



Evaluation of Automated Flagger Assistance Devices in Missouri

TEAM Presentation

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TM

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Have You Ever Wondered If...

- Flagger safety can be improved?

The answer is....

Yes!



https://www.fhwa.dot.gov/innovation/everydaycounts/edcnews/images/20160225_smz_lead.jpg



Presentation Outline

- I. Overview of AFADs
- II. Field Study and Survey
- III. Simulator Study and Survey
- IV. Summary
- V. Conclusions



Scope of project

- To improve highway work zone safety
- To help MoDOT assess the application of STOP/SLOW AFAD
- Three Phases
 - Field test with Changeable Message Sign (CMS)
 - Simulator study
 - Field test without CMS (tentative, not conducted)

Types of AFADs

Federal Highway Administration (FHWA 2005)



STOP/SLOW paddles AFAD
(Safety Technologies 2015)



Red/Yellow lens AFAD
(Safety Technologies 2015)



AFAD Developed by MoDOT



Red/Yellow
Lens

CMS

STOP

STOP/SLOW
Paddles

WAIT
ON
STOP



CMS STOP Sign 1



CMS STOP Sign 2



CMS SLOW Sign 1



CMS SLOW Sign 2

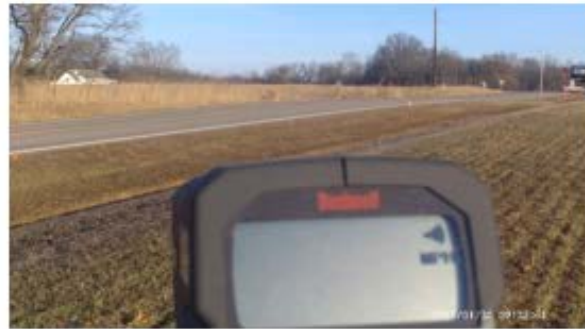


Work Zone Set Up

Location:	MO 23, Knob Noster, MO
	Two-lane highway
AADT:	2,610 vpd (directional 1,305 vpd)
Length:	2,400 ft. (from the flagger to AFAD)
Duration:	1/30 09:10 – 16:50
	1/31 08:30 – 16:30



(a) Highway 23 Work Zone (Google Maps 2017)



(b) South end, first day (AFAD)



(c) North end, first day (Flagger)



(d) South end, second day (Flagger)

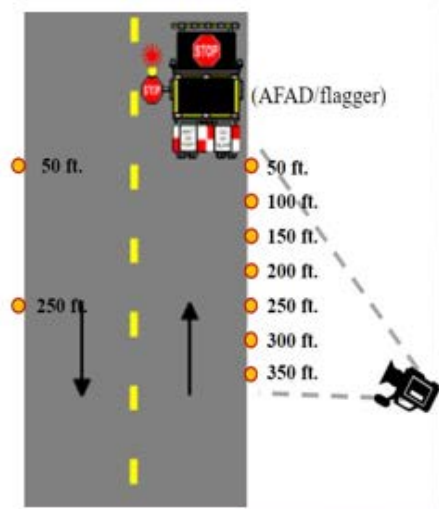


(e) North end, second day (AFAD)



Measures of Effectiveness (MOEs)

- Approach Speed
- Full Stop Location
- Intervention Rate
- Reaction Time
- First brake location (Only captured in simulator study)



Approach Speed (mph)



Location of vehicle's front end when at full stop.



Full Stop Distance (ft.)



Intervention Rate



Reaction Time (sec)

Field Data Results

	MOE 1 Approach Speed (mph)		
	Mean	SD	Diff
Flagger	27.37	6.53	Base
MoDOT AFAD	23.23	5.87	-4.14*
	MOE 2 Full Stop Distance (feet)		
	Mean	SD	Diff
Flagger	49.64	22.75	Base
MoDOT AFAD	61.07	29.26	11.43*

* indicates significance at 99% confidence level

Field Data Results

	MOE 3 Reaction Time (seconds)		
	Mean	SD	Diff
Flagger	1.69	0.91	Base
MoDOT AFAD	0.41	3.29	-1.28*
	MOE 4 Intervention Rate		
	Mean	SD	Diff
Flagger	0.019 (3/155)	0.138	Base
MoDOT AFAD	0.016 (3/193)	0.124	-0.003

* indicates significance at 99% confidence level



Unusual Driving Behavior

- Interventions
 - 3/193 AFAD interventions
 - 3/155 flagger interventions
- Driver inattention led to slow reaction to AFAD (1)
- Driver approached flagger at high speed (1)



Example Intervention



The truck tried to bypass the AFAD directly. It was stopped by the AFAD and reversed.

Survey Overview

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

Four parts, total 16 questions:

1. AFAD understanding
2. Flagger understanding
3. Comparison between AFAD and flagger
4. Demographic information



Survey Preference

Preference	Percentage	
AFAD much more	54%	78%
AFAD more	24%	
Neutral	10%	10%
Flagger more	12 %	12%
Flagger much more	0.00%	
Total	100%	



Summary of Survey Results

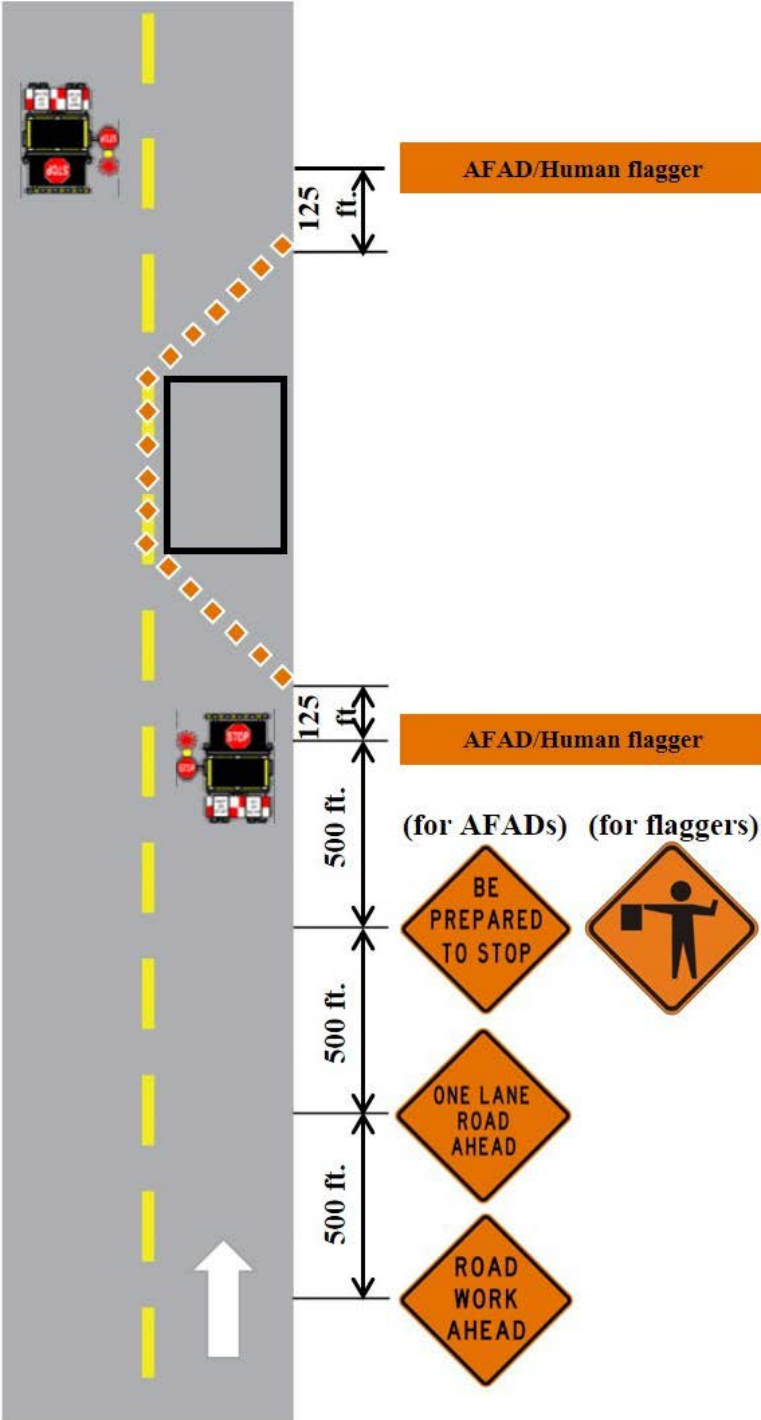
- More responders understood AFAD than flagger correctly (100% vs. 95.2%)
- More responders thought AFAD was very effective than flagger (66.7% vs. 19.1%)
- Most of responders thought CMS was very helpful or helpful (90.5%)
- More responders preferred AFAD than flagger (78.1% vs. 12.2%)

ZouSim Driving Simulator





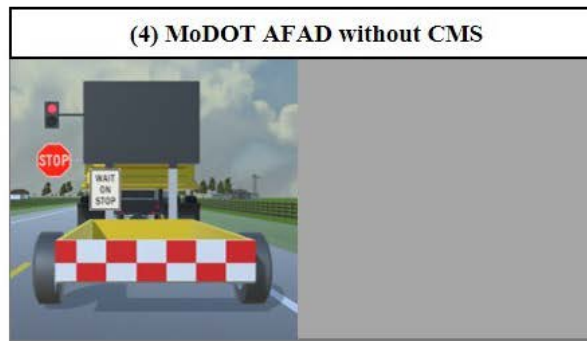
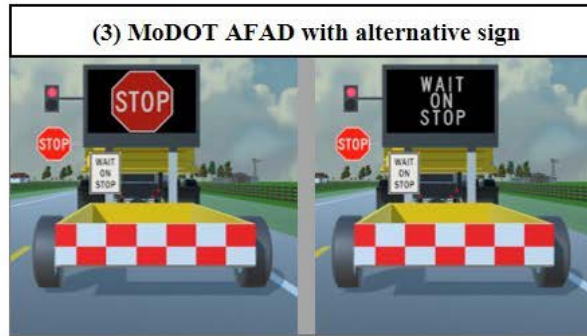
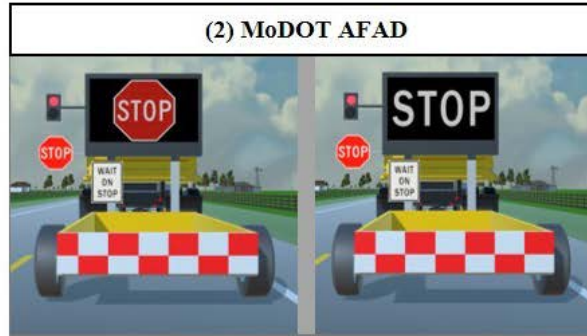
AFAD Simulator Set up and Test Scenarios



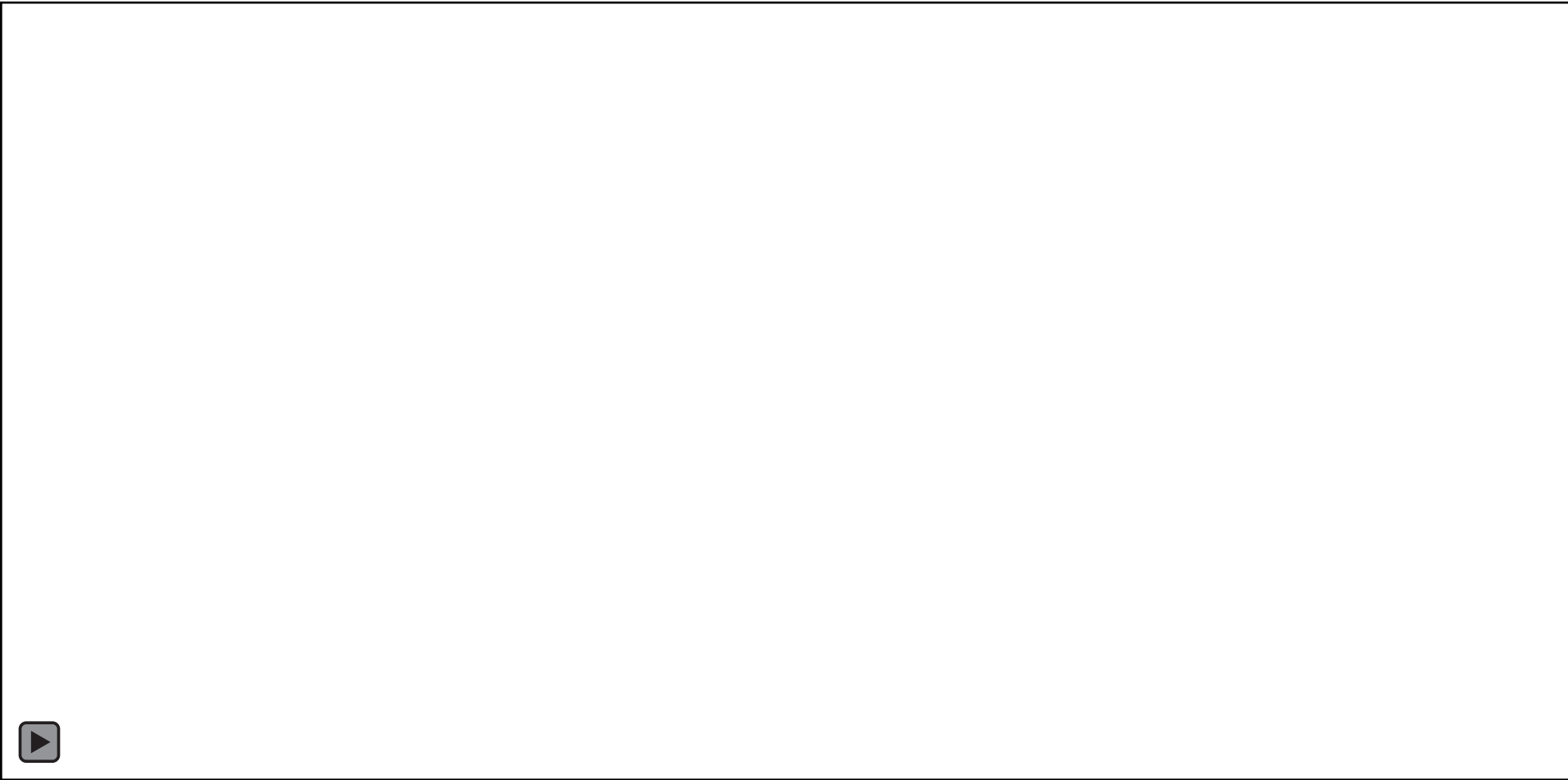
AFAD/Human flagger

AFAD/Human flagger

(for AFADs) (for flaggers)



Video showing simulator scenario



Simulator Results

	MOE 1 Approach Speed (mph)		
	Mean	SD	Diff
Flagger	34.79	13.83	Base line
MoDOT AFAD	26.34	11.63	-8.44*
AFAD with alternative sign	25.98	10.30	-8.80*
AFAD without CMS	26.87	11.07	-7.91*

* indicates significance at 99% confidence level

Simulator Results

	MOE 2 Full Stop Distance (feet)		
	Mean	SD	Diff
Flagger	53.09	36.03	Base line
MoDOT AFAD	97.55	49.93	44.46*
AFAD with alternative sign	90.67	48.69	37.58*
AFAD without CMS	74.20	28.20	21.11*

* indicates significance at 99% confidence level

Simulator Results

	MOE 3 Reaction Time (seconds)		
	Mean	SD	Diff
Flagger	2.05	1.14	Base line
MoDOT AFAD	1.93	1.99	-0.12
AFAD with alternative sign	1.60	1.86	-0.45***
AFAD without CMS	1.23	1.84	-0.82*

* indicates significance at 99% confidence level

*** indicates significance at 90% confidence level

Simulator Results

	MOE 4 Intervention Rate		
	Mean	SD	Diff
Flagger	0.14	0.35	Base line
MoDOT AFAD	0.00	0.00	-0.14*
AFAD with alternative sign	0.00	0.00	-0.14*
AFAD without CMS	0.05	0.21	-0.09***

* indicates significance at 99% confidence level

*** indicates significance at 90% confidence level

Simulator Results

	MOE 5 First Brake Location (feet)		
	Mean	SD	Diff
Flagger	274.02	120.51	Base line
MoDOT AFAD	332.19	108.55	58.17*
AFAD with alternative sign	334.95	112.08	60.94*
AFAD without CMS	320.30	106.09	46.29**

* indicates significance at 99% confidence level

** indicates significance at 95% confidence level



Survey

- Post simulator experiment survey
 - Drivers' understanding of signs
 - Preference
 - Rate of clarity, visibility, safety, efficiency
 - CMS necessity
 - Simulator fidelity
 - Demographic information
- Simulator Sickness Questionnaire (SSQ) (Kennedy et al. 1993)



Simulator Survey Results

- Over 80% of participants understood all four designs.
- Preference order: MoDOT AFAD, AFAD with alternative sign, Flagger, AFAD without CMS.
- Participants rated MoDOT AFAD the highest in clarity (8.87/10), visibility (9.43/10), safety (9.13/10) and efficiency (8.76/10).
- Participants agreed that CMS was necessary (78.15%).



MoDOT AFAD vs. Flagger

- MoDOT AFAD performed better than flagger in field and simulator tests.
- Significantly slower approach speed
 - 23.20 vs. 27.40 mph in field
 - 26.52 vs. 34.53 mph in simulator
- Significantly farther full stop distance
 - 61.07 vs. 49.64 feet in field
 - 98.90 vs. 50.95 feet in simulator
- Lower intervention rate than flagger in both field and simulator study
- Respondents preferred AFAD more



AFADs

- Performance of MoDOT AFAD and AFAD with alternative sign were similar.
- AFAD without CMS performed significantly worse.
- MoDOT AFAD scored highest in clarity, visibility, safety, and efficiency.
- MoDOT AFAD was preferred the most.



Conclusions

- AFAD is a valid and effective replacement of human flaggers to improve highway work zone safety in Missouri.
- Among tested AFADs, MoDOT AFAD performed the best, and was preferred the most.



Other MU Projects Related to Work Zone Safety

- Work zone safety assessment tool
- Guidance for use of work zone Crash Modification Factors (CMFs)
- Work zone split sign (MU & CBB)
- Use of green lights on work vehicles
- Evaluation of mobile work zone alarms
- Assessment tool for moving work zones



Input and Analyze Window

Alternative Description	<input type="text"/>	Facility Type	<input type="text"/>
Directional AADT (Vch / Day)	<input type="text"/>	Number of Closed Lanes	<input type="text"/>
Work Zone Length (Miles)	<input type="text"/>	Total Number of Lanes	<input type="text"/>
Work Zone Duration (Days)	<input type="text"/>	Number of On-Ramps	<input type="text"/>
Urban or Rural	<input type="text"/>	Number of Off-Ramps	<input type="text"/>
Crash Cost Reference, if you choose Other, enter following fields			
PDO Cost	<input type="text"/>	Fatal-Injury Cost	<input type="text"/>
		Publication Year	<input type="text"/>
<input type="button" value="Analyze"/>			
Results from Model # <input type="text"/>			
	Crash Count	Standard Error	Cost (\$)
PDO	<input type="text"/>	<input type="text"/>	<input type="text"/>
Injury+Fatal	<input type="text"/>	<input type="text"/>	<input type="text"/>
Total	<input type="text"/>	<input type="text"/>	<input type="text"/>
<input type="button" value="Save and Continue to Next Alternative"/>			<input type="button" value="Finish and See the Results"/>



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Questions?

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Thank you!