Evaluation of Automated Flagger Assistance Devices

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16. Abstract

Flagger safety is an important issue in work zones due to the proximity of the flagger to traffic. Some strategies for improving flagger safety include slowing down approaching vehicles or removing flaggers from the immediate vicinity of traffic. The Automated Flagger Assistance Device (AFAD) is a system that can potentially accomplish both of the aforementioned strategies. In order to validate the effectiveness of AFADs in highway work zones, field testing was performed using an AFAD with a Changeable Message Sign (CMS) on a 2-lane work zone in Missouri. The field study found that AFADs helped to lower approach speeds and encouraged vehicles to stop farther behind the AFAD than a traditional flagger. In addition, a driver intercept survey found that the AFAD was viewed favorably by the general public. These field results found that AFADs are more effective than human flaggers, and drivers prefer AFADs over human flaggers.

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Evaluation of Automated Flagger Assistance Devices

An Interim Report

presented to

Missouri Department of Transportation

by the University of Missouri-Columbia

In Partial Fulfillment

of the Automated Flagger Assistance Devices (AFAD) Project

by

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TABLE OF CONTENTS

ACKNOWLEDGMENTS 0
CHAPTER 1. INTRODUCTION 1
1.1 Background 1
1.2 Literature Review 3
CHAPTER 2: FIELD DATA COLLECTION 8
2.1 Field Set Up Plan 8
2.2 First Field Data Collection 9
2.3 Second Field Data Collection 10
CHAPTER 3: SURVEY 27
3.1 Survey Methodology 27
3.2 Survey Results 27
CHAPTER 4: CONCLUSION 31
REFERENCES 33
APPENDIX A: DATA COLLECTION RESULTS FOR ALL TYPES OF VEHICLES 35
A.1 Total Data Statistics 35
A.2 South Bound Data Statistics 37
A.3: North Bound Data Statistics 39
APPENDIX B: SURVEY QUESTIONS 41
APPENDIX C: SURVEY RESULTS BY DIFFERENT GROUPS 46
C.1 Results by Age 46
C.2 Results by Gender 52
C.3 Survey Results by Residency 55

LIST OF FIGURES

Figure 1.1.1 AFAD Mounted on TMA 2
Figure 1.2.1 AutoFlagger 76 (Safety Technologies 2015a) 4
Figure 1.2.2 AutoFlagger 54 (Safety Technologies 2015b) 4
Figure 1.2.3 RC Flagman RCF 2.4 (North America Traffic 2016) 5
Figure 1.2.4 Intellistrobe W1-AG (IntelliStrobe 2017) 5
Figure 2.1.1 Field Study Plan of Cameras, Radar Speed Gun, and Delineators 8
Figure 2.2.1 Map of MO 150 Work Zone (Google Maps 2017) 9
Figure 2.2.2 Field Settings on MO 150 Highway Work Zone (Google Maps 2017) 10
Figure 2.3.1 Map of MO 23 Work Zone (Google Maps 2017) 11
Figure 2.3.2 Field Settings on MO 23 Work Zone (Google Maps 2017) 13
Figure 2.3.3 Flagger 13
Figure 2.3.4 MOE 1 example: Speed of the Leading Vehicle at 250 ft. from the AFAD/Flagger 15
Figure 2.3.5 MOE 2 example: Full Stop Location 16
Figure 2.3.6 MOE 3 example: Waiting Time 17
Figure 2.3.7 MOE 4: Reaction Time 18
Figure 2.3.8 MOE 5: Intervention Rate 19
Figure 2.3.9 MOE 6: Speed of the 1st Following Vehicle at 250 ft. from the AFAD/Flagger 20
Figure 2.3.10 MOE 7: Queue Length 21
Figure 2.3.11 Vehicle Approaching Flagger at High Speed 25
Figure 2.3.12 Vehicle Long Reaction Time to SLOW Indication on AFAD 25

LIST OF TABLES

Table 2.2.1 MO 150 Field Data Collection Information 9
Table 2.3.1 MO 23 Field Data Collection Information 11
Table 2.3.2 Summary of Field Data Collected 14
Table 2.3.3 Speed of the Leading Vehicle at 250 ft. from the AFAD/Flagger....................22
Table 2.3.4 Full Stop Location 22
Table 2.3.5 Waiting Time and Queue Length....................23
Table 2.3.6 Reaction Time (AFAD based on CMS, flagger based on paddle)....................23
Table 2.3.7 Intervention Rate....................24
Table 2.3.8 1st Following vehicle Speed at 250 ft.....................24
Table 3.1.1 Survey Numbers 27
Table 3.2.1 Survey Responses Regarding Effectiveness 28
Table 3.2.2 Reason of Effectiveness Rating 28
Table 3.2.3 Summary of Responses to Survey Question Regarding Helpfulness of CMS 29
Table 3.2.4 Summary of Responses to Question About Previous Experience with AFAD and Flagger 29
Table 3.2.5 Respondents' Preference for AFAD or Flagger 29
Table 3.2.6 Demographic Information....................30
Table 3.2.7 Residency and Vehicle Information 30
Table A.1.1 Total Data Statistics, MOE 1 – MOE 4 35
Table A.1.2 Total Data Statistics, MOE 5 – MOE 7 36
Table A.2.1 South Bound Data Statistics, MOE 1 – MOE 4....................37
Table A.2.2 South Bound Data Statistics, MOE 5 – MOE 7....................38
Table A.3.1 North Bound Data Statistics, MOE 1 – MOE 4....................39
Table A.3.2 North Bound Data Statistics, MOE 5 – MOE 7....................40
Table C.1.1 Age Range vs. Effectiveness of AFAD (Figure 1 in Survey) 46
Table C.1.2 Age Range vs. Reasons of Rating 47
Table C.1.3 Age Range vs. Helpfulness of CMS (Figure 1 in Survey) 48
Table C.1.4 Age Range vs. Encountered Signage Before 48
Table C.1.5 Age Range vs. Effectiveness of Flagger (Figure 2 in Survey)....................49
Table C.1.6 Age Range vs. Reasons of Rating 50
Table C.1.7 Age Range vs. Preference 51
Table C.2.1 Gender vs. Effectiveness of AFAD....................52
Table C.2.2 Gender vs. Reasons of Rating 52
Table C.2.3 Gender vs. Helpfulness of CMS....................53
Table C.2.4 Gender vs. Encountered Stop Control Before....................53
Table C.2.5 Gender vs. Effectiveness of Flagger 53
Table C.2.6 Gender vs. Reasons of Rating 54
Table C.2.7 Gender vs. Preference 54
Table C.3.1 Residency vs. Effectiveness of AFAD....................55
Table C.3.2 Residency vs. Reasons of Rating 55
Table C.3.3 Residency vs. Helpfulness of CMS....................56
Table C.3.4 Residency vs. Encountered Stop Control Before....................56
Table C.3.5 Residency vs. Effectiveness of Flagger 56
Table C.3.6 Residency vs. Reasons of Rating 57

Table C.3.7 Residency vs. Preference 57

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CHAPTER 1. INTRODUCTION

1.1 Background

Highway workers are active in areas where vehicles are often traveling at high speeds. Some methods for improving worker safety involve separating workers from traffic, including the use of buffer spaces and barriers. Flaggers are often located closest to the on-coming traffic in order to direct traffic, and as a result, flaggers are always at a risk of injury by on–coming traffic. One possible way to reduce this risk is through the use of an Automated Flagger Assistance Device (AFAD). AFAD is a portable system that can be used to control traffic during lane closures on two-lane highways thus replacing human flaggers and providing protection for construction workers.

This report documents a field verification and a driver behavior study of the effectiveness of an AFAD configuration developed by the Missouri Department of Transportation (MoDOT). As shown in Figure 1.1.1, the AFAD with the MoDOT configuration is built into a truck-mounted attenuator (TMA) unit, thus providing protection for the AFAD operator who sits in the truck. The MoDOT configuration includes a STOP/SLOW paddle, a red and yellow lens, and a changeable message sign (CMS) that changes from "SLOW" to "STOP" indications. In addition to worker protection, AFAD also has the potential benefit of greater visibility by using the large CMS and the TMA checkerboard panel.

Figure 1.1.1 AFAD Mounted on TMA

Flaggers have been playing an important role in traffic and transportation for a long time, as they guide and direct vehicles on the highway, and often, through work zones. Flaggers are trained professionally to display uniform gestures for traffic guidance and direction using signaling devices. Richards and Bowman (1981) examined the effectiveness of flagger gestures and signals and found that some signals are more effective than others. They also validated the importance of using flaggers. Flaggers are exposed to safety risks, as they may be hit by oncoming traffic when drivers are not aware of the presence of workers or are not able to come to a full stop when approaching the work zone. Studies show that a high percentage of work zone-related crashes occurred in the advance warning area where flaggers could be located (Srinivasan et al. 2007), even the highest percentage in one study (Ishak et al. 2012). Finding ways to protect flaggers from crashes and improving work zone safety is an important issue.

Traffic engineers have proposed different methods to slow down the approaching speed and extend the merge distance of vehicles as they approach work zones. Studies investigating new advances include mobile work zone alarm systems (Brown et al. 2015), alternative merge signs (Zhu et al. 2015), automated traffic light systems (Subramaniam et al. 2010), flashing STOP/SLOW paddles (Pigman et al. 2006), Remote Controlled (RC) Flagman (Jessberger 1999), IntelliStrobe Safety Systems (MoDOT 2006) and other types of AFADs (Cottrell Jr 2006; Finley et al. 2011; Terhaar 2014).

1.2 Literature Review

AFADs are designed to protect flaggers in work zones by allowing flaggers to control traffic signals remotely instead of standing right next to the occupied lanes. According to the *Manual on Uniform Traffic Control Devices* (FHWA 2009), there are two different types of AFADs: STOP/SLOW AFADs and Red/Yellow Lens AFADs. Both types of AFADs are remotely controlled. In their 2005 technical provision, FHWA (2005a) regulated the maximum distance between two AFAD devices to 1,000 ft. AFADs should not be used for long term work or as regular traffic control signals. According to the FHWA, a STOP/SLOW AFAD shall include a sign with STOP and SLOW faces showing alternatively, which could be controlled remotely and keep an operator out of immediate traffic. A Red/Yellow Lens AFAD shall include a steady circular red lens and a flashing circular yellow lens. A gate arm is required for Red/Yellow Lens AFAD, which lowers to stop approaching traffic while the red lens is illuminating and raises to release stopped traffic while the yellow lens is illuminating.

Currently, some commercial STOP/SLOW AFADs include the AutoFlagger 76 (AF-76) (Figure 1.2.1) (Safety Technologies 2015a), and J4 Flagger Workstations. Commercial Red/Yellow Lens AFADs include the AutoFlagger 54 (AF-54) (Figure 1.2.2) (Safety Technologies 2015b), RC Flagman RCF 2.4 (Figure 1.2.3) (North America Traffic 2016), Automated Flagger AF-100 (Synergy Technology 2017), and Intellistrobe W1-AG (Figure 1.2.4) (IntelliStrobe 2017). FHWA also created a policy memorandum (FHWA 2005b) and provided technical provisions (FHWA 2005a) for AFADs. Based on the work and materials from FHWA, American Traffic Safety Services Association (ATSSA 2012) published a guidance document on AFAD usage in 2012.

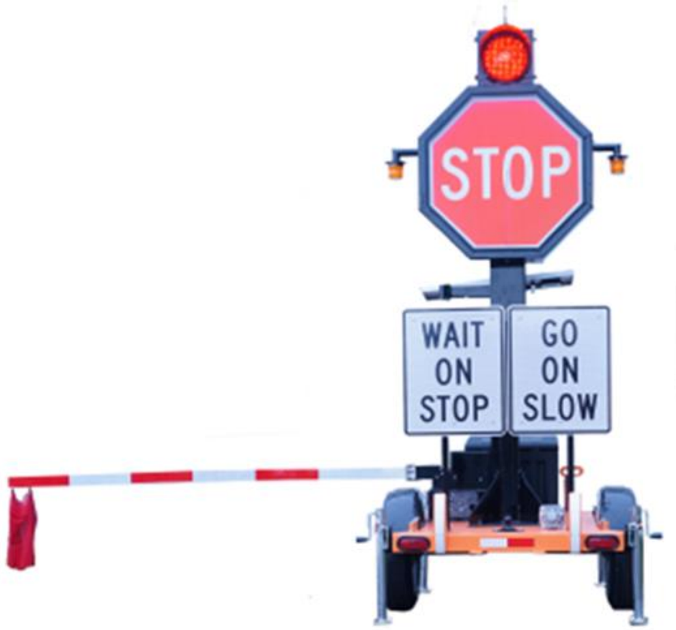

Figure 1.2.1 AutoFlagger 76 (Safety Technologies 2015a)

Figure 1.2.2 AutoFlagger 54 (Safety Technologies 2015b)

Figure 1.2.3 RC Flagman RCF 2.4 (North America Traffic 2016)

Figure 1.2.4 Intellistrobe W1-AG (IntelliStrobe 2017)

To evaluate the effectiveness of AFADs, research and field studies were performed by Ohio Department of Transportation (ODOT) (Jessberger 1999), Washington County (Kansas) Public Works (Harris 2002), Missouri Department of Transportation (MoDOT) (MoDOT 2006), Minnesota Department of Transportation (MnDOT) (MnDOT 2005; Terhaar 2014), Virginia Transportation Research Council (VTRC) (Cottrell Jr 2006), and Texas Transportation Institute (TTI) (Finley 2013; Finley et al. 2011; Trout et al. 2013).

1.2.1 Evaluation of STOP/SLOW AFADs

MnDOT (MnDOT 2005) tested the AutoFlagger traffic control devices in the late 1990s as an enhancement to flagging systems. The human operator controlled the AutoFlagger devices in both directions remotely. Surveys were sent out to drivers and operators to collect opinions on AutoFlagger, and the responses were positive.

VTRC and the Virginia Department of Transportation (VDOT) reviewed applications of AFADs in Minnesota (MnDOT 2005), evaluated AutoFlagger deployments in two areas, and compared AutoFlagger with other AFAD systems (Cottrell Jr 2006). The AutoFlagger deployed in Virginia was a STOP/SLOW paddle device, equipped with a horn for warning purposes. The first deployment was located in the Wytheville area. The AutoFlagger was deployed under different types of construction and maintenance projects and was also displayed at a safety day. The crews used it on roadways with narrow shoulders or no shoulders by putting the device in the lane, with cones at a 50-ft taper in front of it. The deployments in Wytheville showed that the WAIT ON STOP – GO ON SLOW sign was misunderstood by drivers due to the novelty of AutoFlagger. The second deployment was located in the Beach area. In contrast to the deployment in Wytheville, staff in Beach felt more comfortable using AutoFlagger in long straight areas with wide shoulders and clear sight distance, rather than in areas with narrow shoulders. The crews also suggested that horns should be louder to be heard, and flashing lights should be larger and brighter to enhance visibility. VTRC concluded that although the deployment of AutoFlagger is limited by shoulder conditions, the application of AutoFlaggers provides a safe work zone environment, costs less labor, and saves money for long term; however, it may be harder for drivers to locate a flagger for further communication.

1.2.2 Evaluation of Red/Yellow Lens AFADs

In the late 1990s, the Ohio Department of Transportation (ODOT) (Jessberger 1999) evaluated the Remote Controlled (RC) Flagman (North America Traffic 2016). The RC Flagman device is placed in a two-lane highway location, with one lane closed, and the evaluation included comments from ODOT employees who operated the devices, public interviews, assessment of cost effectiveness, and accident statistics. The RC Flagman contains Red/Yellow signals mounted on a mobile trailer, a remote control unit, a gate arm, and a STOP HERE ON RED SIGNAL paddle. During the ODOT field experiment, operators had trouble with short battery life and weak button contact of the remote control units, time delay from the pressing of the button to the changing of the signal light, and slow movement of the gate arm motors. Operators also suggested the visibility of gate arm be enhanced. Operators indicated the set up and operation of RC flagman was easy, and they were satisfied with drivers’ reactions as well. Most of the motorists thought that the device was visible, the STOP message was presented clearly, and the RC Flagman freed one flagger and provided a safer environment for flaggers. Some interviewees were worried about flaggers losing jobs. Although some problems existed, the overall comments from ODOT operators and public regarding the use of RC Flagman were favorable. Based on cost and maintenance history, the study found that using RC Flagman is cost effective. No accidents were reported during the two-year evaluation of RC Flagman. Thus, ODOT concluded that RC Flagman is at least as safe as traditional flaggers. Similar to Ohio, the RC Flagman evaluation in Washington County, Kansas, also found it is cost-effective, and the visibility of the red light makes it work even better than human flaggers (Harris 2002). According to RC Flagman, no accident has been reported since this device was produced in 1993 (Harris 2002).

In fall 2005, Missouri Department of Transportation piloted the IntelliStrobe flagging system (IntelliStrobe 2017) in the south Central District. An IntelliStrobe device contains red/yellow signals, two remote control units to be used by one person, and a danger alert. The yellow light keeps flashing, and when the red light illuminates, the gate arm lowers to stop approaching traffic. In case motorists misunderstand or violate the signal and do not stop, the danger alert sounds to alert operators. The IntelliStrobe Safety System is suitable for short work zones since one flagger controls both ends. It frees up one flagger, and as a result, shortens the time needed for construction, and enhances work zone safety (MoDOT 2006).

1.2.3 Evaluation of both STOP/SLOW and Red/Yellow Lens

In addition to the evaluation of STOP/SLOW AFADs performed in 2005, MnDOT (Terhaar 2014) held two training sessions for its employees in 2013 to further investigate and evaluate AFADs. These sessions include introduction and demonstration of AFADs, set up, operation, and take down, discussion of impressions and limitations, and field tests. Both AutoFlagger AF-76 (STOP/SLOW) and AutoFlagger AF-54 (Red/Yellow Lens) were evaluated. The outcome of this study indicated that a set of AFADs could be operated by one or two personnel remotely from traffic, and maintenance staff were willing to use AFADs overall. Setting up and taking down the AFAD requires more time and effort than traditional flagging. The result also suggested that AF-76 fits in wide shoulder work zones, while AF-54 fits in narrow shoulder locations, and both AF-76 and AF-54 are recommended for two-lane highways.

The review of the previous AFAD evaluations showed there was very little use of quantitative performance measures. This is a major motivation for the present MoDOT study which uses quantitative performance measures such as speeds, stop locations, wait times, reaction times, and intervention rates in addition to surveys.

CHAPTER 2: FIELD DATA COLLECTION

Two goals of the project are to conduct field and simulator studies to verify the AFAD effectiveness and to study driver behavior. The study includes three proposed phases: a field test with Changeable Message Sign (CMS), a simulator study (both with and without CMS), and a tentative field test without CMS. This interim report describes the first phase of the study.

2.1 Field Set Up Plan

Phase one focused on field testing a MoDOT STOP/SLOW AFAD mounted on a TMA and compared it with the human flagging system. In the field, video cameras, speed radar guns and delineators were deployed to collect data measurements. Driver performance and driving behavior at both AFAD and human flagger sides were recorded. These driver performance measures included vehicle approach speed, full stop location, reaction time and other unusual driving behaviors.

The field study plan is shown in Figure 2.1.1. The camera was placed on the right side of the road, to avoid influencing opposite traffic. To measure vehicle approach speed, the speed radar was set in front of the video camera without blocking the image of vehicles, delineators and the AFAD or the flagger. The delineators were placed every 50 feet along the road. There were a total of seven delineators from the stop control at each side. Besides the driver reactions to the AFAD or the flagger, the camera also recorded traffic information on the road, such as traffic volume, waiting time, and queue length.

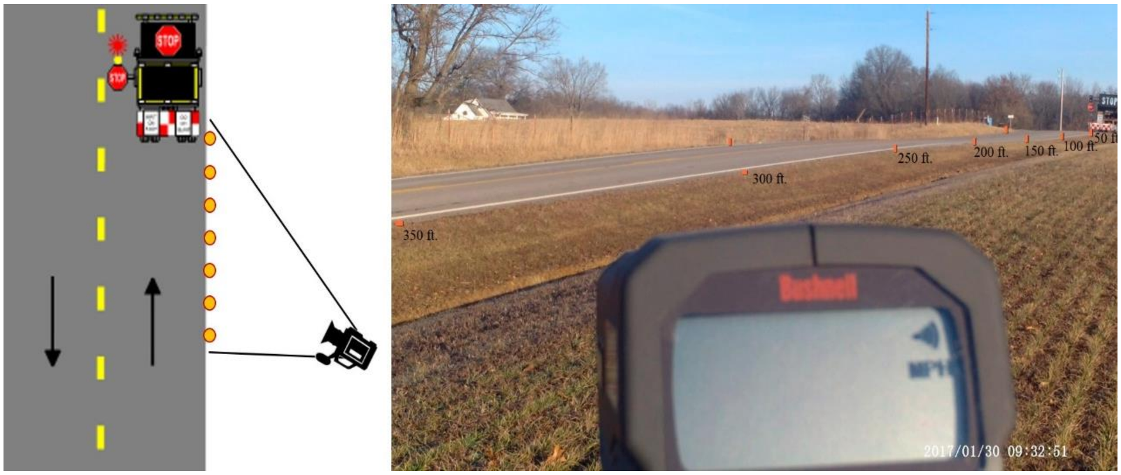

Figure 2.1.1 Field Study Plan of Cameras, Radar Speed Gun, and Delineators

Two field data sessions were conducted to collect field data. The first one was on December 20th, 2016, on MO 150 in Lone Jack, Missouri. The second one was conducted on January 30th and 31st, 2017, on MO 23 in Knob Noster, Missouri.

2.2 First Field Data Collection

The first field data collection was on December 20th, 2016, on MO 150 in Lone Jack, Missouri. MO 150 was a two-lane highway, and the work zone was 2,200 feet long from the AFAD on one end to the flagger at the other end. The annual average daily traffic (AADT) on the road segment was 1,028 vehicles per day, according to the MoDOT Transportation Management Systems (TMS). The work zone layout and descriptions are shown in Figure 2.2.1 and Table 2.2.1.

Figure 2.2.1 Map of MO 150 Work Zone (Google Maps 2017)

Table 2.2.1 MO 150 Field Data Collection Information

Location:	MO 150 in Lone Jack, MO
	Two-lane highway
AADT:	1,028 vpd (directional 514)
Length:	2,200 ft. (from the flagger to AFAD)
Duration:	12/20/2016 10:30 AM - 11:45 AM

In the field, one camera, one radar speed gun, and a set of delineators were placed at each work zone end. The field settings and the field views of the cameras are shown in Figure 2.2.2. The west end camera recorded traffic and driver reaction to the flagger, and the east end camera recorded activities at the AFAD.

Figure 2.2.2 Field Settings on MO 150 Highway Work Zone (Google Maps 2017)

The data collection was conducted from 10:30 AM to 11:45 AM. As the testing was underway, it was determined the AFAD was not functioning properly due to a problem with the wireless controller that changes the paddle and CMS. Therefore, the data collection was aborted. Subsequently, MoDOT changed the AFAD controller from wireless to wired to enhance the reliability, and a second field survey was scheduled.

2.3 Second Field Data Collection

The second field data collection was conducted on January 30th and 31st, 2017, on MO 23 in Knob Noster, Missouri. The work zone was 2,400 ft. long and the AADT value on the road was 2,610 vehicles per day. The work zone layout and information of work zone are shown in Figure 2.3.1 and Table 2.3.1.

Figure 2.3.1 Map of MO 23 Work Zone (Google Maps 2017)

Table 2.3.1 MO 23 Field Data Collection Information

Location:	MO 23, Knob Noster, MO
	Two-lane highway
	Speed limit 55 mph
AADT:	2,610 vpd (directional 1,305)
Length:	2,400 ft. (from the flagger to AFAD)
Duration:	01/30/2017 09:17 AM – 04:47 PM
	01/31/2017 09:57 AM – 04:29 PM

2.3.1 Data Collection

The data collection deployment on MO 23 is shown in Figure 2.3.2. The difference between the deployment and the field study plan was the north side camera was placed on the left side of road due to the topographic constraints. This change had a limited impact for opposite traffic on a small sample size. On one end of the work zone, there was an AFAD mounted on a truck-mounted attenuator (TMA) truck (Figure 1.1.1) with an operator sitting inside the TMA vehicle to control the AFAD remotely. On the other end, there was a human flagger standing next to the traffic lane to show STOP/SLOW paddles (Figure 2.3.3). Speed guns and cameras were set up at each side to record approaching speeds of vehicles. On the first day, the AFAD was located on the south side of the work zone, and the flagger was on the north side. On the second day, the locations of the AFAD and flagger were reversed. Thus each type of flagging was deployed in both directions.

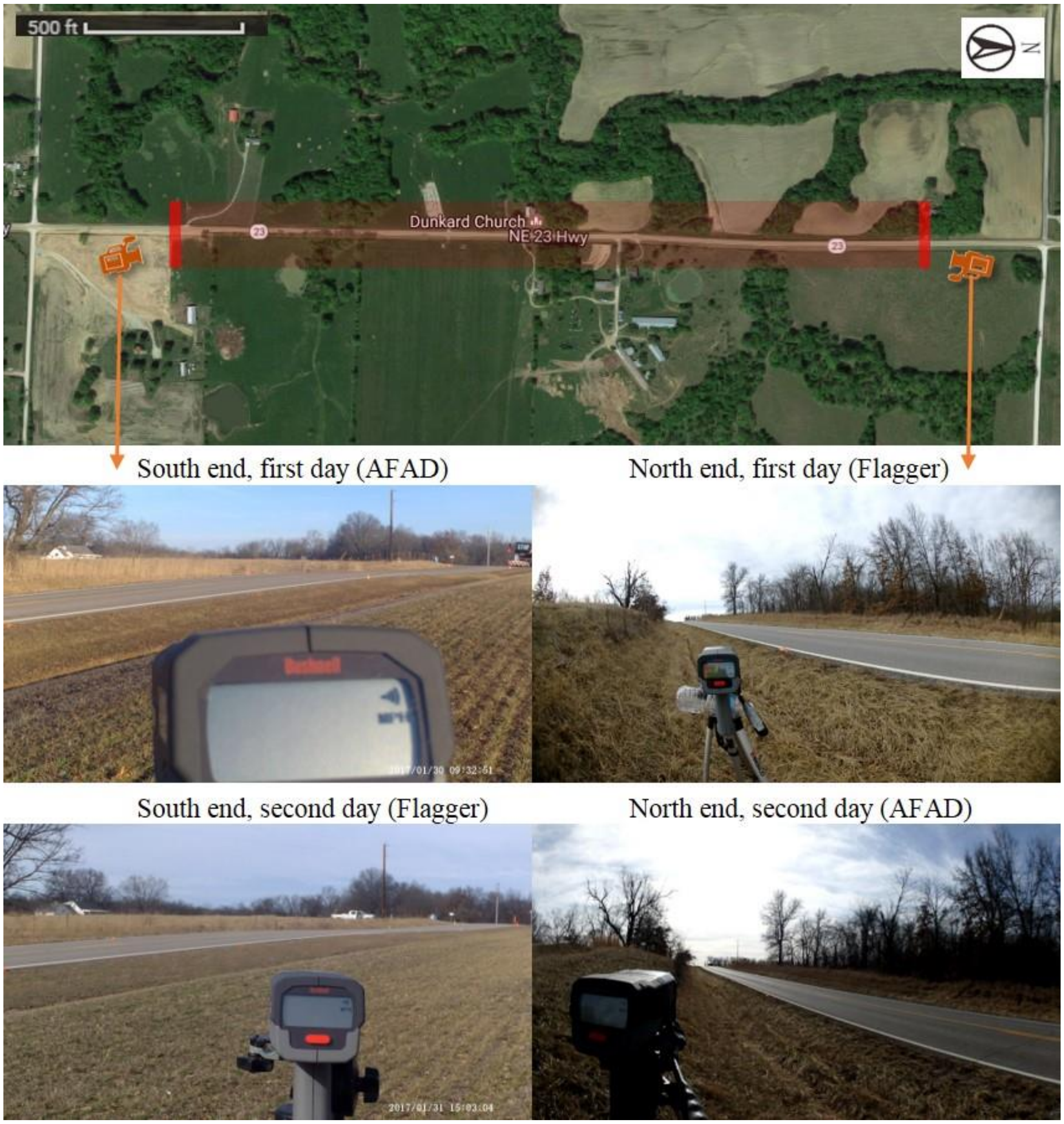

Figure 2.3.2 Field Settings on MO 23 Work Zone (Google Maps 2017)

Figure 2.3.3 Flagger

2.3.2 Data Processing

The videos were reviewed, and the performance data were obtained. Only vehicles that encountered a STOP paddle/message were processed; those vehicles that only encountered SLOW and drove through directly were not processed. The number of samples is shown in Table 2.3.2. The sample size collected was 334 total, of which 186 was for AFAD and 148 for flagger.

Table 2.3.2 Summary of Field Data Collected

Field Data	Traffic Control Types		Total
Location	AFAD	Flagger	
South End	102 (First Day)	82 (Second Day)	184
North End	84 (Second Day)	66 (First Day)	150
Total	186	148	334

After the field data was collected, the research team reviewed the videos, and conducted the data reduction process. Seven Measure of Effectiveness (MOEs) were defined for data reduction as described below.

- MOE 1: speed of the leading vehicle at 250 ft. from the AFAD/Flagger (Figure 2.3.4). The speed was read from the speed gun. However, the speed gun did not display any speeds lower than 10 mph, so researchers estimated speeds less than 10 mph using the speed from the last reading.

Figure 2.3.4 MOE 1 example: Speed of the Leading Vehicle at 250 ft. from the AFAD/Flagger

- MOE 2: full stop location (Figure 2.3.5). Location of vehicle’s front end when the vehicle came to a full stop. The location was the distance from the AFAD or flagger. The distance was determined from the video based on the delineator cones that were placed.

Figure 2.3.5 MOE 2 example: Full Stop Location

- MOE 3: waiting time (Figure 2.3.6). Waiting time was measured as the time gap between the time when the vehicle came to a full stop and when the vehicle started to move again after receiving the SLOW indication from the flagger or AFAD.

Figure 2.3.6 MOE 3 example: Waiting Time

- MOE 4: reaction time (flagger/AFAD CMS) (Figure 2.3.7). Reaction time was measured as the time between when STOP changes to SLOW (paddle for flagger and CMS for AFAD) and the vehicle restart time. At the time of the field experiment, the SLOW paddle on the AFAD and message on CMS were not synchronized. When the message on the CMS changed from STOP to SLOW, the paddle started to turn, and it took four seconds to finish turning. Drivers appeared to react based on the message shown on CMS. The time lag between the paddle and CMS on the AFAD was corrected after the field work. Although recording the time based on paddle on the AFAD and paddle on human flagging system would be consistent, the reaction time was measured based on CMS due to the regular offset and driver behavior.

Figure 2.3.7 MOE 4: Reaction Time

- MOE 5: Intervention rate (Figure 2.3.8). Intervention refers to when a vehicle ignored the STOP sign and was stopped by the AFAD or flagger. If a vehicle approached the AFAD too closely or tried to go through and the AFAD horn honked, or if a vehicle approached a flagger too closely and flagger stopped the vehicle by giving gestures, then it was regarded as one intervention. Intervention rate equals the ratio of interventions over sample size.

Figure 2.3.8 MOE 5: Intervention Rate

- MOE 6: speed of the 1st following vehicle at 250 ft. from the AFAD/Flagger.

Figure 2.3.9 MOE 6: Speed of the 1st Following Vehicle at 250 ft. from the AFAD/Flagger

- MOE 7: queue length (Figure 2.3.10). The number of vehicles in a queue.

The seven MOEs were extracted and data were grouped by direction (southbound/northbound), flagging type (AFAD/Flagger), and vehicle type (sedan, pickup, commercial vehicle). Vehicle types were defined based on the height of wheels, so SUVs and minivans were regarded as pickups.

Figure 2.3.10 MOE 7: Queue Length

2.3.3 Field Data Results

All of the MOEs were recorded and extracted from videos, and their absolute values were presented. The differences between the MOEs for the AFAD and flagger were calculated to allow for comparisons. Confidence level was indicated by the T test result, and Cohen’s d was calculated. Cohen's d is a measure of the effect size, which indicates the standardized difference between two means. Cohen’s d is calculated as the ratio of the difference of means to the pooled standard deviation (Ferguson, 2009).

MOE 1 measured the speed of the leading vehicle at 250 ft. from the AFAD/Flagger. As shown in Table 2.3.3, the average approaching speed of vehicles that encountered the AFAD was 23.2 mph, and the approaching speed of vehicles that encountered the human flagger was 27.4 mph. Approach speeds for vehicles that traveled through the AFAD were significantly lower than for the human flagger with a confidence level higher than 99.9%. Cohen's d indicated that the standardized mean of AFAD speed was 0.667 standard deviations lower than the mean of flagger.

Table 2.3.3 Speed of the Leading Vehicle at 250 ft. from the AFAD/Flagger

	Speed at 250 ft. (mph)
AFAD	23.2
Flagger	27.4
T test	<0.001*
Difference	-4.1
Cohen's d	-0.667

MOE 2 measured the full stop location of vehicles that encountered STOP message/paddle. As shown in Table 2.3.4, the average full stop location of vehicles that encountered the AFAD was 61.07 ft. behind the AFAD, and the average full stop location of vehicles that encountered human flagger was 49.64 ft behind the flagger. The full stop location for the AFAD was significantly farther away than the flagger with the confidence level being higher than 99.9%. Cohen's d indicated the mean of the AFAD full stop location was 0.436 units of standard deviation farther than flagger.

Table 2.3.4 Full Stop Location

	Full Stop Location (ft.)
AFAD	61.07
Flagger	49.64
T test	<0.001*
Difference	11.44
Cohen's d	0.436

MOE 3 measured the waiting time of the first vehicle in the queue, and MOE 7 measured the queue length in stopped queue. MOEs 3 and 7 are shown in Table 2.3.5. These two MOEs were not related to safety but efficiency. Since waiting time was defined as the time gap between vehicle restart and full stop, the time when the vehicle restarted was recorded. However, one factor influenced the waiting time difference between the AFAD and flagger. When the AFAD changed the message from STOP to SLOW, vehicles from the other direction may not have been cleared, and vehicles were still coming out from the work zone. As a result, vehicles that encountered the AFAD would still have to wait for other direction to be cleared, even after the AFAD showed SLOW and vehicles restarted. Meanwhile, human flaggers would wait until all vehicles from the other direction to be cleared, then turn the paddle from STOP to SLOW. Since MOE 3 captured the time gap between when vehicle came to a full stop and vehicle restarted, the waiting time recorded for the AFAD may be underestimated.

Table 2.3.5 Waiting Time and Queue Length

	Waiting Time (s)	Queue Length (veh)
AFAD	72.25	1.70
Flagger	105.52	2.08
T test	0.002	0.006
Difference	-33.26	-0.39
Cohen's d	-0.389	-0.301

MOE 4 measured the reaction time of the first vehicle in the queue. It was calculated as the time gap between the first appearance of SLOW message (AFAD) or paddle (flagger) and when the vehicle started to move again. As previously discussed, the reaction time based on the AFAD CMS was ultimately used instead of the AFAD paddle. As shown in Table 2.3.6, the average reaction time for the AFAD was 4.41 s, and for the flagger was 1.69 s. The reaction time for the AFAD was significantly longer than for the flagger. This result may be due to the differences in interpersonal communication with a person as opposed to interaction with a device. Another reason for the significant longer reaction time for drivers who encountered the AFAD may be that some drivers were looking at their cellphones or were otherwise distracted, but the drivers that passed through the flagger may have been less distracted due to the presence of a live human flagger standing by the side. Also, as previously discussed, the lag between the CMS display and the paddle turning could also have been a factor. Cohen's d (effect size) indicated that the mean reaction to the AFAD was 2.921 units of standard deviation longer than reaction time to flagger.

Table 2.3.6 Reaction Time (AFAD based on CMS, flagger based on paddle)

	Reaction Time (CMS) (s) Based on AFAD CMS	Reaction Time (CMS) (s) Based on AFAD Paddle
AFAD	4.41	0.412
Flagger	1.69	1.690
T test	<0.001*	<0.001*
Difference	2.72	-1.279
Cohen's d	2.921	-0.530

MOE 5 measured the intervention rate, which could be an indication of driver's misunderstanding of the AFAD or flagger. Intervention refers to when a vehicle ignored the STOP sign, thus requiring the AFAD to honk its horn or the flagger to stop the vehicle using gestures. In some instances, the vehicle backed up to the proper position after the intervention. The total number of interventions for the AFAD and flagger were the same, but because the sample size for the AFAD was larger than the flagger, the intervention rate for AFAD was slightly lower than flagger, as shown in Table 2.3.7. However, the difference was not statistically significant. A previous MnDOT (2005) evaluation reported an intervention rate of 0.0096 (5/313). This is a similar low but non-negligible intervention rate.

Table 2.3.7 Intervention Rate

	Intervention Rate
AFAD	0.016 (3/193)
Flagger	0.019 (3/155)
T test	0.787
Difference	-0.004
Cohen's d	-0.029

MOE 6 measured the approaching speed of the second vehicle in the queue. As shown in Table 2.3.8, the average speed of the second vehicle in the AFAD queue at 250 ft. was 20.6 mph, and in the flagger queue was 23.1 mph. The difference was significant at the 99.5% confidence level. This result indicates that the second vehicle approached the AFAD at a lower speed than vehicles approaching the flagger.

Table 2.3.8 1st Following vehicle Speed at 250 ft.

	1st Following Vehicle Speed at 250 ft. (mph)
AFAD	20.6
Flagger	23.1
T test	0.005*
Difference	-2.5
Cohen's d	-0.460

During the field collection process, unusual driving behavior was observed. Types of unusual driving behaviors include high approaching speed, and extra-long reaction time. In two instances at a location 250 ft. from the flagger, the approach speed of a pickup was 47 mph, and the approach speed of an SUV was 55 mph (Figure 2.3.11). These two vehicles had approaching speeds which were much higher than the other vehicles since the average approaching speed was 27.4 mph. In another instance (Figure 2.3.12), one leading vehicle at the AFAD had a very long reaction time of 20 seconds, while the average reaction time for the AFAD was 4.41 s. After the CMS showed the SLOW sign, the leading vehicle did not realize the change of message on CMS, and the AFAD honked twice to get the vehicle’s attention.

Figure 2.3.11 Vehicle Approaching Flagger at High Speed

Figure 2.3.12 Vehicle Long Reaction Time to SLOW Indication on AFAD

Interventions at the south side of the work zone were less frequent than interventions at the north side of the work zone. One reason why the intervention rate at the north side was higher (Table A-2.2 and A-3.2, Appendix A) may be the difference in grades at the two ends. In the field study, the north end was at the top of a steep hill while the approach to the south end was more level. Some drivers may have wanted to know what was going on behind the stop control. At the south side, they could see more of the work zone as they approached. But at the north side, their view was more limited and some of them tried to bypass the AFAD or flagger.

CHAPTER 3: SURVEY

3.1 Survey Methodology

A driver intercept survey was conducted for vehicles that traveled through the AFAD end of the work zone. Vehicles were stopped in the work zone after they went through the AFAD and given a short survey. There were two survey formats: hard copies with stamped envelopes and an index card with a link (including QR code) to an online version of the survey. In some cases, drivers were given a choice of which survey format they preferred. In other instances, to reduce vehicle delay, drivers were assigned a survey format based on the researcher's judgment of the survey format preference. For example, drivers who had their cell phones readily available or were texting on their phones were typically given the online version of the survey. The research team distributed 104 hard copies and 182 online links (Table 3.1.1). A total of 42 responses were received, and the response rate was 14.7%. This response rate is relatively low but is similar to some of the mail surveys discussed in Hager et al. (2003).

Table 3.1.1 Survey Numbers

Survey	Hard Copy	Online	Total
Sent Out	104	182	286
Response Received	30	12	42

The survey consisted of three parts. Parts 1 and 2 asked questions about drivers' understanding of the AFAD signage and human flagger gesture, their perceptions regarding the effectiveness of the two different stop controls, their opinion regarding whether the CMS was helpful, and any additional comments. Part 3 asked for their preference between the AFAD and flagger. Part 4 asked for their demographic information and regular vehicle type. The complete survey is attached in Appendix B.

Survey responses included two types: hard copies and online. To ensure consistency in survey data processing, hard copy entries were entered into the online survey system. Results were extracted directly from the online survey system.

3.2 Survey Results

Two multiple choice questions involved the meaning of the AFAD signage and human flagger gesture, respectively. Among the 42 respondents, all of them understood the AFAD meaning correctly, but two of them chose the wrong answer for the meaning of the flagger gesture. The results implied the AFAD was more understandable than the flagger.

The survey responses indicate that most of the respondents thought both AFAD and flagger were effective. Although 88.1% of respondents thought AFAD was effective or very effective and

92.86% of respondents thought flagger was effective or very effective, the proportion of respondents who thought AFAD was very effective was more than the proportion who thought that the flagger was very effective. However, there were more respondents who thought that AFAD was ineffective or very ineffective, as shown in Table 3.2.1. This result could be caused by the novelty of the AFAD as these drivers had not previously encountered the AFAD. Some drivers may have preferred the interpersonal communication with the flagger.

Table 3.2.1 Survey Responses Regarding Effectiveness

Effectiveness	STOP/SLOW AFAD			Flagger		
	Count	Percentage		Count	Percentage	
Very Effective	28	66.67%	88.10%	8	19.05%	92.86%
Effective	9	21.43%		31	73.81%	
Neutral	1	2.38%	2.38%	1	2.38%	2.38%
Ineffective	1	2.38%	9.52%	1	2.38%	4.76%
Very Ineffective	3	7.14%		1	2.38%	
Total	42	100.00%		42	100.00%	

Respondents were asked about the reasons for their effectiveness ratings for the AFAD and flagger. Five factors were provided as possible answers: clarity, visibility, safety, efficiency, and other. Among the four factors, visibility ranked number one, in both the AFAD and flagger situations as shown in Table 3.2.2. Clarity and safety were also both considered as important reasons for the effectiveness ratings.

Table 3.2.2 Reason of Effectiveness Rating

Factor	Count		
	AFAD	Flagger	Total
Clarity	21	31	52
Visibility	23	36	59
Safety	20	30	50
Efficiency	13	20	33
Other	5	5	10

As shown in Table 3.2.3, 90.48% of the respondents thought that the CMS was helpful, with 57.14% of the respondents strongly in agreement. Only one respondent (2.38%) disagreed or strongly disagreed that CMS was helpful. While most of the respondents thought the CMS improved the visibility of stop control and could help them to understand signage, one respondent felt the CMS was redundant and unnecessary since the STOP/SLOW paddle was present and informative enough.

Table 3.2.3 Summary of Responses to Survey Question Regarding Helpfulness of CMS

CMS helpfulness	Count	Percentage	
Strongly Agree	24	57.14%	90.48%
Agree	14	33.33%	
Neutral	3	7.14%	7.14%
Disagree	0	0.00%	2.38%
Strongly Disagree	1	2.38%	
Total	42	100.00%	

The survey asked if the drivers had encountered the two types of stop controls before. Less than half of them responded they had encountered an AFAD before, while all of them had previously encountered a flagger (Table 3.2.4). All of the respondents should have answered that they had encountered an AFAD since they were given the survey immediately after passing through the AFAD.

Table 3.2.4 Summary of Responses to Question About Previous Experience with AFAD and Flagger

Encountered Before	AFAD		Flagger	
	Count	Percentage	Count	Percentage
Yes	19	45.24%	41	100%
No	23	54.76%	0	0%
Total	42	100.00%	41	100%

When drivers were asked for their preference between the AFAD and flagger, no respondents preferred the flagger much more than the AFAD, and only 12.2% of the respondents preferred the flagger more. Although the percentage of respondents who thought that the flagger was effective or very effective was higher than the percentage who thought that the AFAD was effective or very effective, respondents preferred the AFAD more than the flagger. As shown in Table 3.2.5, 53.66% respondents preferred the AFAD much more than flagger, and 24.39% preferred the AFAD more than flagger.

Table 3.2.5 Respondents' Preference for AFAD or Flagger

Preference	Count	Percentage	
AFAD much more	22	53.66%	78.05%
AFAD more	10	24.39%	
Neutral	4	9.76%	9.76%
Flagger more	5	12.20%	12.20%
Flagger much more	0	0.00%	
Total	41	100.00%	

Demographic information was collected, and the results are shown in Tables 3.2.6 and 3.2.7. Among the survey respondents, gender distributions were even, with the number of female drivers slightly less than the number of male drivers. Older drivers were more prevalent than younger drivers, and over 64% of the respondents were over 55 years old. The field work was performed in a rural area, and 83.33% of respondents were rural residents. Most of the respondents drove passenger cars as their regular vehicle type. Different responses by age, gender, and residency are attached in Appendix C.

Table 3.2.6 Demographic Information

Gender		**Age**				
Male	Female	16-25	26-40	41-55	56-70	71-95
22	19	1	5	8	14	13
52.38%	45.24%	2.38%	11.90%	19.05%	33.33%	30.95%

Table 3.2.7 Residency and Vehicle Information

Residency		**Regular Vehicle Type**	
Urban	Rural	Passenger car	Other
3	35	37	4
7.14%	83.33%	88.10%	9.52%

Respondents commented on the advantages and disadvantages of the AFAD. They thought the advantages of the AFAD included increased visibility, multi-functionality, adaptability to weather conditions, and enhanced safety, as a human flagger means a worker is standing near traffic. Some concerns raised by some respondents about the AFAD included:

- Sun glare reduced visibility
- Potential confusion in case of its malfunction
- AFAD may not be respected as well as a live human flagger
- It may be easier to communicate with human flaggers than the AFAD

Some additional comments include:

- The higher cost of AFAD was worthwhile due to its benefits
- A warning noise for violations would help to alert both drivers and workers in the work zone
- Advanced signage for TMA instructions would be beneficial

CHAPTER 4: CONCLUSION

For the field data collection, there were 334 total queues collected, of which 186 were for the AFAD, and 148 were for the flagger. The results of field data analysis show that the vehicle approach speed for the AFAD was significantly slower (23.2 mph versus 27.4 mph) than the vehicle approach speed for the flagger. The lower approaching speed means the AFAD helps to improve work zone safety. The AFAD full stop location was significantly farther from stop control (61.07 ft. versus 49.68 ft.) than the flagger full stop location. The intervention rate for AFAD was slightly lower than flagger (3/193 vs. 3/155). With the AFAD, the approaching speeds for the 1st following vehicles were significantly slower than without the AFAD (20.63 mph versus 23.09 mph). In summary, the performance measures of vehicle approach speed, stop location, intervention rate, and first vehicle approach speed all favor the AFAD over the flagger.

The reaction time for the AFAD was significantly longer than for the flagger (4.41s vs. 1.69s) and may cause extra traffic delay. But the reason for the longer delay is not completely clear. The following are some possible reasons for the difference in reaction time between the AFAD and the flagger. On the AFAD, there was a time lag for turning the slow paddle, thus the paddle and the CMS message were out of synchronization. This delay has since been corrected. The delay may also be due to differences in interpersonal communication with a person as opposed to interaction with a device. In addition, drivers who encountered the AFAD may be distracted by their cellphones or other things, while drivers who encountered human flagger may be less distracted with the nearby presence of a construction worker. The Phase Two simulator study will continue to investigate the issue with the reaction time.

For the driver intercept survey, there were 42 survey responses received, including 30 paper responses and 12 online responses. The results of survey showed that the AFAD was more understandable than the flagger; more respondents thought the AFAD was very effective than the flagger (66.67% versus 19.05%), most of respondents thought CMS was very helpful or helpful (90.48%), and more respondents preferred the AFAD than flagger (78.05% vs. 12.20%). Visibility was the biggest reason for the drivers' effectiveness ratings of the two devices, followed by clarity, safety, and efficiency. The overall survey results indicate that the general public was more favorable towards the AFAD than the human flagger.

In conclusion, the results from the field study and driver intercept survey indicate that the AFAD may enhance safety over the human flagger based on a reduced vehicle approach speed and farther full stop location, but AFADs may cause slightly longer delays due to increased reaction times. The AFAD also has the potential to improve safety by removing the flagger from direct exposure to traffic and protecting the construction worker inside the construction vehicle with the TMA. The public had a favorable impression of the AFAD and generally preferred it over the human flagger.

After Phase One was completed, the Phase Two simulator study began. In the simulator study, flagger, STOP/SLOW AFAD with CMS, and STOP/SLOW AFAD without CMS will be evaluated. The two AFAD options presented in the MUTCD (2009) are STOP/SLOW, and red and yellow lenses and a gate; thus the simulator scenarios will be designed to be consistent with

MUTCD guidance. Simulation scenarios will involve a two-lane highway and a scenario similar to the Phase One field study. Two options for the CMS message under the stop condition will be tested: “STOP” and “WAIT ON STOP”. MOEs for the simulator study will be similar to the field study but include much more detailed information. Post-test surveys will be given out to simulator participants. In the simulator, influences caused by geometric condition will be eliminated to avoid bias. If the results from the AFAD with CMS and AFAD without CMS show that removal of the CMF does not compromise safety or clarity, then a Phase Three field study of AFAD with CMS and AFAD without CMS will be conducted to verify the results in the field after Phase Two is completed. The use of AFAD without CMS would help to reduce costs and speed up the AFAD implementation.

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APPENDIX A: DATA COLLECTION RESULTS FOR ALL TYPES OF VEHICLES

A.1 Total Data Statistics

Table A.1.1 Total Data Statistics, MOE 1 – MOE 4

MOE 1 – MOE 4		Total							
		AFAD				Flagger			
		Sedan	Pickup	CV	Total	Sedan	Pickup	CV	Total
Speed at 250 ft. (mi/hr)	Sample Size	57	123	13	193	55	91	9	155
	Mean	23.947	23.211	20.231	23.228	28.273	27.198	23.556	27.368
	SD	6.323	5.553	6.260	5.871	6.404	6.684	4.275	6.527
	Max	39	38	32	39	43	58	30	58
	Min	10	10	10	10	11	16	18	11
	T-test					0.000	0.000	0.183	0.000
Full Stop Location (ft.)	Sample Size	52	102	9	163	49	85	7	141
	Mean	58.942	62.059	62.222	61.074	50.735	49.212	47.143	49.638
	SD	35.207	25.817	31.236	29.259	31.944	15.784	20.178	22.752
	Max	170	170	100	170	220	100	65	220
	Min	10	25	0	0	10	25	10	10
	T-test					0.224	0.000	0.287	0.000
Waiting Time (s)	Sample Size	44	83	7	134	38	71	7	116
	Mean	84.584	62.364	111.991	72.253	98.911	111.602	79.629	105.515
	SD	71.607	74.660	184.048	82.565	79.927	96.231	34.484	88.500
	Max	290.791	548.765	518.518	548.765	367.474	464.508	124.515	464.508
	Min	1.418	2.002	2.976	1.418	2.555	4.721	24.950	2.555
	T-test					0.395	0.000	0.656	0.002
Reaction Time (s) (Based on CMS)	Sample Size	43	83	7	133	38	69	6	113
	Mean	4.500	4.398	4.024	4.412	1.492	1.758	2.171	1.690
	SD	3.179	3.477	1.376	3.290	0.955	0.860	1.008	0.908
	Max	17.491	27.161	6.072	27.161	4.332	4.725	3.433	4.725
	Min	1.193	0.804	2.457	0.804	0.204	0.177	0.612	0.177
	T-test					0.000	0.000	0.020	0.000

Table A.1.2 Total Data Statistics, MOE 5 – MOE 7

MOE 5 – MOE 7		Total							
		AFAD				Flagger			
		Sedan	Pickup	CV	Total	Sedan	Pickup	CV	Total
Intervention	Sample Size	57	123	13	193	55	91	9	155
	Abs Number	1	1	1	3	2	1	0	3
	Mean	0.018	0.008	0.077	0.016	0.036	0.011	0.000	0.019
	T-test					0.542	0.831	0.419	0.787
1st Following Vehicle Speed at 250 ft. (mph)	Sample Size	25	41	5	71	24	52	6	82
	Mean	22.160	20.195	16.600	20.634	22.667	23.308	22.833	23.085
	SD	5.498	5.105	3.130	5.284	5.639	5.319	5.565	5.371
	Max	31	31	20	31	37	33	30	37
	Min	10	10	14	10	13	13	17	13
	T-test					0.752	0.005	0.054	0.005
Queue Length (veh)	Sample Size	57	123	13	193	55	90	9	154
	Mean	1.825	1.610	2.000	1.699	1.927	2.178	2.111	2.084
	SD	1.167	1.185	2.236	1.272	1.245	1.346	0.928	1.288
	Max	6	8	9	9	6	6	3	6
	Min	1	1	1	1	1	1	1	1
	T-test					0.653	0.001	0.890	0.006

A.2 South Bound Data Statistics

Table A.2.1 South Bound Data Statistics, MOE 1 – MOE 4

MOE 1 – MOE 4		South							
		AFAD				Flagger			
		Sedan	Pickup	CV	Total	Sedan	Pickup	CV	Total
Speed at 250 ft. (mph)	Sample Size	32	57	8	97	30	47	4	81
	Mean	23.094	22.053	21.875	22.381	26.800	25.149	20.500	25.531
	SD	6.130	4.673	6.978	5.355	5.804	7.587	1.732	6.883
	Max	34	35	32	35	38	58	22	58
	Min	10	13	10	10	17	16	18	16
	T-test					0.018	0.012	0.712	0.001
Full Stop Location (ft.)	Sample Size	32	57	7	96	29	46	3	78
	Mean	58.906	64.912	63.571	62.813	49.862	50.609	31.667	49.603
	SD	41.673	30.713	35.674	34.799	23.760	19.797	22.546	21.464
	Max	170	170	100	170	120	100	55	120
	Min	10	25	0	0	10	25	10	10
	T-test					0.309	0.007	0.197	0.004
Waiting Time (s)	Sample Size	25	41	5	71	21	39	3	63
	Mean	68.055	59.420	30.060	60.393	97.956	129.182	93.266	117.063
	SD	50.508	57.821	33.187	54.178	83.763	117.410	31.777	104.825
	Max	184.962	237.783	85.632	237.783	367.474	464.508	124.515	464.508
	Min	4.010	2.879	2.976	2.879	2.555	4.721	60.987	2.555
	T-test					0.143	0.001	0.038	0.000
Reaction Time (s) (Based on CMS)	Sample Size	25	42	5	72	21	39	2	61
	Mean	4.565	3.821	3.902	4.085	1.491	1.566	1.850	1.551
	SD	4.078	2.865	1.596	3.260	0.765	0.582	0.078	0.636
	Max	17.491	14.932	6.072	17.491	4.194	2.987	1.906	4.194
	Min	1.193	0.804	2.457	0.804	0.365	0.177	1.795	0.177
	T-test					0.001	0.000	0.146	0.000

Table A.2.2 South Bound Data Statistics, MOE 5 – MOE 7

MOE 5 – MOE 7		South							
		AFAD				Flagger			
		Sedan	Pickup	CV	Total	Sedan	Pickup	CV	Total
Intervention	Sample Size	32	57	8	97	30	47	4	81
	Abs Number	0	0	1	0	0	0	0	0
	Mean	0.000	0.000	0.125	0.010	0.000	0.000	0.000	0.000
	T-test					\	\	0.506	0.356
1st Following Vehicle Speed at 250 ft. (mph)	Sample Size	12	17	2	31	14	31	3	48
	Mean	20.833	17.412	20.000	18.903	20.714	22.290	22.333	21.833
	SD	3.538	5.432	0.000	4.812	3.451	5.503	6.807	5.012
	Max	27	25	20	27	28	33	30	33
	Min	15	10	20	10	16	13	17	13
	T-test					0.932	0.005	0.677	0.012
Queue Length (veh)	Sample Size	32	57	8	97	30	47	4	81
	Mean	1.719	1.509	1.250	1.557	1.967	2.319	2.250	2.185
	SD	1.170	0.966	0.707	1.020	1.299	1.337	0.957	1.305
	Max	6	5	3	6	6	6	3	6
	Min	1	1	1	1	1	1	1	1
	T-test					0.432	0.001	0.066	0.000

A.3: North Bound Data Statistics

Table A.3.1 North Bound Data Statistics, MOE 1 – MOE 4

MOE 1 – MOE 4		North							
		AFAD				Flagger			
		Sedan	Pickup	CV	Total	Sedan	Pickup	CV	Total
Speed at 250 ft. (mile/hr)	Sample Size	25	66	5	96	25	44	5	74
	Mean	25.040	24.212	17.600	24.083	30.040	29.386	26.000	29.378
	SD	6.522	6.073	4.278	6.262	6.755	4.736	4.183	5.486
	Max	39	38	23	39	43	38	30	43
	Min	15	10	12	10	11	18	20	11
	T-test					0.011	0.000	0.014	0.000
Full Stop Location (ft.)	Sample Size	20	45	2	67	20	39	4	63
	Mean	59.000	58.444	57.500	58.582	52.000	47.564	58.750	49.683
	SD	22.219	17.478	10.607	18.644	41.751	9.023	7.500	24.427
	Max	120	120	65	120	220	70	65	220
	Min	35	40	50	35	30	25	50	25
	T-test					0.512	0.001	0.872	0.021
Waiting Time (s)	Sample Size	19	42	2	63	17	32	4	53
	Mean	106.334	65.238	316.817	85.619	100.090	90.177	69.401	91.789
	SD	89.269	88.710	285.249	104.724	77.460	56.122	37.144	62.179
	Max	290.791	548.765	518.518	548.765	297.378	229.726	110.055	297.378
	Min	1.418	2.002	115.115	1.418	5.024	5.393	24.950	5.024
	T-test					0.825	0.168	0.122	0.707
Reaction Time (s) (Based on CMS)	Sample Size	18	41	2	61	18	30	4	52
	Mean	4.410	4.990	4.330	4.797	1.493	2.007	2.332	1.854
	SD	1.214	3.958	0.955	3.310	1.154	1.085	1.260	1.133
	Max	7.691	27.161	5.005	27.161	4.332	4.725	3.433	4.725
	Min	2.520	1.718	3.654	1.718	0.204	0.734	0.612	0.204
	T-test					0.000	0.000	0.125	0.000

Table A.3.2 North Bound Data Statistics, MOE 5 – MOE 7

MOE 5 – MOE 7		North							
		AFAD				Flagger			
		Sedan	Pickup	CV	Total	Sedan	Pickup	CV	Total
Intervention	Sample Size	25	66	5	96	25	44	5	74
	Abs Number	1	1	0	2	2	1	0	3
	Mean	0.040	0.015	0.000	0.021	0.080	0.023	0.000	0.041
	T-test					0.561	0.773	\	0.454
1st Following Vehicle Speed at 250 ft. (mph)	Sample Size	13	24	3	40	10	21	3	34
	Mean	23.385	22.167	14.333	21.975	25.400	24.810	23.333	24.853
	SD	6.752	3.875	0.577	5.299	7.058	4.771	5.508	5.434
	Max	31	31	15	31	37	33	27	37
	Min	10	14	14	10	13	18	17	13
	T-test					0.494	0.047	0.048	0.024
Queue Length (veh)	Sample Size	25	66	5	96	25	43	5	73
	Mean	1.960	1.697	3.200	1.844	1.880	2.023	2.000	1.973
	SD	1.172	1.347	3.347	1.475	1.201	1.354	1.000	1.269
	Max	5	8	9	9	4	5	3	5
	Min	1	1	1	1	1	1	1	1
	T-test					0.813	0.220	0.464	0.551

APPENDIX B: SURVEY QUESTIONS

Date ______________________

Work Zone Signage Survey

Note: To complete this survey online using a computer or mobile device, please visit https://goo.gl/BM40Ju or scan the QR code below.

Proper communication of work zone information is critical for the safe movement of traffic through work zones. Please provide us with your perspective on the following communication alternatives.

Please refer to the device shown below in Figure 1.

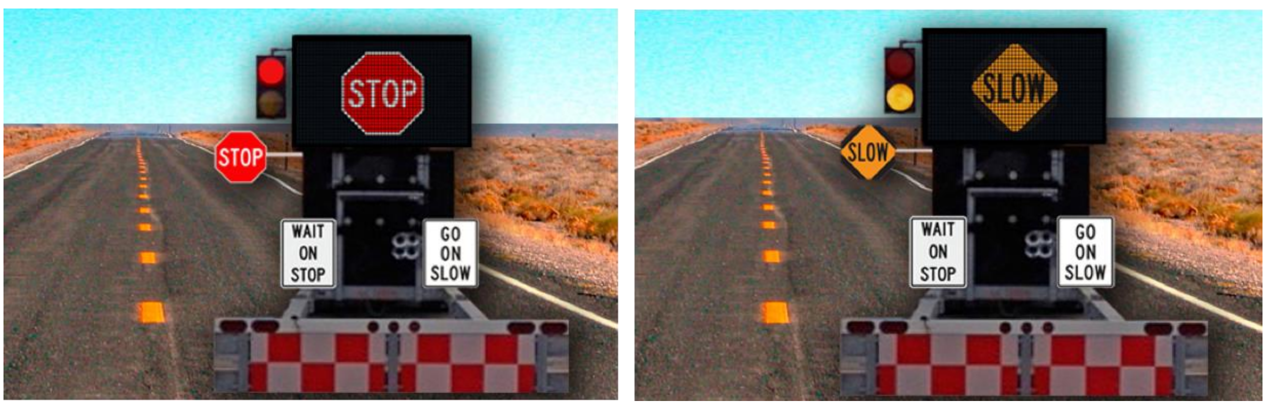


Figure 1

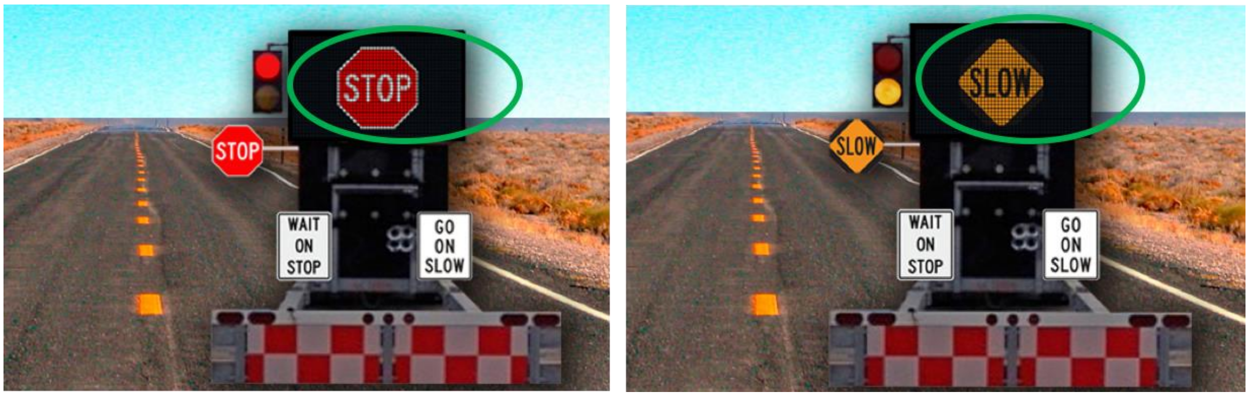
1. **What is the meaning of the device shown in Figure 1?**
   a. Narrow lanes ahead – reduce speed.
   b. Wait if “stop” indicated, proceed if “slow” indicated.
   c. The device makes no sense.

2. **Please rate the effectiveness of the device shown in Figure 1.**
   [ ] Very Effective [ ] Effective [ ] Neutral [ ] Ineffective [ ] Very Ineffective

3. **Please check any reasons for your rating on the device shown in Figure 1.**
   [ ] Clarity [ ] Visibility [ ] Safety [ ] Efficiency

[ ] Other

____



4. **The message board on the device in Figure 1 (circled in green) was helpful in complementing the instructions provided by the stop/slow paddle.**
   [ ] Strongly agree [ ] Agree [ ] Neutral [ ] Disagree [ ] Strongly disagree

5. **I have encountered the device shown in Figure 1 before.**
   [ ] Yes [ ] No [ ]

6. **Please enter any additional comments you may have regarding the device shown in Figure 1.**

____
____
____

Figure 2

7. **What is the meaning of the signage shown in Figure 2?**
    a. Narrow lanes ahead – reduce speed.
    b. Wait if "stop" indicated, proceed if "slow" indicated.
    c. The signage makes no sense.

8. **Please rate the effectiveness of the signage shown in Figure 2.**
    [ ] Very Effective [ ] Effective [ ] Neutral [ ] Ineffective [ ] Very Ineffective

9. **Please check any reasons for your rating on the signage shown in Figure 2.**
    [ ] Clarity [ ] Visibility [ ] Safety [ ] Efficiency
    [ ] Other

____
_

10. **I have encountered the signage shown in Figure 2 before.**
    [ ] Yes [ ] No

11. **Please enter any additional comments you may have regarding the signage shown in Figure 2.**

____
____
____

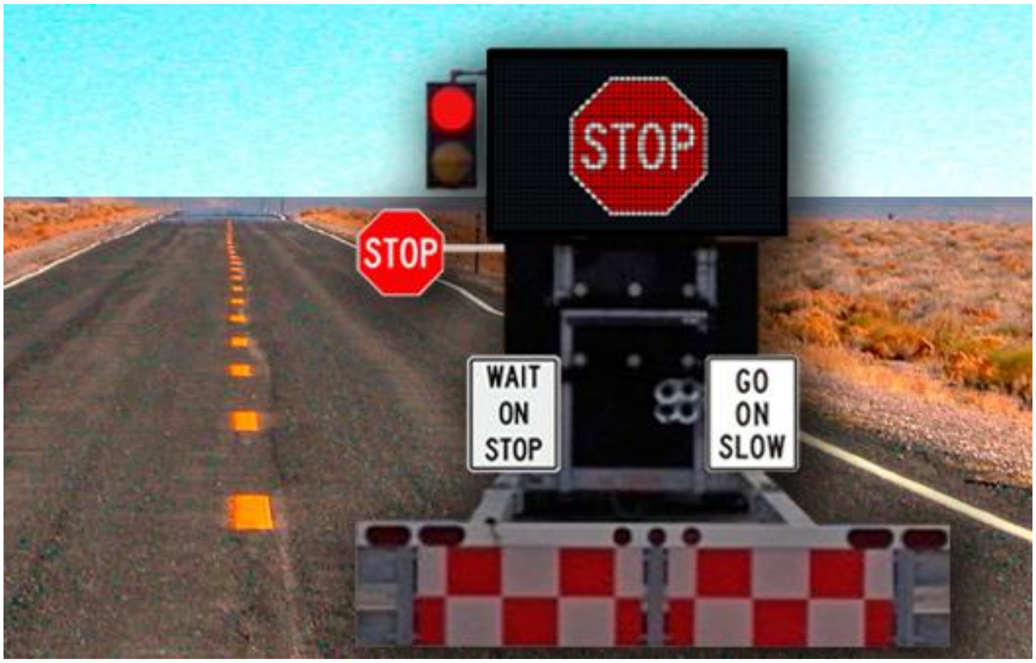


Figure 1

Figure 2

12. Please indicate your preference.

[ ] Figure 1 much more   [ ] Figure 1 more   [ ] Neutral   [ ] Figure 2 more   [ ] Figure 2 much more

Please answer the demographic questions below.

13. Age range
[ ] 16-25   [ ] 26-40   [ ] 41-55   [ ] 56-70   [ ] 71-95

14. Gender
[ ] Male   [ ] Female

15. My Residency
[ ] Urban   [ ] Rural

16. My Regular Vehicle Type
[ ] Passenger Car   [ ] Vehicle towing trailer   [ ] Delivery/Moving Truck
[ ] Tractor trailer truck   [ ] Bus

Please contact Mr. Henry Brown (brownhen@missouri.edu) for additional comments, concerns or information on this survey. Thank you for completing this survey! We greatly appreciate your time!

APPENDIX C: SURVEY RESULTS BY DIFFERENT GROUPS

C.1 Results by Age

Table C.1.1 Age Range vs. Effectiveness of AFAD (Figure 1 in Survey)

Age Ranges	Effectiveness	Count
16-25	Very Effective	1
26-40	Very Effective	3
	Effective	1
41-55	Very Effective	4
	Effective	3
	Neutral	1
56-70	Very Effective	9
	Effective	2
	Ineffective	1
	Very Ineffective	2
71-95	Very Effective	9
	Effective	3
	Very Ineffective	1

Table C.1.2 Age Range vs. Reasons of Rating

Age Ranges	Factor	Count
16-25	Clarity	1
	Visibility	1
	Safety	1
	Efficiency	1
	Other	0
26-40	Clarity	4
	Visibility	5
	Safety	5
	Efficiency	3
	Other	2
41-55	Clarity	5
	Visibility	7
	Safety	6
	Efficiency	3
	Other	3
56-70	Clarity	12
	Visibility	11
	Safety	10
	Efficiency	7
	Other	0
71-95	Clarity	9
	Visibility	12
	Safety	10
	Efficiency	6
	Other	0

Table C.1.3 Age Range vs. Helpfulness of CMS (Figure 1 in Survey)

Age Ranges	Categories	Count
16-25	Strongly Agree	1
26-40	Strongly Agree	3
	Agree	2
41-55	Strongly Agree	5
	Agree	1
	Neutral	1
	Strongly Disagree	1
56-70	Strongly Agree	9
	Agree	3
	Neutral	2
71-95	Strongly Agree	5
	Agree	8

Table C.1.4 Age Range vs. Encountered Signage Before

Age Ranges	Yes or No	Count
16-25	Yes	1
	No	0
26-40	Yes	4
	No	1
41-55	Yes	4
	No	4
56-70	Yes	4
	No	10
71-95	Yes	6
	No	7

Table C.1.5 Age Range vs. Effectiveness of Flagger (Figure 2 in Survey)

Age Ranges	Effectiveness	Count
16-25	Very Effective	1
26-40	Effective	5
41-55	Effective	8
56-70	Very Effective	3
	Effective	9
	Ineffective	1
	Very Ineffective	1
71-95	Very Effective	3
	Effective	9
	Neutral	1

Table C.1.6 Age Range vs. Reasons of Rating

Age Ranges	Factor	Count
16-25	Clarity	1
	Visibility	1
	Safety	1
	Efficiency	1
	Other	0
26-40	Clarity	2
	Visibility	3
	Safety	2
	Efficiency	2
	Other	0
41-55	Clarity	4
	Visibility	3
	Safety	1
	Efficiency	3
	Other	2
56-70	Clarity	7
	Visibility	6
	Safety	8
	Efficiency	2
	Other	1
71-95	Clarity	9
	Visibility	8
	Safety	10
	Efficiency	6
	Other	1

Table C.1.7 Age Range vs. Preference

Age Ranges	Preference	Count
16-25	Neutral	1
26-40	AFAD Much More	3
	AFAD More	2
41-55	AFAD Much More	6
	AFAD More	1
	Flagger More	1
56-70	AFAD Much More	8
	AFAD More	2
	Neutral	1
	Flagger More	2
71-95	AFAD Much More	4
	AFAD More	5
	Neutral	2
	Flagger More	2

C.2 Results by Gender

Table C.2.1 Gender vs. Effectiveness of AFAD

Gender	Effectiveness	Count
Male	Very Effective	16
	Effective	3
	Neutral	1
	Ineffective	1
	Very Ineffective	1
Female	Very Effective	11
	Effective	6
	Ineffective	0
	Very Ineffective	2

Table C.2.2 Gender vs. Reasons of Rating

Gender	Factor	Count
Male	Clarity	14
	Visibility	19
	Safety	15
	Efficiency	10
	Other	2
Female	Clarity	17
	Visibility	17
	Safety	15
	Efficiency	10
	Other	3

Table C.2.3 Gender vs. Helpfulness of CMS

Gender	Category	Count
Male	Strongly Agree	12
	Agree	8
	Neutral	1
	Strongly Disagree	1
Female	Strongly Agree	11
	Agree	6
	Neutral	2

Table C.2.4 Gender vs. Encountered Stop Control Before

Gender	Yes or No	Count
Male	Yes	10
	No	12
Female	Yes	9
	No	10

Table C.2.5 Gender vs. Effectiveness of Flagger

Gender	Effectiveness	Count
Male	Very effective	4
	Effective	17
	Ineffective	1
Female	Very effective	3
	Effective	14
	Neutral	1
	Very Ineffective	1

Table C.2.6 Gender vs. Reasons of Rating

Gender	Factor	Count
Male	Clarity	10
	Visibility	12
	Safety	11
	Efficiency	9
	Other	1
Female	Clarity	11
	Visibility	11
	Safety	9
	Efficiency	4
	Other	4

Table C.2.7 Gender vs. Preference

Gender	Preference	Count
Male	AFAD Much More	12
	AFAD More	4
	Neutral	2
	Flagger More	4
Female	AFAD Much More	9
	AFAD More	6
	Neutral	2
	Flagger More	1

C.3 Survey Results by Residency

Table C.3.1 Residency vs. Effectiveness of AFAD

Residency	Effectiveness	Count
Urban	Very Effective	4
	Effective	1
	Very Ineffective	1
Rural	Very Effective	23
	Effective	8
	Neutral	1
	Ineffective	1
	Very Ineffective	2

Table C.3.2 Residency vs. Reasons of Rating

Residency	Factor	Count
Urban	Clarity	6
	Visibility	4
	Safety	4
	Efficiency	3
	Other	0
Rural	Clarity	25
	Visibility	32
	Safety	26
	Efficiency	17
	Other	5

Table C.3.3 Residency vs. Helpfulness of CMS

Residency	Categories	Count
Urban	Strongly Agree	3
	Agree	3
Rural	Strongly Agree	20
	Agree	11
	Neutral	3
	Strongly Disagree	1

Table C.3.4 Residency vs. Encountered Stop Control Before

Residency	Yes or No	Count
Urban	Yes	3
	No	3
Rural	Yes	16
	No	19

Table C.3.5 Residency vs. Effectiveness of Flagger

Residency	Effectiveness	Count
Urban	Very Effective	2
	Effective	3
	Ineffective	1
Rural	Very Effective	5
	Effective	28
	Neutral	1
	Very Ineffective	1

Table C.3.6 Residency vs. Reasons of Rating

Age Ranges	Factor	Count
Urban	Clarity	3
	Visibility	6
	Safety	3
	Efficiency	2
	Other	0
Rural	Clarity	18
	Visibility	17
	Safety	17
	Efficiency	11
	Other	5

Table C.3.7 Residency vs. Preference

Residency	Preference	Count
Urban	AFAD Much More	2
	AFAD More	2
	Neutral	2
Rural	AFAD Much More	19
	AFAD More	8
	Neutral	2
	Flagger More	5