approach at the intersection. The district currently has some safety concerns due to high approach speeds. The following reasons were used for selecting this intersection as an AWEGS site:

- high approach speeds, and
- the district has inductive loops for dilemma zone detection at proper location.

Site 4 - San Antonio District: The intersection of US 281 and FM 306 is to the north of the City of San Antonio in the San Antonio District. This site is a T intersection. US 281 is a two-lane highway in the north-south direction. FM 306 is the westbound approach at the intersection. The district currently has some safety concerns due to high approach speeds and signal visibility. The following reasons were used for selecting this intersection as an AWEGS site:

- high approach speeds, and
- the district initially intended to install inductive loops for dilemma zone detection at proper location (however, they later decided to use radar) .

Table 1. Review of Districts for Site Selection.

District	Director Traffic Operations	Contact if different	Contacted by TTI	Received Response	# of Potential Sites	Site Selected	Comments
Abilene	Roy Wright		Yes	Yes	1		Curve on one approach without dilemma zone detectors
Amarillo	Chris Freeman		Yes	Yes	1		City signal
Atlanta	Carlos Ibarra		Yes	Yes	2	YES	Two others were visited. 3 more have high ADTs.
Austin	Imelda Barrett		Yes	Yes	4		Late response - no information
Beaumont	Janet Manley	Kevin Waldrep	Yes	Yes	2		1 other has DLZ at 140 ft and other has VIVIDS
Brownwood	Howard Holland		Yes	No	None		No intersections
Bryan	Kirk Barnes		No	N/A	N/A		District already has two AWEGS deployed
Childress	Darwin Lankford		Yes	No	None		No intersections
Corpus Christi	Ismael Soto	Gabriel I. Garcia	Yes	Yes	2		4 lane hwys and T interections. 2 others have lower speeds
Dallas	Kelly Selman	Chris Blain	Yes	Yes	1		2 lane hwy with ILD for DLZ
El Paso	Carlos V. Chavez		No	N/A	N/A		Did not contact
Fort Worth	Jimmey Bodiford		Yes	No	None		No Response
Houston	Stuart Corder		Yes	Yes	1		High volumes, low response
Laredo	Danny Magee		Yes	Yes	4		Late response - City Signals. Remaining two have low speeds
Lubbock	Frank Phillips	Ted Copeland	Yes	Yes	None		No intersections
Lufkin	Herbert E. Bickley		Yes	No	None		No response
Odessa	Mike McAnally	Kelli Williams	Yes	Yes	1	YES	4 lane hwy with ILD for DLZ at correct locations
Paris	Jerry E. Keisler	Darius Samuels	Yes	Yes	2		Low volumes
Pharr	Jesus Leal	Stuart Jenkins	Yes	Yes	2	YES	4 Lane hwy with ILD for DLZ at correct loc. The other one already has flashers
San Angelo	Dennis W. Wilde		Yes	No	None		No intersections
San Antonio	Rick Castaneda	Craig Williams	Yes	Yes	2	YES	Late response. 1 two lane and 1 four lane hwy. May try other tech for adv det.
Tyler	Peter C. Eng		Yes	Yes	1		Has too high ADTs and no DLZs
Waco	Larry Colclasure		Yes	Yes	None		No intersections
Wichita Falls	Tim Hertel		Yes	No	None		D-CS locations
Yoakum	Marla Jasek		Yes	No	None		No intersections

ATLANTA DISTRICT

The Atlanta District personnel installed AWEGS infrastructure during the summer of 2007. TTI researchers visited the site on September 17 and 18, 2007, and verified the infrastructure installed for AWEGS. Figure 3 illustrates the AWEGS infrastructure installed at the site in the Atlanta District. TTI researchers then implemented AWEGS in the shadow mode. AWEGS system was then installed on March 24, 2008, and its performance was evaluated. Figure 4 illustrates the AWEGS system installed in the Atlanta District. Table 2 illustrates the statistics of the advance warning by AWEGS in the Atlanta District. From Table 3, the warning times provided by AWEGS are higher than what is normally expected by AWEGS for the volumes at the intersection. A detailed analysis of the data illustrated that the advance warning duration is affected by the use of video detection for dilemma zone protection. It was seen that video detection is not allowing the major street phases to gap out as frequently as inductive loops. AWEGS was designed for dilemma zone detection with inductive loops. This results in an increase in advance warning provided by AWEGS.

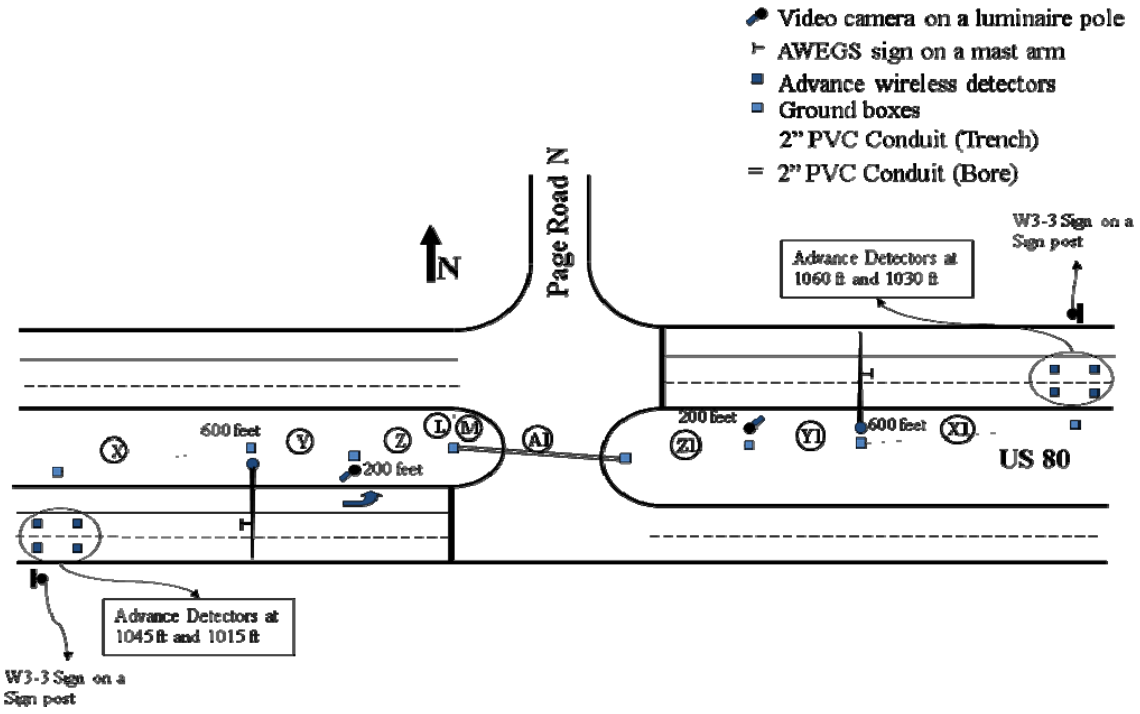

Figure 3. AWEGS Infrastructure in Atlanta District.

Figure 4. AWEGS Installation in Atlanta District.

Table 2. Advance Warning Statistics in Atlanta District.

	Sunday		Monday		Tuesday		Wednesday		Thursday		Friday		Saturday	
	3/30/2008		3/31/2008		4/1/2008		4/2/2008		4/3/2008		4/4/2008		4/5/2008	
	Phase 2	Phase 6	Phase 2	Phase 6	Phase 2	Phase 6	Phase 2	Phase 6	Phase 2	Phase 6	Phase 2	Phase 6	Phase 2	Phase 6
# of Warnings	438	745	529	857	522	820	521	844	481	807	501	832	425	746
# of false flashes	193	130	110	69	160	85	100	73	104	80	196	152	115	88
Min.	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Max.	39	38	44	38	39	43	56	48	55	31	67	37	42	35
Ave.	8.1	7.8	8.7	7.5	10.1	9.0	9.6	8.3	10.9	9.1	11.2	10.2	7.3	6.6
0 warn.	6	6	4	3	5	3	4	4	3	3	5	3	6	5
50%tile	6.1	5.0	7.5	7.0	7.9	7.0	7.7	7.0	8.6	7.0	8.7	7.7	6.6	5.0
85%tile	15.6	15.1	15.7	14.0	20.9	19.8	18.8	16.6	21.3	19.1	22.0	22.0	12.5	11.3
95%tile	31.1	31.2	24.7	22.8	28.6	29.6	28.2	28.1	29.9	29.7	29.7	30.8	25.4	24.9
> than 10	103	155	158	198	186	243	182	230	203	256	212	303	88	123
> than 20	53	96	50	68	91	122	69	95	81	113	115	177	33	52
> than 30	32	59	6	15	20	38	22	37	24	39	21	49	17	31
> than 40	0	0	1	0	0	1	3	1	3	0	2	0	2	0
> than 50	0	0	0	0	0	0	2	0	1	0	1	0	0	0
Holds	1	2	0	4	5	4	3	3	6	5	9	4	2	7
Daily Volume	5170	4638	9418	8496	9533	8987	9776	9176	10198	9148	9994	8621	7785	7750

PHARR DISTRICT

The Pharr District personnel installed AWEGS infrastructure during the summer of 2007. TTI researchers visited the site on August 13 and 14, 2007, and verified the infrastructure installed for AWEGS. Figure 5 illustrates the AWEGS infrastructure installed on one of the approaches at the site in the Pharr District. TTI researchers then implemented AWEGS in the shadow mode. AWEGS performance in the shadow mode was then evaluated and found to be satisfactory. An AWEGS system was then installed on August 28, 2008, and its performance was evaluated. Figure 6 illustrates the AWEGS system installed in the Pharr District. Table 3 illustrates the statistics of the advance warning by AWEGS in the Pharr District. Table 3 illustrates that AWEGS performance is satisfactory.

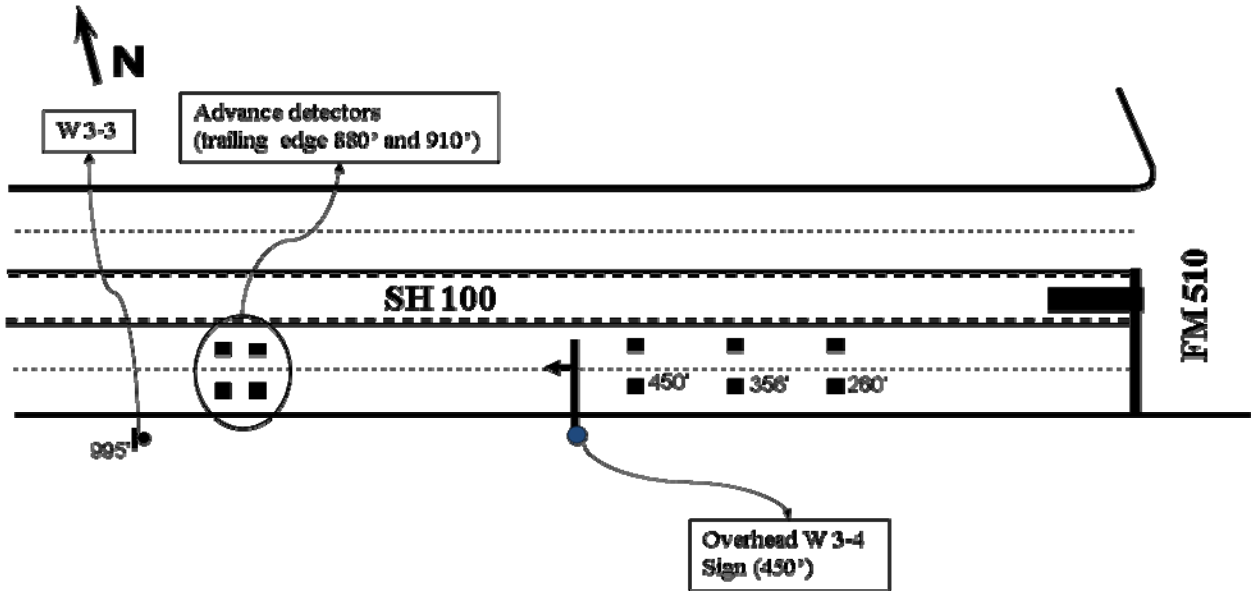

Figure 5. AWEGS Infrastructure on the Eastbound Approach in Pharr District.

Figure 6. AWEGS Installation in Pharr District.

ODESSA DISTRICT

The Odessa District personnel installed AWEGS infrastructure during the summer of 2008. TTI researchers visited the site on June 9 and 10, 2008, and verified the infrastructure installed for AWEGS. Figure 7 illustrates the AWEGS infrastructure installed at the site in the Odessa District. TTI researchers then implemented AWEGS in the shadow mode. AWEGS performance in the shadow mode was then evaluated and found to operate in a satisfactory manner. AWEGS system was then installed on July 28, 2008, and its performance was evaluated. Figure 8 illustrates the AWEGS system installed in the Odessa District. Table 4 illustrates the statistics of the advance warning provided by AWEGS in the Odessa District. Table 4 illustrates that the AWEGS performance is satisfactory. This location also has rail preemption programmed to accommodate 20 to 25 trains per day. AWEGS was modified to operate satisfactorily during rail preemption operations.

Table 3. AWEGS Warning Statistics in Pharr District.

	Sunday		Monday		Tuesday		Wednesday		Thursday		Friday		Saturday	
	9/7/2008		9/1/2008		9/2/2008		9/3/2008		9/4/2008		9/5/2008		9/6/2008	
	Phase 2	Phase 6	Phase 2	Phase 6	Phase 2	Phase 6	Phase 2	Phase 6	Phase 2	Phase 6	Phase 2	Phase 6	Phase 2	Phase 6
# of Warnings	1076	1093	1082	1100	1116	1133	1135	1152	1112	1133	1179	1203	1173	1194
# of false flashes	3	19	3	15	9	31	2	16	4	34	1	14	4	26
Min.	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Max.	31	31	20	20	21	21	23	23	35	19	16	16	23	23
Ave.	3.2	3.2	3.0	3.0	3.1	3.1	3.3	3.3	3.5	3.5	3.5	3.5	3.3	3.3
0 warn.	19	21	18	18	13	14	15	16	8	10	9	9	28	31
50%tile	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	2.1	2.2	2.6	2.4	1.9	1.8
85%tile	6.1	6.1	6.0	6.0	6.0	6.0	6.3	6.2	6.5	6.5	6.5	6.5	6.2	6.2
95%tile	7.5	7.5	7.4	7.4	7.4	7.4	7.7	7.7	8.0	8.0	7.8	7.7	7.5	7.6
> than 10	14	15	18	18	8	8	20	20	23	22	13	13	16	17
> than 20	2	2	1	1	1	1	2	2	1	0	0	0	1	1
> than 30	1	1	0	0	0	0	0	0	1	0	0	0	0	0
> than 40	0	0	0	0	0	0	0	0	0	0	0	0	0	0
> than 50	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Holds	2	29	4	73	1	46	1	52	2	30	3	35	6	47
Daily Volume	3621	7783	4067	8999	3538	6366	3714	6341	3806	6243	4888	6857	5536	7597

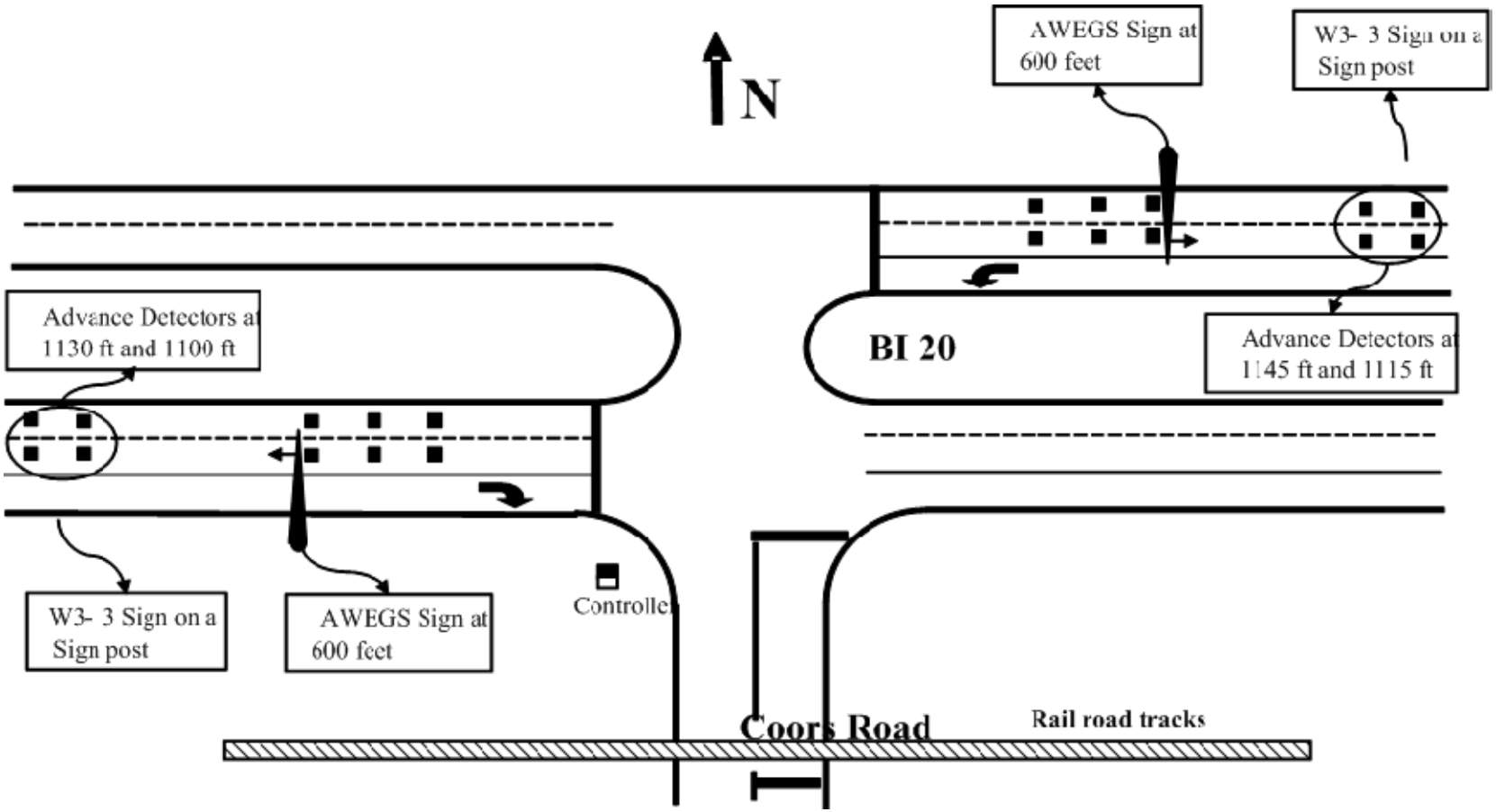

Figure 7. Illustration of AWEGS Infrastructure in Odessa District.

Figure 8. AWEGS Implementation in Odessa District.

SAN ANTONIO DISTRICT

Personnel from the San Antonio District had installed all the necessary conduits and poles to install the advance detectors by August 31st 2008. Subsequently Wavetronics detectors were installed at the intersection as well as upstream of the intersection on both approaches. These detectors were configured for AWEGs operation. AWEGS has been be implemented in the shadow mode. TTI researchers will implement AWEGS in the near future once the results in the shadow mode are satisfactory.

Table 4. Advance Warning Statistics in Odessa District.

	Sunday		Monday		Tuesday		Wednesday		Thursday		Friday		Saturday	
	8/3/2008		8/4/2008		8/5/2008		8/6/2008		8/7/2008		8/8/2008		8/9/2008	
	Phase 2	Phase 6	Phase 2	Phase 6	Phase 2	Phase 6	Phase 2	Phase 6	Phase 2	Phase 6	Phase 2	Phase 6	Phase 2	Phase 6
# of Warnings	480	367	947	651	965	663	961	671	1013	694	944	677	621	439
# of false flashes	47	41	93	85	85	79	69	66	108	88	105	86	69	56
Min.	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Max.	41	41	36	47	31	31	30	30	41	41	41	45	41	41
Ave.	3.2	3.3	4.1	4.4	3.7	3.9	3.6	3.8	4.9	4.9	4.6	4.6	3.0	3.3
0 warn.	4	5	14	12	8	9	15	11	17	11	8	9	6	6
50%tile	1.4	1.4	2.9	3.5	2.6	3.7	2.2	2.7	3.1	3.4	3.7	4.1	1.4	1.5
85%tile	6.0	6.0	6.2	6.4	6.1	6.3	6.0	6.1	7.1	7.0	6.4	6.4	6.0	6.0
95%tile	6.2	6.4	9.7	11.4	7.9	8.7	8.4	9.5	15.2	13.1	11.4	11.3	6.6	7.1
> than 10	8	7	46	38	25	22	36	30	87	55	62	44	9	8
> than 20	2	2	17	15	2	2	4	4	42	30	27	17	1	2
> than 30	2	2	8	7	2	1	0	0	16	11	16	9	1	2
> than 40	2	2	0	1	0	0	0	0	7	3	5	2	1	1
> than 50	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Holds	7	0	15	3	11	1	30	1	20	1	24	4	14	1
Daily Volume	3761	3702	7893	7889	8041	7875	8011	7954	8392	7991	8668	8671	5630	6303
Daily Train Volume	29		22		15		31		28		28		20	

CONCLUSIONS

AWEGS, when properly designed and implemented, improves the dilemma zone protection at isolated intersections with high speed approaches. The system was designed to operate at intersections that have typical dilemma zone protection. This protection was in the form of inductive loops or their equivalent detection devices placed at appropriate location on the approach to the intersection. Improving dilemma zone on high speed approaches by using AWEGS has resulted in reduction of red-light-running of approximately 45 to 50 percent (*2*).

Three of the four AWEGS implementations that were planned in this project were installed. AWEGS was implemented in the shadow mode in San Antonio. Once the data has been verified, the system will be fully implemented.

The sites in the Pharr and Odessa Districts use inductive loops for dilemma zone protection. AWEGS performance at these two sites was as expected and provided the necessary advance warning. The site in the Atlanta District uses video detection for dilemma zone protection. All attempts were made to ensure that the video detection performed in a manner consistent to inductive loops. However, the evaluation of AWEGS performance indicated that the warning times being provided by AWEGS was higher than expected. Careful analysis of the data illustrated that video detection for dilemma zone performed in a manner inconsistent with the expectation of AWEGS. The detectors were not gapping out as expected under higher volume conditions. Thus it is recommended that AWEGS be installed only at locations using detection similar to inductive loops

REFERENCES

1 Messer, C.J., S.R. Sunkari, H.A. Charara, and R.T. Parker. *Development of Advance Warning Systems for End-of-Green Phase at High Speed Traffic Signals.* Report 4260-4, Texas Transportation Institute, College Station, Texas, September 2003.

2 Messer, C.J., Sunkari, S.R., Charara, H.A., and Parker, R.T. *Design and Installation Guidelines for Advance Warning Systems for End-of-Green Phase at High Speed Traffic Signals.* Texas Transportation Research Report 4260-2, September 2003.