Evaluation of Dynamic Speed Feedback Signs on Curves: A National Demonstration Project

PUBLICATION NO. FHWA-HRT-14-020

JANUARY 2015

U.S. Department of Transportation
Federal Highway Administration

Research, Development, and Technology
Turner-Fairbank Highway Research Center
6300 Georgetown Pike
McLean, VA 22101-2296

FOREWORD

The overall goal of the Federal Highway Administration's (FHWA) Speed Management Program is to improve the safety of the Nation's highways through the reduction of speeding and speed-related crashes. Drivers who exceed the speed limit or drive too fast for ambient conditions are involved in nearly one-third of all fatal crashes. Each year, more than 13,000 people are killed in speeding-related crashes. The majority of speeding-related crashes occur on roads that are not part of the interstate system. Local streets and collector roads have the highest speeding-related fatality rate on a per vehicle miles driven basis. The challenge facing the safety professional is to design roadways so that drivers better understand the nature of the roadway and adjust their speed appropriately. Design guidance is needed so that roadways are designed and/or retrofitted to induce drivers to drive at more appropriate speeds.

This report discusses treatments that can potentially reduce speeds and speeding-related crash risks on rural horizontal curves. This report describes the effectiveness of dynamic signs that alert drivers to changes in roadway conditions and that provide those drivers with recommended speeds to safely negotiate a curve. The effectiveness of these signs were determined based on field analysis in 22 locations.

Monique R. Evans
Director, Office of Safety
Research and Development

TECHNICAL REPORT DOCUMENTATION PAGE

1. Report No. FHWA-HRT-14-020	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle Evaluation of Dynamic Speed Feedback Signs on Curves: A National Demonstration Project		5. Report Date January 2015 6. Performing Organization Code:
7. Author(s) Shauna L. Hallmark, Neal Hawkins, and Omar Smadi		8. Performing Organization Report No. InTrans Project 08-320
9. Performing Organization Name and Address Center for Transportation Research and Education Iowa State University 2711 South Loop Drive, Suite 4700 Ames, IA 50010-8664		10. Work Unit No. 11. Contract or Grant No. DTFH61-07-H-00022
12. Sponsoring Agency Name and Address Office of Infrastructure Research & Development Federal Highway Administration 6300 Georgetown Pike McLean, VA 22101-2296 Iowa Highway Research Board Iowa Department of Transportation, Office of Traffic and Safety 800 Lincoln Way Ames, IA 50010 Midwest Transportation Consortium 2711 South Loop Drive, Suite 4700 Ames, IA 50010-8664 Texas Department of Transportation 125 E. 11th Street Austin, TX 78701-2483		13. Type of Report and Period Covered Final Report 14. Sponsoring Agency Code IHRB Project TR-579

15. Supplementary Notes

The Contracting Officer's Technical Representative was Richard Knoblauch.

16. Abstract

Lane departure crashes are a significant safety concern. The majority of lane departure crashes occur on rural two-lane roadways, with a disproportionate number of these crashes on horizontal curves. Curve-related crashes involve a number of roadway and driver causative factors. A primary driver factor is speeding.

Dynamic speed feedback sign (DSFS) systems are one method to reduce vehicle speeds and, consequently, crashes on curves. These systems show promise but they have not been fully evaluated on curves. The Center for Transportation Research and Education at Iowa State University conducted a national demonstration project to evaluate the effectiveness of two different DSFSs in reducing speed and crashes on curves at 22 total sites on rural two-lane roadways in seven States. The goal is to provide traffic safety engineers and other professionals with additional tools to manage speeds and crashes on rural horizontal curves more effectively.

Data were collected before and at 1, 12, and 24 months after installation of the DSFS. On average, most sites had decreases in mean speeds, with decreases up to 10.9 miles per hour (mph) noted for both the point of curvature (PC) and center of curve (CC). Most sites experienced changes in 85th percentile speed of 3 mph or more at the PC, with the majority of sites having a decrease of 2 mph at the CC. The numbers of vehicles traveling 5, 10, 15, or 20 mph over the posted or advisory speed limit were also compared. Large reductions in the number of vehicles traveling over the posted or advisory speed occurred for all of the after periods at the PC and CC, indicating that the signs were effective in reducing high-end speeds, as well as average and 85th percentile speeds.

A before-and-after crash analysis was also conducted, and crash modification factors (CMF) were developed. CMFs ranged from 0.93 to 0.95 depending on the crash type and direction of the crash.

17. Key Words	18. Distribution Statement
crash mitigation, curve speed safety, horizontal curves, lane position, low-cost safety improvements, rural road safety, speed-activated displays, speed warning signs	No restrictions. This document is available to the public through NTIS: National Technical Information Service, Springfield, VA 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	206	N/A

Form DOT F 1700.7 (8-72) **Reproduction of completed page authorized**

SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
	NOTE: volumes greater than 1000 L shall be shown in m^3			
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
°F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	$candela/m^2$	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact degrees)		
°C	Celsius	1.8C+32	Fahrenheit	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	$candela/m^2$	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.
(Revised March 2003)

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LIST OF ACRONYMS AND ABBREVIATIONS

AADT	Annual Average Daily Traffic
ADT	Average Daily Traffic
Caltrans	California Department of Transportation
CC	Center of Curve
CI	Confidence Interval
CMF	Crash Modification Factor
CTRE	Center for Transportation Research and Education
DSFS	Dynamic Speed Feedback Sign
EB	Eastbound
EB approach	Empirical Bayes approach
FARS	Fatality Analysis Reporting System
FB	Full Bayesian
FHWA	Federal Highway Administration
HSIS	Highway Safety Information System
Iowa DOT	Iowa Department of Transportation
LED	Light-Emitting Diode
mph	Miles Per Hour
MUTCD	Manual on Uniform Traffic Control Devices
NB	Northbound
PC	Point of Curvature
SB	Southbound
SD	Standard Deviation
SPF	Safety Performance Function
STDE	Standard Error
SV	Single-Vehicle
vpd	Vehicles per Day
WB	Westbound

EXECUTIVE SUMMARY

BACKGROUND

Lane departure crashes are a significant safety concern. The majority of these crashes occur in rural areas, mostly on two-lane roadways. A disproportionate number of them occur on horizontal curves. Curve-related crashes involve a number of roadway and driver causative factors.

The frequency and severity of curve-related crashes correlate to a number of geometric factors, such as curve radius, degree of curve, length of curve, type of curve transition, lane and shoulder width, and preceding tangent length.

The primary driver factor is speeding, given a large number of run-off-road fatal crashes on curves are speeding related. The amount of speed reduction from the tangent speed to the speed required to traverse a curve also has an impact on the frequency and severity of crashes on curves.

Dynamic speed feedback sign (DSFS) systems are one method to reduce vehicle speeds and, consequently, crashes on curves. DSFS systems show promise, but they have not been fully evaluated.

The Center for Transportation Research and Education (CTRE) at Iowa State University undertook this project to evaluate the effectiveness of DSFS systems in reducing speed and crashes on curves on rural two-lane roadways. The project was sponsored by the Federal Highway Administration (FHWA), the Midwest Transportation Consortium, the Iowa Department of Transportation (Iowa DOT), the Iowa Highway Research Board, and the Texas Department of Transportation. This report summarizes the results of the study.

PROJECT OVERVIEW

The project included the following tasks:

- Select a sample of geographically representative States to participate in the study.
- Select high-crash curve sites within those States to serve as treatment and control sites.
- Select candidate DSFS systems for evaluation.
- Collect speed and volume data before and at regular periods after installation of the signs at treatment sites.
- Assess the effectiveness of the signs in reducing speeds on curves.
- Conduct a statistical analysis to compare the impact of the signs on reducing crashes at the treatment and control sites.
- Report the results.

BRIEF DESCRIPTION OF SITE AND SIGN SELECTION

The objective of this project was to conduct a national evaluation of the effectiveness of DSFS systems. The team made every effort to obtain geographic diversity in selecting States where the signs would be tested. The team selected seven States during the Request for Proposals stage of the project or after the project started.

In most cases, an initial list of sites for an individual State was provided by a local or State agency. In two States, the team had access to crash data, so they selected initial sites and then discussed those sites with the corresponding agency.

After reviewing the initial sites and selecting those that met the criteria (defined in chapter 2 of this report), the team made visits to each State and surveyed the potential sites.

During the site visits, the team conducted a brief speed study using a radar gun to ensure that a speeding problem existed. After the site visits, the team selected final sites based on the number and type of crashes, whether a speeding problem existed, and other factors. A total of 51 viable sites across the 7 study States resulted. The researchers randomly selected 22 treatment sites, and the remaining 29 sites served as control sites for the crash analysis.

Two different types of dynamic speed-activated signs were selected for evaluation in the study. (Chapter 2 describes the methodology for selecting the signs.)

Figure 1 shows one type of sign displaying vehicle speed (referred to as the speed display sign), and figure 2 shows the other displaying a curve warning sign (referred to as the curve display sign).

Figure 1. Photo. Speed display sign used in study.

Figure 2. Photo. Curve (warning) display sign used in study.

Both signs activate when drivers exceed the 50th percentile speed. The speed sign displays the vehicle's actual speed, up to a certain threshold, and then the speed indication is replaced by the actual posted speed limit. The threshold was selected to avoid drivers using the sign to test their speeds above the threshold.

Sign installation is described in chapter 4 of this report. It should be noted that, in all cases, the signs were considered supplementary traffic control devices and did not replace existing traffic control.

BRIEF DESCRIPTION OF DATA COLLECTION

Speeds collected after installation of the signs were compared with speeds collected before installation. Data were collected only at treatment sites. There were not sufficient project resources to collect data at 29 additional sites, so the control sites were used only in the crash analysis.

Prior to installation of the signs, speed and volume data were collected at each site using pneumatic road tubes and counters. Data were collected at 1, 12, and 24 months after installation of the signs. Data were collected using Trax I automatic traffic recorders (also called pneumatic road tubes) manufactured by JAMAR Technologies, Inc. These units can collect individual speeds, headways, vehicle class, and volume.

Speed and volume data were collected at three points: approximately 0.5 miles upstream from the curve, at the point of curvature (PC) where the sign was installed, and at the center of curve (CC). Speed and volume data were collected 0.5 miles upstream of the signs to provide some indication whether speeds had changed independent of the signs given drivers at the upstream location had not yet encountered the speed feedback signs. This site served as a comparison location.

Chapter 5 of this report describes the data collection methodology. Chapter 6 presents results for each site. The final evaluation assesses sign performance over a 24-month after period.

Chapter 6 reports results of the speed analyses. A summary of the speed analysis is discussed in the next section.

SUMMARY OF SPEED ANALYSES

Mean and 85th percentile speeds were calculated for each curve for each data collection location before installation of the signs and at 1, 12, and 24 months after installation. The fraction of vehicles traveling at or above the posted speed limit or advisory speed by a certain threshold amount was also calculated. If an advisory speed was present, the fraction of vehicles traveling 5, 10, 15, and 20 miles per hour (mph) or more above the advisory speed was calculated. If no advisory speed was present, the fraction of vehicles traveling a certain threshold over the posted speed limit was calculated.

This metric provides a measure of the number of vehicles traveling at high speeds. In many cases, agencies are more concerned with reducing the number of drivers traveling at excessive speeds than with simply reducing average speeds.

Results are presented for traffic traveling in the direction of the DSFS system. Data for each after period were compared with the before period. Speed metrics for the before period were subtracted from the after period, so a negative change indicates that speeds were reduced from the before to the after period.

The changes in mean speeds from the before to the after periods were evaluated using a *t*-test, and the changes in the fraction of vehicles traveling over the posted or advisory speed by a certain threshold were compared using a test of proportions. Unless indicated otherwise, differences in means and percents over the posted or advisory speeds were statistically significant at the 95-percent level of significance.

The changes in the fraction of vehicles traveling a certain threshold over the posted or advisory speeds are presented showing the percent change from the before to the after period. Percent change was calculated by subtracting the fraction of vehicles exceeding a particular threshold in the before period from the fraction exceeding the threshold in the after period and dividing this by the fraction in the before period.

For example, if the fraction of vehicles traveling 5 mph or more over the posted speed limit was 0.413 for the before period and the fraction of vehicles traveling 5 mph or more over at 1 month after installation was 0.083, the percent change is $(0.083 - 0.413) \div 0.413 = -0.799$. Therefore, 79.9 percent fewer vehicles exceeded the posted or advisory speed by 5 mph or more after the sign had been in place for 1 month.

During the course of the study, maintenance and vandalism issues occurred with some signs, and data could not be collected for a particular interval. As a result, data for 21 sites were available for the 1-month after period, data for all 22 sites were available for the 12-month after period, and data for 18 sites were available for the 24-month after period.

Change in Mean and 85th Percentile Speed at the Point of Curvature

Table 1 provides the change in speed metrics averaged over all treatment sites for data collected at the PC. Table 2 through table 11 summarize overall results by individual curve. The speed data shown are the difference, in mph, between the before period speed and the specific after period speed.

These tables provide the curve identification number, sign type, road name, and posted speed limit for each curve. An "S" for Sign Type indicates a speed display sign, and a "C" designates a curve display sign. When an advisory curve speed was displayed, the advisory speed is shown as well.

Table 1 shows the average change in speed over all sites by analysis period. As shown, the change in mean speed at the 1-month after period was a decrease of 1.8 mph. The average decrease in mean speed at the 12-month after period was even greater than the 1-month after period with a decrease of 2.6 mph. The average speed decrease of about 2.0 mph for the 24-month after period was similar to the 1-month period. The change in 85th percentile speed was a decrease of about 2.2 mph for the 1- and 24-month after periods while the average decrease was 2.9 mph for the 12-month after period.

Also shown in table 1, sites on average had a decrease of 12 percent in the fraction of vehicles traveling at 5 mph or more over the posted or advisory speed limit for the 1-month after period. The fraction of vehicles traveling 10 mph or more over the posted or advisory speed decreased by an average of 30 percent for the 1-month after period and by 36 percent for the fraction traveling 15 mph or more over the posted or advisory speed. Similarly, the average decrease in vehicles traveling 20 mph or more over the posted or advisory speed was 29 percent.

Results for the 12-month after period were somewhat higher, with average decreases of 19, 34, 36, and 50 percent for the fraction of vehicles traveling 5, 10, 15, and 20 mph or more over, respectively.

Results for the 24-month after period were similar to the 1-month after period.

Data were also tabulated and compared by sign type. In general, larger decreases were noted for the speed signs than for the curve signs, although differences were not statistically significant. A closer examination of results by sign type is provided in Comparison of Mean and 85th Percentile Speed Changes Over Time.

Table 2 through table 4 show changes in the speed metrics at the PC for data collected about 1 month after installation of the signs. Changes in mean speed range from a decrease of 5.6 mph at site AZ-6 to an increase of 3.3 mph at site FL-32. The changes in 85th percentile speeds at the PC 1 month after installation ranged from a decrease of 8 mph to an increase of 4 mph.

Table 1. Average change across sites at the PC.

		1 Month			12 Months			24 Months		
		All Sites	**Curve Sign Sites**	**Speed Sign Sites**	**All Sites**	**Curve Sign Sites**	**Speed Sign Sites**	**All Sites**	**Curve Sign Sites**	**Speed Sign Sites**
Average Mean Speed (mph)		-1.82	-1.68	-1.95	-2.57	-2.47	-2.66	-1.97	-1.99	-1.96
Average 85th Percentile Speed (mph)		-2.19	-1.90	-2.45	-2.86	-2.40	-2.70	-2.17	-2.00	-2.30
Average Percent Change in Fraction of Vehicle Exceeding Posted or Advisory Speed by:	**5 mph**	-11.8%	-9.8%	-13.7%	-18.6%	-22.1%	-15.0%	-19.8	-27.1%	-13.3%
	10 mph	-29.9%	-30.4%	-29.4%	-34.4%	-36.5%	-32.2%	-29.3%	-42.5%	-17.7%
	15 mph	-36.3%	-39.4%	-33.5%	-36.2%	-27.3%	-45.2%	-29.6%	-42.5%	-18.2%
	20 mph	-28.5%	-29.6%	-27.6%	-49.8%	-46.1%	-53.5%	-30.0%	-42.6%	-18.7%

Table 2. Summary of results for individual sites at the PC 1 month after sign installation (part 1).

Curve		AZ-6	AZ-2	FL-6	FL-32	FL-8	IA-10	IA-31	IA-33
Sign Type		C	S	C	S	S	C	S	C
Road		SR 377	SR 95	SR 267	SR 20	SR 20	US 30	US 67	US 69
Posted		65	55	55	55	55	55	55	55
Curve Advisory		none	45	none	45	none	none	none	50
Change in Mean Speed (mph)		-5.6	-4.4	-0.9	3.3	-1.4	-0.9	-0.8	-0.2
Change in 85th Percentile Speed (mph)		-8	-8	-1	4	-1	-1	-1	0
Percent Change in Fraction of Vehicles Exceeding Posted or Advisory Speed by:	**5 mph**	-79.9%	-18.6%	-20.9%	2.8%	-31.1%	-19.5%	-19.6%	-3.1%
	10 mph	-91.3%	-54.6%	-25.0%	16.0%	-34.8%	-44.2%	-43.1%	-14.3%
	15 mph	-92.5%	-70.8%	-57.1%	71.3%	-44.4%	-37.5%	-42.9%	-24.5%
	20 mph	-96.4%	-70.1%	0.0%	172.9%	0.0%	100.0%	-66.7%	-25.0%

C = Curve display sign
S = Speed display sign

Table 3. Summary of results for individual sites at the PC 1 month after sign installation (part 2).

Curve		IA-14	OH-6	OH-8	OH-14	OR-4	OR-12	OR-5	OR-9
Sign Type		S	S	C	S	C	C	S	S
Road		Iowa 136	Alkire	Norton	Pontius	US 101	OR 126	US 42	OR 238
Posted		50	55	55	55	55	55	55	55
Curve Advisory		45	30	35	30	45	40	35	30
Change in Mean Speed (mph)		-2.7	-0.5	-0.9	0.9	-0.8	-0.6	-4.1	-3.4
Change in 85th percentile Speed (mph)		-4	-1	0	0	-1	0	-4	-3
Percent Change in Fraction of Vehicles Exceeding Posted or Advisory Speed by:	**5 mph**	-16.8%	0.2%	-1.5%	0.9%	-2.3%	-1.5%	-6.1%	-16.7%
	10 mph	-57.9%	-2.4%	-8.5%	4.0%	-15.0%	-9.9%	-19.9%	-42.1%
	15 mph	-71.9%	-11.9%	-15.6%	11.4%	-34.6%	-11.6%	-40.2%	-61.0%
	20 mph	-73.0%	-27.1%	-11.8%	34.2%	-53.5%	9.3%*	-64.5%	-62.1%

*Not statistically significant at 95-percent level of significance
C = Curve display sign
S = Speed display sign

Table 4. Summary of results for individual sites at the PC 1 month after sign installation (part 3).

Curve		TX-38	TX-30	TX-39	WA-15	WA-8
Sign Type		S	C	C	C	S
Road		FM 481	FM 359	US 90	US 101	SR 7
Posted		65	70	70	50	50
Curve Advisory		50	none	none	40	35
Change in Mean Speed (mph)		-5.2	-3.4	1.6	-5.1	-3.2
Change in 85th Percentile Speed (mph)		-4	-5	2	-5	-5
Percent Change in Fraction of Vehicles Exceeding Posted or Advisory Speed by	**5 mph**	-14.1%	-75.0%	110.5%	-4.3%	-32.0%
	10 mph	-28.5%	-80.0%	75.0%*	-16.2%	-60.5%
	15 mph	-42.3%	-78.9%	0.0%*	-41.4%	-65.6%
	20 mph	-91.3%	-50.0%	-100.0%	-68.2%	-56.0%

*Not statistically significant at 95-percent level of significance
C = Curve display sign
S = Speed display sign

Table 5 through table 7 provide changes in the speed metrics at the PC for data collected about 12 months after installation of the signs for individual sites. Decreases in mean speeds ranged from 6.5 mph to an increase of 0.6 mph. Decreases in 85th percentile speeds range from a

decrease of 8 mph to an increase of 1 mph. Signs were functioning for all 22 sites for the 12-month after period.

Table 5. Summary of results for individual sites at the PC 12 months after sign installation (part 1).

Curve		AZ-6	AZ-2	FL-6	FL-32	FL-8	IA-10	IA-31	IA-33
Sign Type		C	S	C	S	S	C	S	C
Road		SR 377	SR 95	SR 267	SR 20	SR 20	US 30	US 67	US 69
Posted		65	55	55	55	55	55	55	55
Curve Advisory		none	45	none	45	none	none	none	50
Change in Mean Speed (mph)		-3.6	-3.9	-6.5	-2.8	-1.9	-2.5	-1.0	-1.3
Change in 85th Percentile speed (mph)		-5	-7	-8	-4	-2	-3	-1	0
Percent Change in Fraction of Vehicles Exceeding Posted or Advisory Speed by:	**5 mph**	-44.8%	-16.9%	-95.4%	-3.6%	-45.5%	-53.2%	-30.2%	-13.7%
	10 mph	-78.5%	-48.8%	-96.4%	-24.7%	-50.0%	-76.6%	-45.8%	-19.9%
	15 mph	-83.6%	-58.9%	-100.0%	-64.2%	-44.4%	-62.5%	-42.9%	-28.6%
	20 mph	-89.3%	-57.5%	-100.0%	-77.1%	-50.0%	0.0%*	-33.3%	-37.5%

*Not statistically significant at 95-percent level of significance
C = Curve display sign
S = Speed display sign

Table 6. Summary of results for individual sites at the PC 12 months after sign installation (part 2).

Curve		IA-14	OH-6	OH-8	OH-14	OR-4	OR-12	OR-5	OR-9
Sign Type		S	S	C	S	C	C	S	S
Road		Iowa 136	Alkire	Norton	Pontius	US 101	OR 126	US 42	OR 238
Posted		50	55	55	55	55	55	55	55
Curve Advisory		45	30	35	30	45	40	35	30
Change in Mean Speed (mph)		-0.8	-2.8	-2.4	0.1	-1.8	-0.2*	-6.1	-2.8
Change in 85th Percentile Speed (mph)		-1	-3	-2	0	-1	1	-6	-3
Percent Change in Fraction of Vehicles Exceeding Posted or Advisory Speed by:	**5 mph**	-2.8%	-7.9%	-3.6%	1.1%	-10.7%	-3.3%	-12.5%	-11.8%
	10 mph	-22.2%	-25.1%	-16.7%	-0.2%*	-26.2%	-10.2%	-32.2%	-35.4%
	15 mph	-31.5%	-41.1%	-36.0%	-4.0%*	-35.8%	-0.5%*	-61.6%	-59.4%
	20 mph	-52.3%	-54.2%	-54.8%	3.3%	-30.2%	44.9%	-81.1%	-72.4%

*Not statistically significant at 95-percent level of significance
C = Curve display sign
S = Speed display sign

Table 7. Summary of results for individual sites at the PC 12 months after sign installation (part 3).

Curve		TX-38	TX-30	TX-4	TX-39	WA-15	WA-8
Sign Type		S	C	C	C	C	S
Road		FM 481	FM 359	FM 755	US 90	US 101	SR 7
Posted		65	70	65	70	50	50
Curve Advisory		50	none	50	none	40	35
Change in Mean Speed (mph)		-5.6	-1.7	-2.9	0.6	-4.9	-1.7
Change in 85th Percentile Speed (mph)		-4	-3	-4	1	-5	-3
Percent Change in Fraction of Vehicles Exceeding Posted or Advisory Speed by:	**5 mph**	-16.5%	-51.2%	-10.0%	47.4%	-4.7%	-18.5%
	10 mph	-29.8%	-58.2%	-28.3%	25.0%*	-15.9%	-40.4%
	15 mph	-47.3%	-73.7%	-35.6%	200.0%	-43.6%	-41.7%
	20 mph	-70.1%	-100.0%	-68.5%	0.0%*	-71.5%	-44.0%

*Not statistically significant at 95-percent level of significance
C = Curve display sign
S = Speed display sign

Table 8 through table 10 show changes in speed metrics at the PC for the 24-month after period. Signs at two sites in Oregon and two sites in Texas had various issues between the 12- and 24-month after periods. Given a number of other signs had already been repaired, it was determined there were not sufficient project resources to make additional trips to perform maintenance at those sites.

As shown, in the 24-month after period, decreases in mean speeds ranged from 0.8 to 5.7 mph, with one site experiencing an increase in mean speed of 0.5 mph. Decreases in 85th percentile speeds ranged from 1 to 6 mph, with one site having an increase of 1 mph.

Table 8. Summary of results for individual sites at the PC 24 months after sign installation (part 1).

Curve		AZ-6	AZ-2	FL-6	FL-32	FL-8	IA-10	IA-31
Sign Type		C	S	C	S	S	C	S
Road		SR 377	SR 95	SR 267	SR 20	SR 20	US 30	US 67
Posted		65	55	55	55	55	55	55
Curve Advisory		none	45	none	45	none	none	None
Change in Mean Speed (mph)		-4.7	-1.4	-1.1	-1.1	-1.1	-0.8	-2.4
Change in 85th Percentile Speed (mph)		-6	-3	-1	-2	-1	-1	-3
Percent Change in Fraction of Vehicles Exceeding Posted or Advisory Speed by:	**5 mph**	-60.3%	-7.0%	-32.0%	0.1%*	-22.6%	-21.4%	-57.9%
	10 mph	-86.2%	-15.9%	-60.7%	-7.2%	37.0%	-50.6%	-72.2%
	15 mph	-91.0%	-21.0%	-71.4%	-33.2%	122.2%	-25.0%	-71.4%
	20 mph	-92.9%	-12.6%	-100.0%	-44.8%	150.0%	0.0%*	-66.7%*

*Not statistically significant at 95-percent level of significance
C = Curve display sign
S = Speed display sign

Table 9. Summary of results for individual sites at the PC 24 months after sign installation (part 2).

Curve		IA-33	IA-14	OH-6	OH-8	OH-14	OR-12	OR-9
Sign Type		C	S	S	C	S	C	S
Road		US 69	IA 136	Alkire	Norton	Pontius	OR 126	OR 238
Posted		55	50	55	55	55	55	55
Curve Advisory		50	45	30	35	30	40	30
Change in Mean Speed (mph)		-2.7	-2.1	-2.4	0.6	-1.9	-1.7	-2.1
Change in 85th Percentile Speed (mph)		-2	-2	-2	1	-2	-1	-2
Percent Change in Fraction of Vehicles Exceeding Posted or Advisory Speed by:	**5 mph**	-35.2%	-13.1%	-6.6%	0.0%*	-3.1%	-6.5%	-9.1%
	10 mph	-58.5%	-38.7%	-19.6%	0.2%*	-15.0%	-18.0%	-27.1%
	15 mph	-61.2%	-52.5%	-38.3%	6.6%	-28.7%	-23.4%	-40.6%
	20 mph	-87.5%	-89.2%	-44.9%	22.0%	-25.0%	-14.4%	-34.5%

*Not statistically significant at 95-percent level of significance
C = Curve display sign
S = Speed display sign

Table 10. Summary of results for individual sites at the PC 24 months after sign installation (part 3).

Curve		TX-38	TX-30	WA-15
Sign Type		S	C	C
Road		FM 481	FM 359	US 101
Posted		65	70	50
Curve Advisory		50	none	40
Change in Mean Speed (mph)		-5.7	-1.9	-3.6
Change in 85th Percentile Speed (mph)		-5	-3	-3
Percent Change in Fraction of Vehicles Exceeding Posted or Advisory Speed by:	**5 mph**	-0.1%	-57.1%	-4.1%
	10 mph	-0.4%	-54.5%	-11.3%
	15 mph	-0.5%	-47.4%	-26.9%
	20 mph	-0.7%	-16.7%	-51.3%

C = Curve display sign
S = Speed display sign

Decreases in mean and 85th percentile speeds were plotted to show the distribution of change. Figure 3 shows the percent of sites experiencing decreases in mean speeds of a certain magnitude at 1, 12, and 24 months. Figure 4 provides changes in 85th percentile speeds of a certain magnitude.

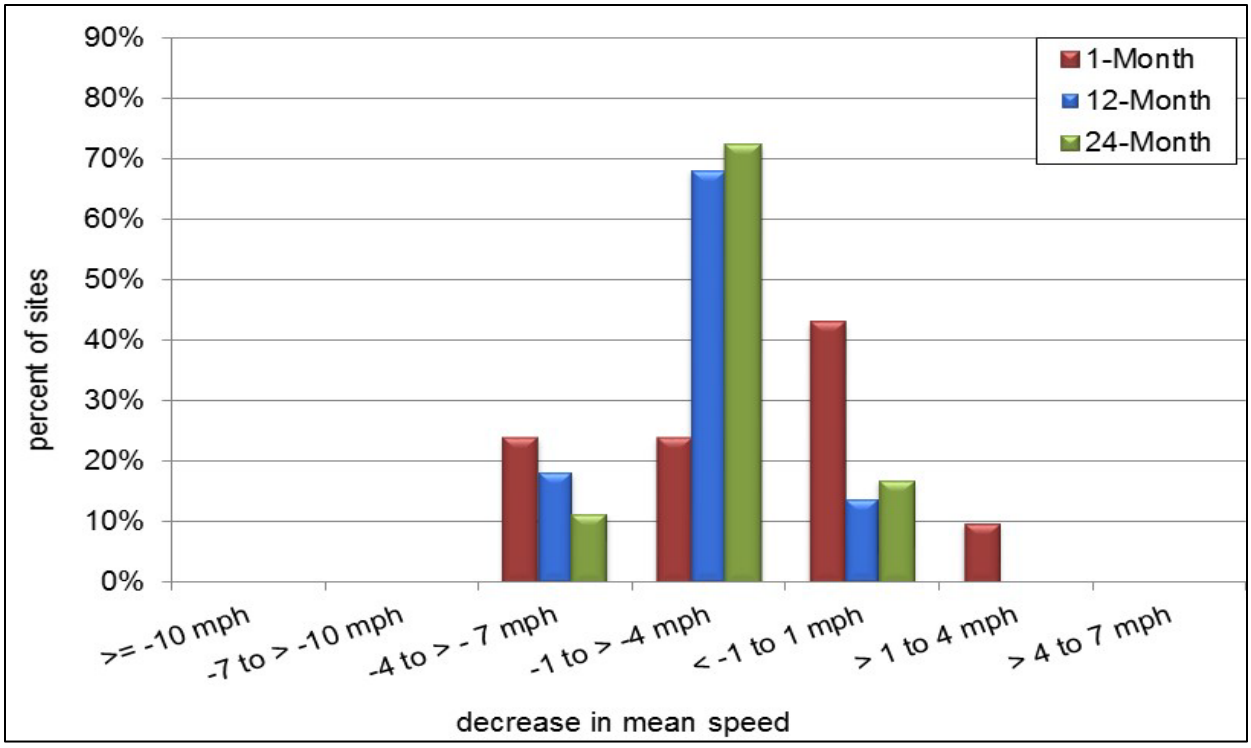


Figure 3. Chart. Percent of sites experiencing a change in mean speed of a certain magnitude at the PC.

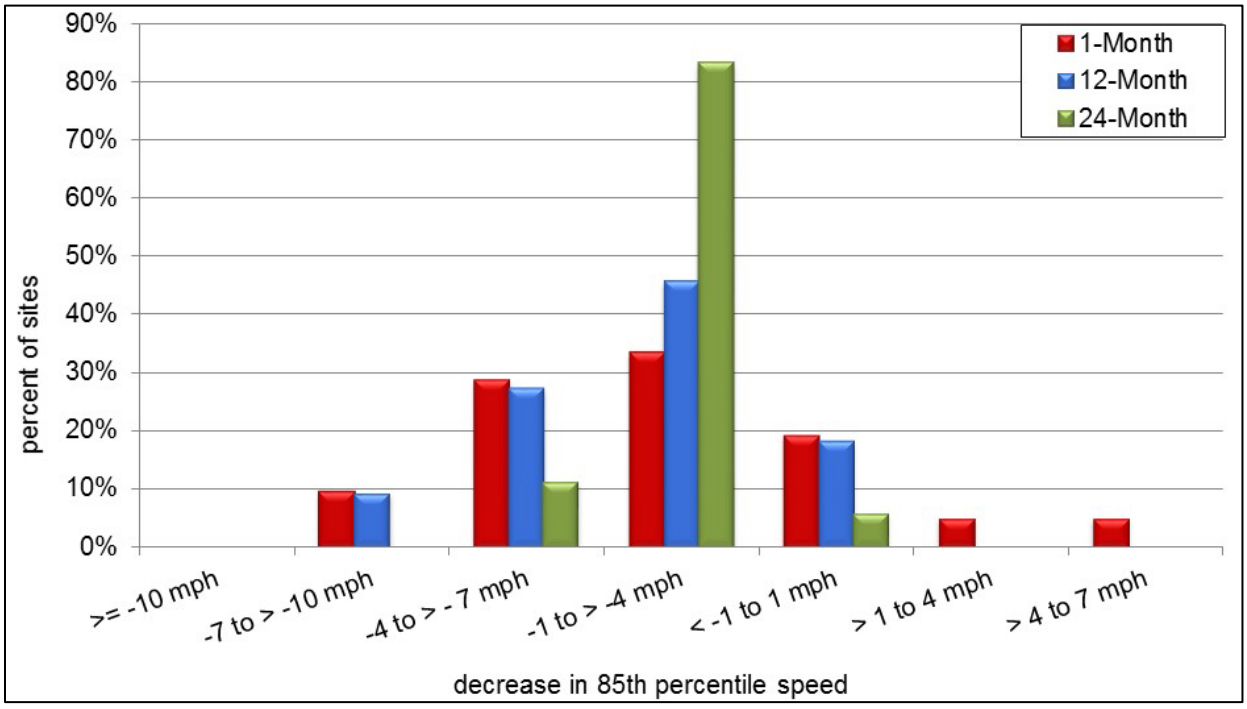


Figure 4. Chart. Percent of sites experiencing a change in 85th percentile speed of a certain magnitude at the PC.

As shown, at 1 month, 2 of the 21 sites had increases in mean speeds between 1 and 4 mph, 9 of the sites (43 percent) experienced virtually no changes in mean speeds, 5 sites (24 percent) experienced decreases of 1 to 4 mph, and 5 sites had decreases between 4 and 7 mph.

As illustrated in figure 4, two sites (10 percent) experienced increases between 1 and 7 mph, four sites (19 percent) had little change in 85th percentile speeds, seven sites (33 percent) had decreases between 1 and 4 mph, six sites (29 percent) had decreases of 4 to 7 mph, and two sites (10 percent) had decreases of more than 7 mph.

Also, as shown in figure 3, no sites experienced significant increases in mean speeds at 12 months, 3 of the 22 sites (14 percent) had little change, 15 sites (68 percent) had decreases of 1 to 4 mph, and 4 sites had decreases from 4 to 7 mph.

As shown in figure 4, no sites had increases in 85th percentile speeds while 3 of the 22 sites (18 percent) had little change, 10 sites (45 percent) had decreases of 1 to 4 mph, 6 sites (27 percent) had decreases of 4 to 7 mph, and 2 sites (9 percent) had decreases of 7 mph or more.

Figure 3 and figure 4 also show results for 24 months after installation of the signs. Data were available for 18 sites. (As indicated in chapter 6, issues had occurred with several other signs, so 24-month after data were not available for all sites.)

As shown in figure 3, at 24 months, no signs had significant increases in mean speeds while three sites had little change. The majority (13 sites or 72 percent) had decreases of 1 to 4 mph while 2 sites (11 percent) had decreases between 4 and 7 mph. As shown in figure 4, at the 24-month after period, 1 site (6 percent) had no relevant change in 85th percentile speed, 14 sites (83 percent) had decreases of 1 to 4 mph, and 2 sites (11 percent) had decreases of 4 mph or more.

Percent of Vehicles Exceeding the Posted or Advisory Speed, by Speed Bin at the Point of Curvature

Figure 5 through figure 8 show changes in the percent of vehicles traveling 5 mph or more, 10 mph or more, 15 mph or more, and 20 mph or more, respectively, over the posted speed or advisory speed at the PC. Researchers used advisory speed if present; if not present, the posted speed limit was used. Figure 5 shows the percent of sites with a change at a particular magnitude. For instance, the first interval is the percent of sites that had decreases of 70 percent or more in the number of vehicles traveling 5 mph or more over the posted or advisory speed.

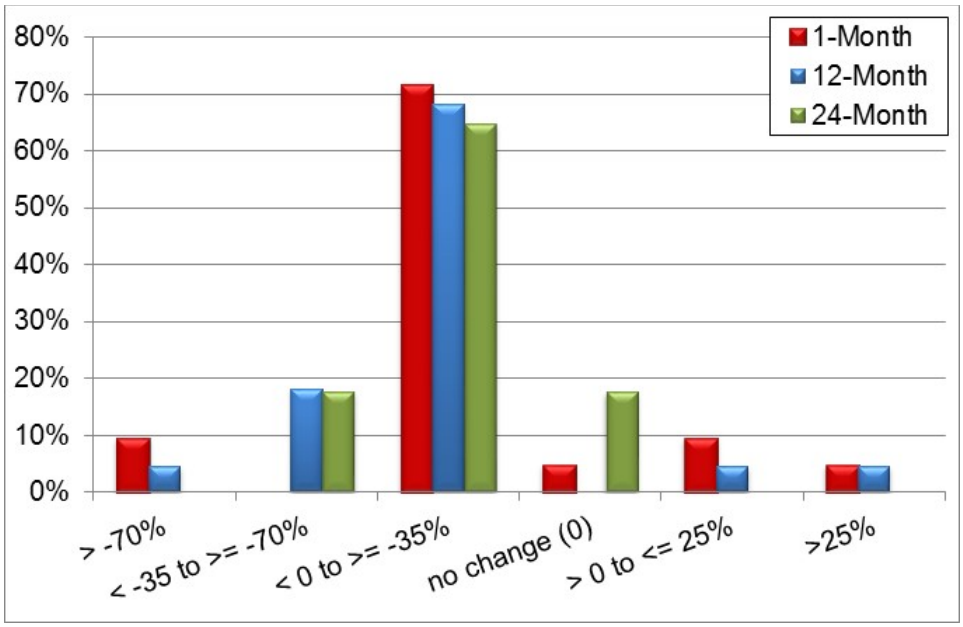


Figure 5. Chart. Changes in percent of vehicles traveling 5 or more mph over posted limit or advisory speed at the PC.

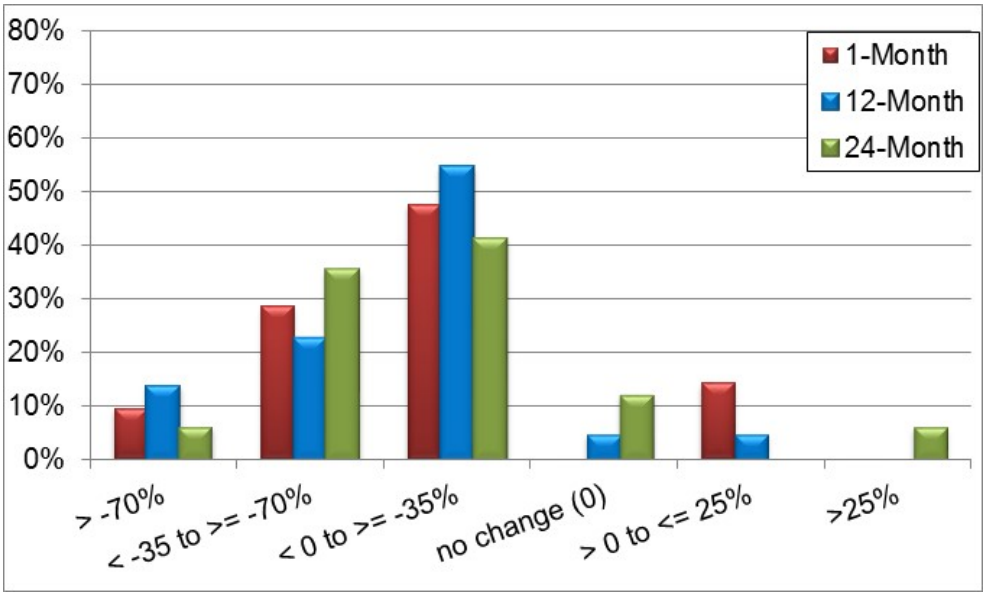


Figure 6. Chart. Changes in percent of vehicles traveling 10 or more mph over posted limit or advisory speed at the PC.

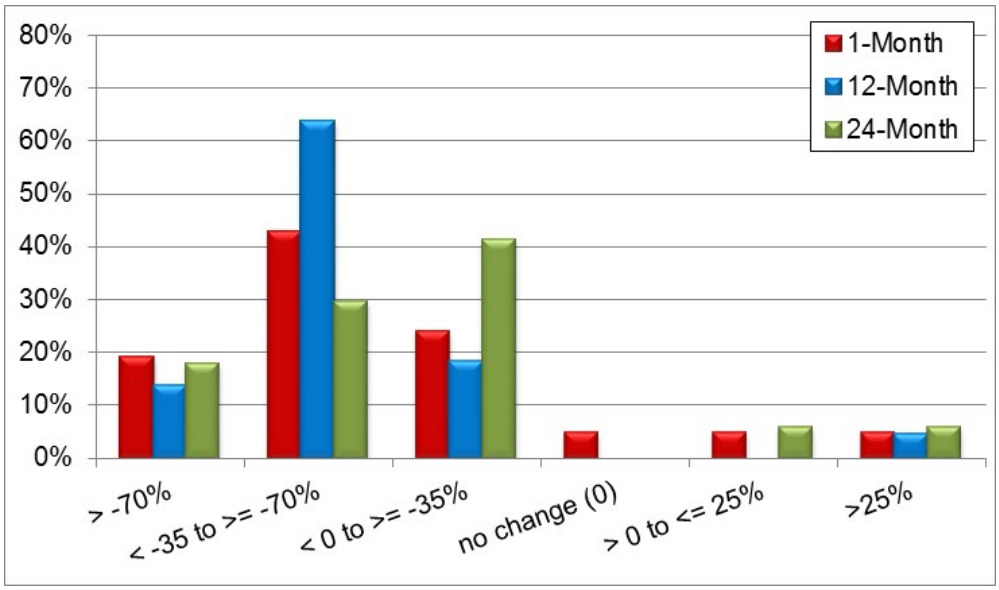


Figure 7. Chart. Changes in percent of vehicles traveling 15 or more mph over posted limit or advisory speed at the PC.

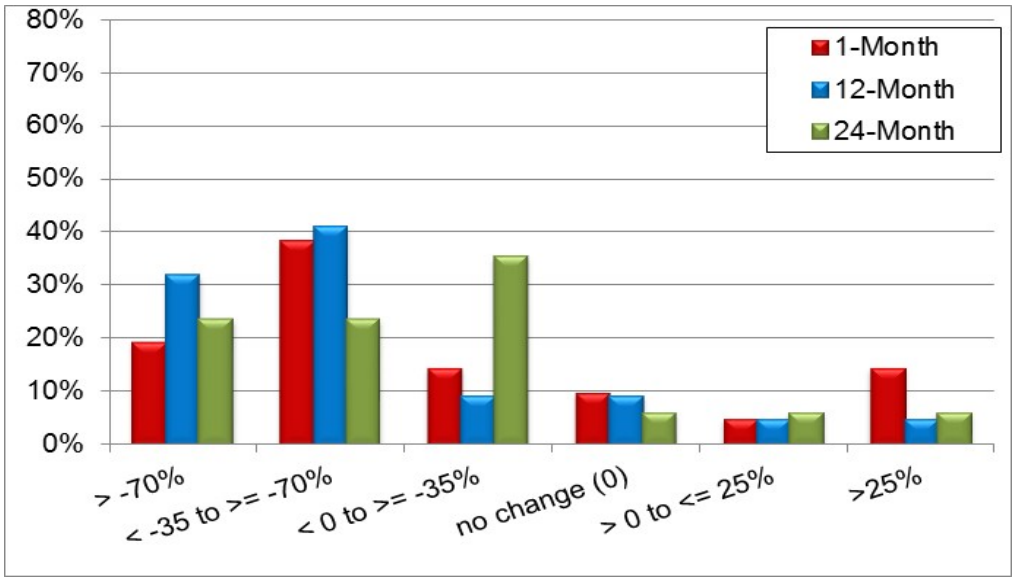


Figure 8. Chart. Changes in percent of vehicles traveling 20 or more mph over posted limit or advisory speed at the PC.

Data for vehicles traveling 5 mph or more over the posted or advisory speed are fairly consistent over the 1-, 12-, and 24-month after periods. As shown, 5 to 10 percent of sites had reductions of 70 percent or more, and about 15 percent of sites had decreases from 35 to 70 percent. The majority of sites for all time periods had decreases up to 35 percent. A small number of sites had little change, with up to 10 percent having increases up to 25 percent and about 5 percent with increases of more than 25 percent.

Figure 6 also shows data for the proportion of vehicles traveling 10 mph or more over the posted speed limit or advisory speed. The majority of sites (41 to 55 percent, depending on time period)

had decreases up to 35 percent in the fraction of vehicles traveling 10 mph or more over the posted or advisory speed while 23 to 35 percent had decreases between 35 and 70 percent.

About 10 percent of sites for 1 month, 14 percent for 12 months, and 6 percent for 24 months had decreases of 70 percent or more. At 1 month, 14 percent of sites, and at 12 months, 5 percent of sites, had increases up to 25 percent in the fraction of vehicles traveling 10 mph or more over the posted or advisory speed. Six percent of vehicles had increases of more than 25 percent for the 24-month after period. Up to 12 percent of sites had no change.

Figure 7 also shows changes in the fraction of vehicles traveling 15 mph or more over the posted or advisory speed. Less than 6 percent of sites for any analysis after period had increases or no change in the fraction of vehicles traveling 15 mph or more over the posted or advisory speed. Twenty-four percent of vehicles, 18 percent at 12 months, and 41 percent at 24 months had decreases up to 35 percent in the percent of vehicles traveling 15 mph or more over the posted or advisory speed. The majority of sites, 43 and 64 percent for 1 and 12 months after, respectively, and 29 percent for 24 months after had decreases between 35 and 70 percent. Up to 19 percent of sites had decreases of more than 70 percent.

Figure 8 also shows results for changes in the percent of vehicles traveling 20 mph or more over the posted or advisory speed. The majority of sites (35 percent) at 24 months had decreases up to 35 percent in the fraction of vehicles traveling 20 mph or more over the posted or advisory speed.

About 9 and 14 percent of sites experienced decreases in that range for the 1- and 12-month after periods, respectively. The majority of sites, 38 percent for 1 month after and 41 percent for 12 months after, had decreases of 35 to 70 percent in vehicles traveling 20 mph or more over the posted or advisory speed. Between 19 and 32 percent of sites had decreases in the fraction of vehicles traveling 20 mph or more over the posted or advisory speed.

A few sites (14 percent for 1 month after and about 5 percent for 12 and 24 months after) had increases of more than 25 percent. About 5 percent had increases up to 25 percent and about 6 to 9 percent had no change. About 20 percent of sites at 1 and 24 months after and about 30 percent at 12 months after had decreases in the percent of vehicles traveling 20 mph or more over the posted or advisory speed.

As noted, significant reductions in the number of vehicles traveling over the posted or advisory speed occurred for all of the after periods at the PC. In most cases, the majority of sites had reductions between 35 and 70 percent in the fraction of vehicles exceeding the posted or advisory speed. This was the case for all of the speed thresholds (5, 10, 15, and 20 mph or more over). In addition, reductions of greater than 70 percent were noted for all time periods and thresholds except for one. This indicates the signs were effective in reducing high-end speeds, as well as average and 85th percentile speeds.

Change in Mean and 85th Percentile Speed at the Center of Curve

Table 11 provides the change in speed metrics averaged for all sites for data collected at the CC. Table 12 through table 20 summarize overall results by curve. The speed data shown are the difference in mph between the before period speed and the specific after period speed. These

tables provide the curve identification number, sign type, road name, and posted speed limit for each curve. An “S” for Sign Type indicates a speed display sign, and a “C” designates a curve display sign. When an advisory curve speed was present, the advisory speed is also shown.

Table 11 provides the average change in speed overall for all sites by after analysis period. As shown, the change in mean speed at the 1-month after period was a decrease of 2.1 mph. The average decreases, 1.7 and 1.8 mph, in mean speeds at the 12-month and 24-month after periods, respectively, were smaller than the average decrease at 1 month.

The average changes in 85th percentile speeds were a decrease of 2.5 mph for 1 month, 1.6 mph for 12 months, and 1.9 mph for 24 months. Results are also presented by sign type. A more in-depth discussion of results by sign type is presented in Comparison of Mean and 85th Percentile Speed Changes Over Time.

Table 11. Average change across sites at the CC.

		1 Month			12 Months			24 Months		
		All Sites	Curve Sign Sites	Speed Sign Sites	All Sites	Curve Sign Sites	Speed Sign Sites	All Sites	Curve Sign Sites	Speed Sign Sites
Average Mean Speed (mph)		-2.08	-2.01	-2.15	-1.65	-1.47	-1.84	-1.76	-1.46	-2.00
Average 85th Percentile Speed (mph)		-2.52	-2.50	-2.55	-1.55	-0.82	-2.27	-1.89	-1.25	-2.40
Average Percent Change in Fraction of Vehicle Exceeding Posted or Advisory Speed by:	**5 mph**	-0.28%	-0.28%	-0.27%	-0.20%	-0.21%	-0.18%	-0.26%	-0.30%	-0.23%
	10 mph	-0.42%	-0.43%	-0.41%	-0.33%	-0.32%	-0.33%	-0.42%	-0.43%	-0.40%
	15 mph	-0.57%	-0.71%	-0.44%	-0.37%	-0.42%	-0.33%	-0.44%	-0.38%	-0.50%
	20 mph	-0.31%	-0.55%	-0.09%	-0.14%	-0.35%	0.07%	-0.37%	-0.25%	-0.47%

Table 12 through table 14 show results at the CC for individual sites at the 1-month after period. Speed reductions were generally larger at the CC than at the PC. Changes in mean speeds ranged from a decrease of 10.9 mph to an increase of 2.8 mph. Changes in 85th percentile speeds ranged from a decrease of 12 mph to an increase of 6 mph.

Data are presented for 21 of the 22 sites. At the 1-month after period, a sign had been knocked down at one of the Texas sites and had not been repaired when data were collected.

As noted, most sites had significant decreases in the fraction of vehicles traveling 5, 10, 15, or 20 mph or more over the posted or advisory speed. Reductions up to almost 100 percent were reported for the fraction traveling 5, 10, or 15 mph or more over the posted or advisory speed. One site had a 211-percent reduction, and another site had a 161-percent reduction in the fraction of vehicles traveling 20 mph or more over the posted or advisory speed limit.

Table 12. Summary of results for individual sites at the CC 1 month after sign installation (part 1).

Curve		AZ-6	AZ-2	FL-6	FL-32	FL-8	IA-10	IA-31	IA-33
Sign Type		C	S	C	S	S	C	S	C
Road		SR 377	SR 95	SR 267	SR 20	SR 20	US 30	US 67	US 69
Posted		65	55	55	55	55	55	55	55
Curve Advisory		none	45	none	45	none	none	none	50
Change in Mean Speed (mph)		-1.7	-5.3	-0.7	-3.7	-2.9	-1.5	-10.9	0.0
Change in 85th Percentile Speed (mph)		-3	-7	-1	-4	-3	-1	-12	1
Percent Change in Fraction of Vehicles Exceeding Posted or Advisory Speed by:	**5 mph**	-52.5%	-41.5%	-17.2%	-7.1%	-65.4%	-25.6%	-96.5%	-2.5%
	10 mph	-70.2%	-73.3%	-28.6%	-21.2%	-78.3%	-58.2%	-99.0%	0.4%
	15 mph	-79.2%	-85.6%	-50.0%	-69.9%	-70.0%	-63.6%	-97.9%	-95.8%
	20 mph	-60.0%	-88.9%	0.0%*	-80.4%	-50.0%	-50.0%	-95.2%	-100.0%

*Not statistically significant at 95-percent level of significance
C = Curve display sign
S = Speed display sign

Table 13. Summary of results for individual sites at the CC 1 month after sign installation (part 2).

Curve		IA-14	OH-6	OH-8	OH-14	OR-4	OR-12	OR-5	OR-9
Sign Type		S	S	C	S	C	C	S	S
Road		IA 136	Alkire	Norton	Pontius	US 101	OR 126	US 42	OR 238
Posted		50	55	55	55	55	55	55	55
Curve Advisory		45	30	35	30	45	40	35	30
Change in Mean Speed (mph)		-0.6	0.4	-3.1	2.8	-5.6	-1.3	-2.7	-2.5
Change in 85th Percentile Speed (mph)		-2	0	-3	6	-6	-1	-3	-3
Percent Change in Fraction of Vehicles Exceeding Posted or Advisory Speed by:	**5 mph**	-1.5%	3.0%	-14.4%	-0.5%*	-43.0%	-3.5%	-23.6%	-34.0%
	10 mph	-28.6%	6.6%	-41.3%	-1.0%*	-78.7%	-19.4%	-44.3%	-62.6%
	15 mph	-40.2%	14.2%	-63.9%	22.0%	-95.3%	-32.5%	-54.7%	-77.8%
	20 mph	-43.8%	-21.4%	-73.7%	210.7%	-96.7%	-46.8%	-46.2%	-50.0%

*Not statistically significant at 95-percent level of significance
C = Curve display sign
S = Speed display sign

Table 14. Summary of results for individual sites at the CC 1 month after sign installation (part 3).

Curve		TX-38	TX-30	TX-39	WA-15	WA-18
Sign Type		S	C	C	C	S
Road		FM 481	FM 359	US 90	US 101	SR 7
Posted		65	70	70	50	50
Curve Advisory		50	none	none	40	35
Change in Mean Speed (mph)		1.3	-2.3	-1.0	-2.9	0.5
Change in 85th Percentile Speed (mph)		3	-3	-1	-7	-3
Percent Change in Fraction of Vehicles Exceeding Posted or Advisory Speed by:	**5 mph**	-1.8%*	-66.1%	-29.4%	-26.2%	-28.3%
	10 mph	-0.2%*	-59.6%	-33.3%*	-44.7%	-45.6%
	15 mph	13.1%	-68.8%	-100.0%	-59.0%	-38.6%
	20 mph	160.9%	-57.1%	0.0%*	-69.2%	0.0%

*Not statistically significant at 95-percent level of significance
C = Curve display sign
S = Speed display sign

Table 15 through table 17 provide results for the CC for 12 months after installation of the signs. Changes in mean speeds ranged from a decrease of 7.9 mph to an increase of 3.7 mph. The changes in 85th percentile speeds ranged from a decrease of 9 mph to an increase of 3 mph.

Table 15. Summary of results for individual sites at the CC 12 months after sign installation (part 1).

Curve		AZ-6	AZ-2	FL-6	FL-32	FL-8	IA-10	IA-31	IA-33
Sign Type		C	S	C	S	S	C	S	C
Road		SR 377	SR 95	SR 267	SR 20	SR 20	US 30	US 67	US 69
Posted		65	55	55	55	55	55	55	55
Curve Advisory		none	45	none	45	none	none	none	50
Change in Mean Speed (mph)		0.2	-2.9	-1.9	-3.7	-1.1	0.4	-7.9	-2.5
Change in 85th Percentile Speed (mph)		0	-4	-2	-4	-1	3	-9	-2
Percent Change in Fraction of Vehicles Exceeding Posted or Advisory Speed by:	**5 mph**	4.3%	-17.8%	-41.8%	-6.5%	-29.6%	22.0%	-82.2%	-30.5%
	10 mph	-26.2%	-41.8%	-42.9%	-32.0%	-40.6%	29.6%	-94.8%	-59.6%
	15 mph	-58.3%	-61.0%	-50.0%	-70.2%	-40.0%	9.1%	-96.9%	-70.8%
	20 mph	0.0%	-66.7%	0.0%*	-80.4%	-50.0%	-50.0%	-95.2%	-100.0%

*Not statistically significant at 95-percent level of significance
C = Curve display sign
S = Speed display sign

Table 16. Summary of results for individual sites at the CC 12 months after sign installation (part 2).

Curve		IA-14	OH-6	OH-8	OH-14	OR-4	OR-12	OR-5	OR-9
Sign Type		S	S	C	S	C	C	S	S
Road		IA 136	Alkire	Norton	Pontius	US 101	OR 126	US 42	OR 238
Posted		50	55	55	55	55	55	55	55
Curve Advisory		45	30	35	30	45	40	35	30
Change in Mean Speed (mph)		-2.0	-2.9	-0.2	-2.0	-5.6	-4.4	-2.3	-0.4
Change in 85th Percentile Speed (mph)		-3	-3	0	-2	-5	-4	-3	-1
Percent Change in Fraction of Vehicles Exceeding Posted or Advisory Speed by:	**5 mph**	-17.0%	-13.4%	-0.9%	-2.2%	-41.4%	-26.5%	-20.7%	-6.2%
	10 mph	-44.8%	-35.4%	-8.4%	-16.2%	-67.7%	-54.9%	-42.5%	-10.0%
	15 mph	-64.4%	-49.1%	-3.9%	-33.8%	-86.0%	-72.4%	-52.6%	-18.5%
	20 mph	-75.0%	-71.4%	-7.9%	-48.4%	-93.3%	-87.1%	-15.4%	0.0%

C = Curve display sign
S = Speed display sign

Table 17. Summary of results for individual sites at the CC 12 months after sign installation (part 3).

Curve		TX-38	TX-30	TX-4	TX-39	WA-15	WA-18
Sign Type		S	C	C	C	C	S
Road		FM 481	FM 359	FM 755	US 90	US 101	SR 7
Posted		65	70	65	70	50	50
Curve Advisory		50	none	50	none	40	35
Change in Mean (mph)		-0.9	-2.8	-1.4	-1.6	-2.0	3.7
Change in 85th Percentile speed (mph)		0	-3	1	-1	-2	2
Percent Change in Fraction of Vehicles Exceeding Posted or Advisory Speed by:	**5 mph**	-7.7%	-55.0%	4.0%*	-52.9%	-17.4%	6.7%
	10 mph	-14.4%	-72.3%	-0.3%*	-16.7%*	-33.9%	8.9%
	15 mph	-12.7%	-87.5%	10.5%*	0.0%*	-47.4%	136.8%
	20 mph	4.7%	-85.7%	100.0%*	0.0%*	-61.5%	575.0%

*Not statistically significant at 95-percent level of significance
C = Curve display sign
S = Speed display sign

Table 18 through table 20 provide changes in speed metrics for the 24-month after period. Data are presented for 18 sites, given 4 sites were no longer functioning at the 24-month after period. One site had an increase in mean speed of 2.0 mph, while the remaining sites had decreases from 0.8 to 7.0 mph. Two sites experienced increases in 85th percentile speeds (1 and 2 mph), and two sites had no change. The remaining sites had decreases in 85th percentile speeds from 1 to 8 mph.

Table 18. Summary of results for individual sites at the CC 24 months after sign installation (part 1).

Curve		AZ-6	AZ-2	FL-6	FL-32	FL-8	IA-10	IA-31	IA-33
Sign Type		C	S	C	S	S	C	S	C
Road		SR 377	SR 95	SR 267	SR 20	SR 20	US 30	US 67	US 69
Posted		65	55	55	55	55	55	55	55
Curve Advisory		none	45	none	45	none	none	none	50
Change in Mean Speed (mph)		-3.5	-4.1	-0.8	-1.2	-2.1	-2.0	-7.0	-1.3
Change in 85th Percentile Speed (mph)		-4	-5	-1	-1	-2	-2	-8	0
Percent Change in Fraction of Vehicles Exceeding Posted or Advisory Speed by:	**5 mph**	-69.9%	-29.6%	-23.8%	-1.1%	-48.6%	-44.0%	-74.1%	-19.3%
	10 mph	-84.5%	-53.8%	-66.7%	-6.3%	-66.7%	-67.3%	-93.7%	-22.9%
	15 mph	-79.2%	-69.2%	-100.0%	-28.1%	-60.0%	-54.5%	-97.9%	-12.5%*
	20 mph	-60.0%	-66.7%	0.0%*	-40.2%	0.0%	-50.0%	-100.0%	0.0%*

*Not statistically significant at 95-percent level of significance
C = Curve display sign
S = Speed display sign

Table 19. Summary of results for individual sites at the CC 24 months after sign installation (part 2).

Curve		IA-14	OH-6	OH-8	OH-14	OR-12	OR-9	TX-38
Sign Type		S	S	C	S	C	S	S
Road		IA 136	Alkire	Norton	Pontius	OR 126	OR 238	FM 481
Posted		50	55	55	55	55	55	65
Curve Advisory		45	30	35	30	40	30	50
Change in Mean Speed (mph)		-1.5	-3.9	2.0	-1.9	-2.1	-1.1	-1.0
Change in 85th Percentile Speed (mph)		-1	-4	2	-2	-1	-2	0
Percent Change in Fraction of Vehicles Exceeding Posted or Advisory Speed by:	**5 mph**	-9.2%	-19.0%	5.2%	-1.8%	-12.0%	-14.5%	-7.3%
	10 mph	-25.4%	-43.1%	18.5%	-13.6%	-28.5%	-36.5%	-21.9%
	15 mph	-44.8%	-63.6%	60.5%	-32.8%	-35.4%	-40.7%	-12.0%
	20 mph	-68.8%	-73.8%	110.5%	-40.2%	-40.3%	-50.0%	15.6%

C = Curve display sign
S = Speed display sign

Table 20. Summary of results for individual sites at the CC 24 months after sign installation (part 3).

Curve		TX-30	WA-15
Sign Type		C	C
Road		FM 359	US 101
Posted		70	50
Curve Advisory		none	40
Change in Mean Speed (mph)		-2.4	-1.6
Change in 85th Percentile Speed (mph)		-3	-1
Percent Change in Fraction of Vehicles Exceeding Posted or Advisory Speed by:	**5 mph**	-64.3%	-13.8%
	10 mph	-68.1%	-26.0%
	15 mph	-50.0%	-34.6%
	20 mph	-57.1%	-100.0%

C = curve display sign

The following figures show the distribution of results. Figure 9 shows the percent of sites experiencing changes in mean speeds of a certain magnitude. As indicated, the majority of sites had decreases in mean speeds from 1 to 4 mph.

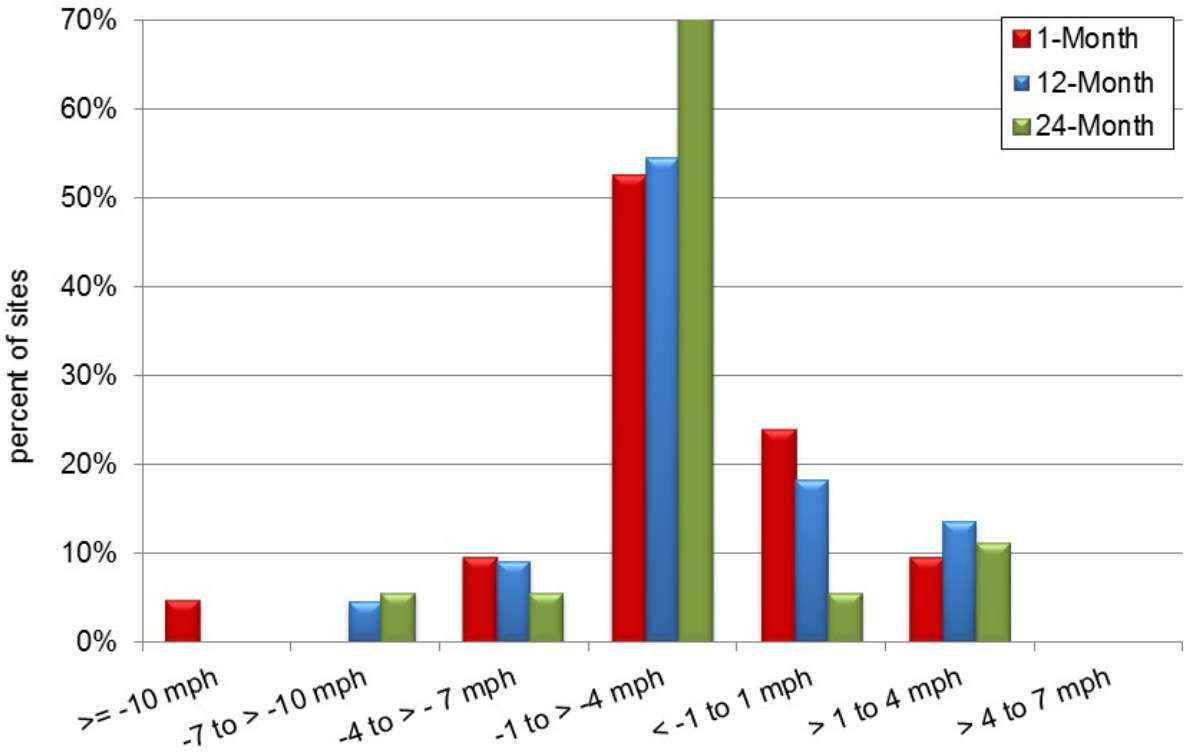


Figure 9. Chart. Percent of sites experiencing a change in mean speed of a certain magnitude at the CC.

At 1 month, 2 of the 21 sites (10 percent) had increases in mean speeds that were greater than 1 to 4 mph, 5 of the sites (24 percent) experienced virtually no change in mean speeds, and 11 sites (52 percent) experienced decreases of 1 to 4 mph. Finally, three sites (15 percent) had decreases of 4 mph or more.

Similar results occurred for the 12-month and 24-month after periods. At 12 and 24 months, about 14 percent of sites had increases between 1 and 4 mph. Eighteen percent of sites at 12 months and 6 percent at 24 months had little change.

The majority of sites (55 and 72 percent) had decreases in mean speeds from 1 to 4 mph. At 12 months, 9 percent and 6 percent of sites had decreases between 4 and 7 mph, respectively. About 5 percent of sites for both the 12- and 24-month after periods had decreases of more than 7 mph.

Figure 10 shows the changes in 85th percentile speeds at the CC at 1, 12, and 24 months. Overall, as indicated, the majority of sites for all after periods had decreases in mean speeds from 1 to 4 mph.

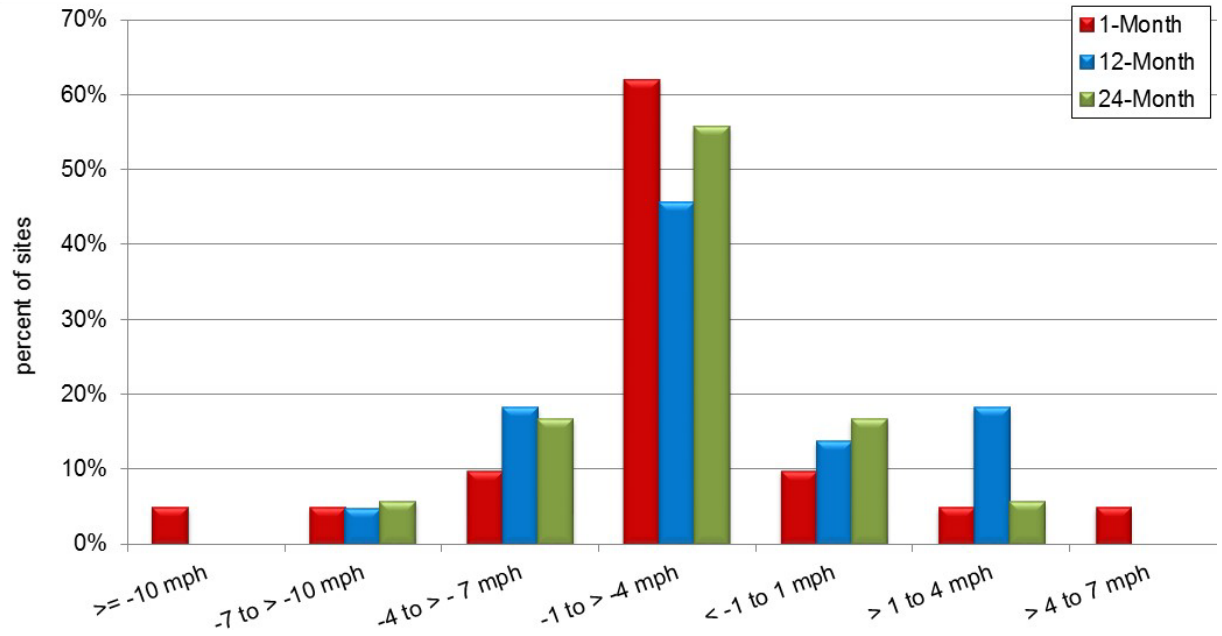


Figure 10. Chart. Percent of sites experiencing a change in 85th percentile speed of a certain magnitude at the CC.

At 1 and 24 months, two sites (about 10 percent) had increases that were more than 1 mph while four sites (18 percent) saw an increase at 12 months. Between 6 and 14 percent of sites experienced little change in 85th percentile speed depending on the after period.

Thirteen sites (62 percent) at 1 month, 10 sites (45 percent) at 12 months, and 10 sites (56 percent) at 24 months had decreases from 1 to 4 mph. Two sites (10 percent) at 1 month, four sites (18 percent) at 12 months, and three sites (17 percent) at 24 months had decreases from 4 to 7 mph. One site (about 5 percent) for each after period experienced a decrease from 7 to 10 mph,

and one site (5 percent) had an 85th percentile speed decrease that was more than 10 mph at 1 month after.

Percent of Vehicles Exceeding the Posted or Advisory Speed, by Speed Bin at the Center of Curve

Figure 11 through figure 14 show changes in the percent of vehicles traveling at 5, 10, 15, and 20 mph or more over the posted speed limit or advisory speed at the CC. Each figure shows the percent of sites that experienced a change within a particular range. Data are fairly consistent over the 1-, 12-, and 24-month after periods.

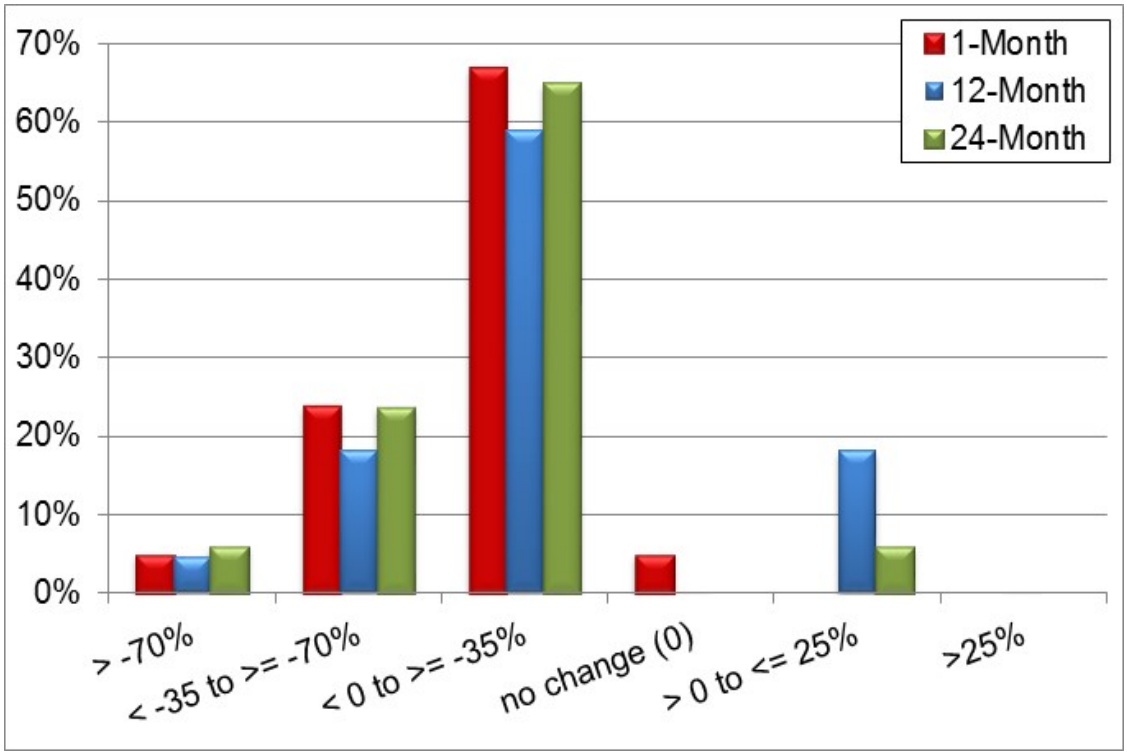


Figure 11. Chart. Changes in percent of vehicles traveling 5 or more mph over posted limit or advisory speed at the CC.

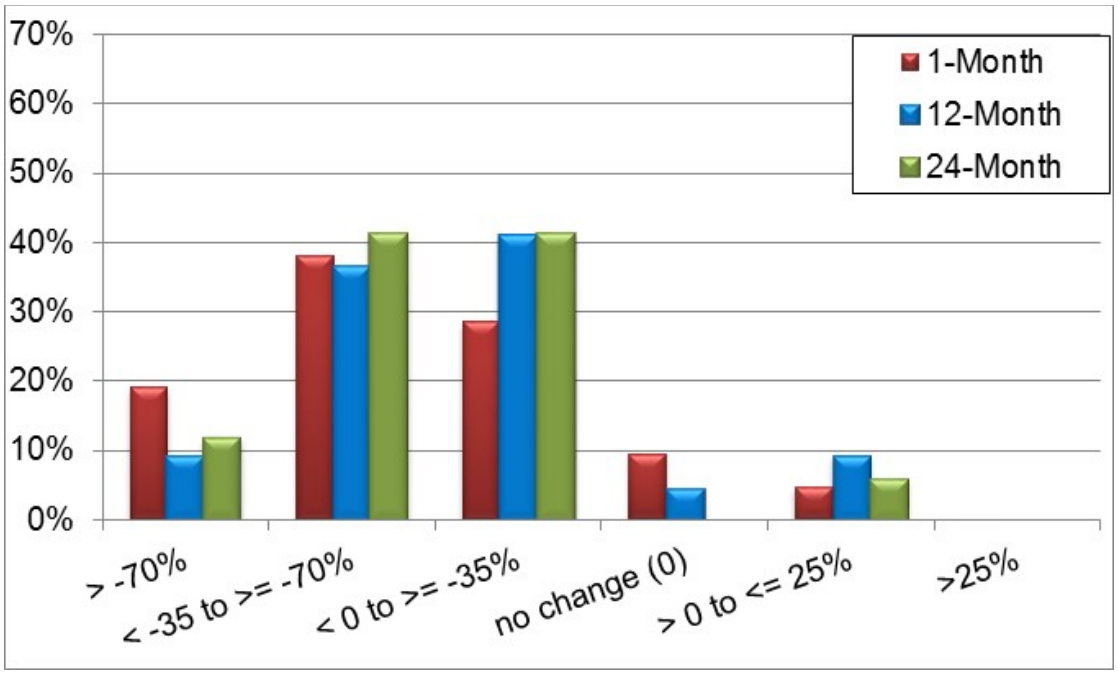


Figure 12. Chart. Changes in percent of vehicles traveling 10 or more mph over posted limit or advisory speed at the CC.

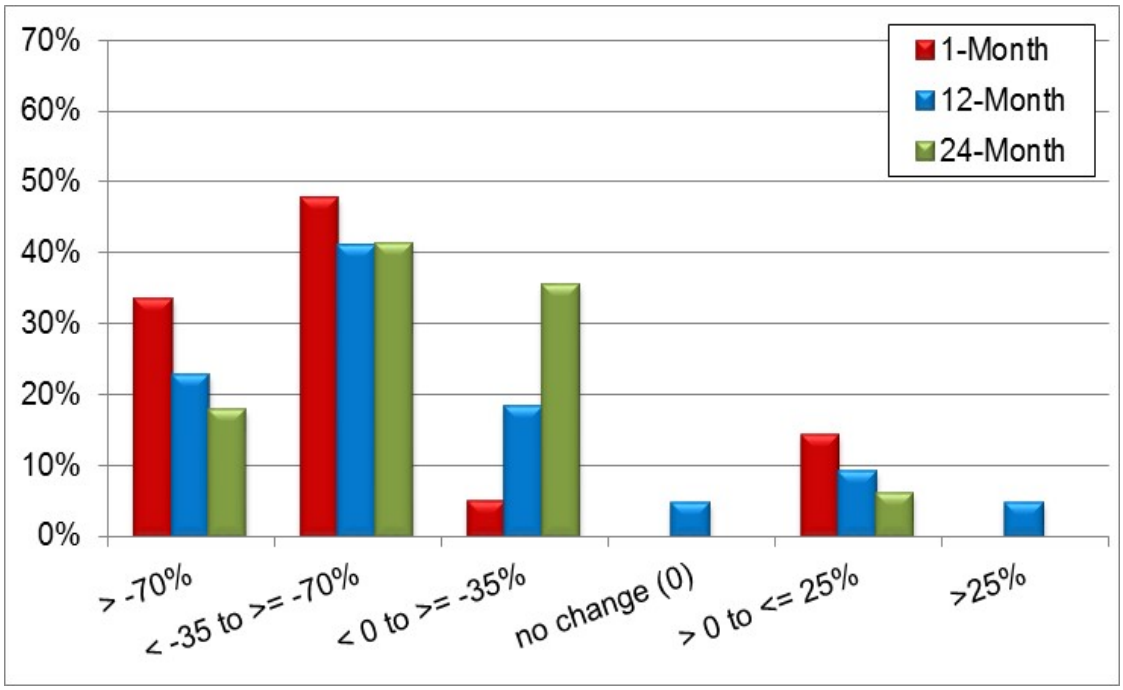


Figure 13. Chart. Changes in percent of vehicles traveling 15 or more mph over posted limit or advisory speed at the CC.

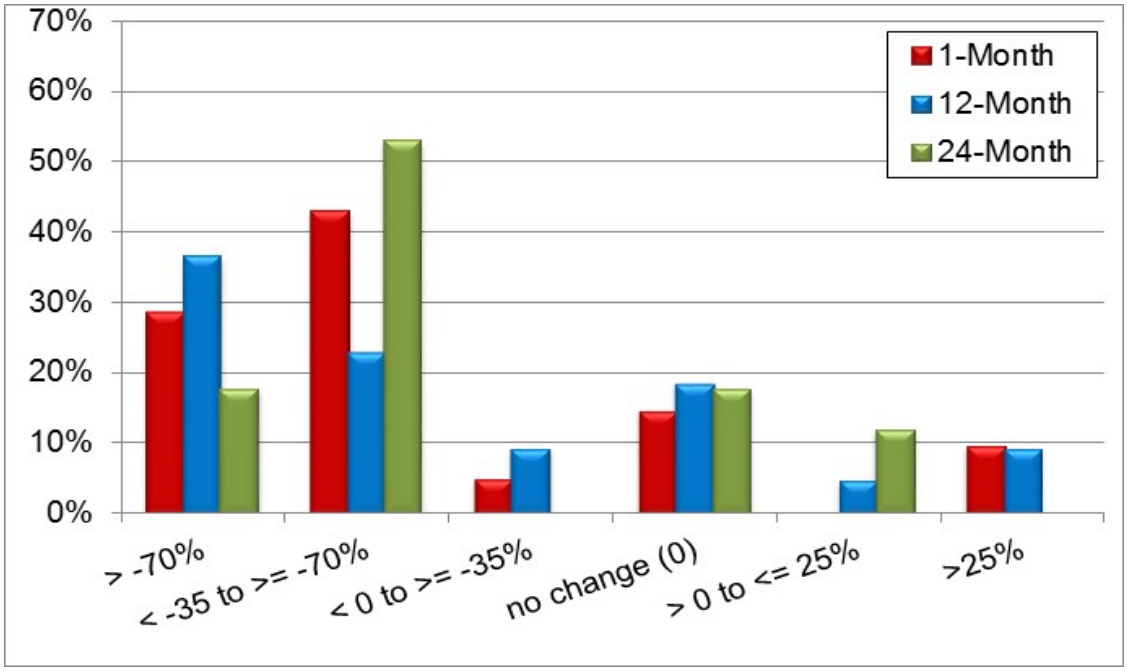


Figure 14. Chart. Changes in percent of vehicles traveling 20 or more mph over posted limit or advisory speed at the CC.

As shown, 18 and 6 percent of sites had increases in the fraction of vehicles traveling 5 mph or more over the posted or advisory speed at the 12- and 24-month after periods, respectively, and 5 percent had no change at the 1-month after period.

The majority of sites (67 percent for 1 month, 59 percent for 12 months, and 65 percent for 24 months) had decreases up to 35 percent in the fraction of vehicles traveling 5 mph or more over the posted or advisory speed. About 24 percent of sites had reductions between 35 and 70 percent, and about 5 percent had reductions of 70 percent or more.

Figure 12 provides results for the percent of vehicles traveling at 10 mph or more over the posted or advisory speed at the CC. Five to 9 percent of sites at 1 and 12 months, respectively, had increases up to 25 percent and 10 percent, and 5 percent of sites had no change for the 1- and 12-month after periods, respectively.

Most sites had reductions in the fraction of vehicles traveling 10 mph or more over the posted or advisory speed that were up to 35 percent or between 35 and 70 percent. About 29 percent of sites at 1 month and 41 percent at 12 and 24 months experienced reductions in the fraction of vehicles traveling 10 mph or more over the posted or advisory speed. Thirty-six to 41 percent of sites had reductions between 35 and 70 percent. Finally, about 20 percent of sites at 1 month, 9 percent at 12 months, and 12 percent at 24 months had reductions in the fraction of vehicles traveling 10 mph or more over the posted or advisory speed.

Figure 13 shows changes in the fraction of vehicles traveling 15 mph or more over the posted or advisory speed. Five percent of sites at 12 months had increases of more than 25 percent, and 5 percent had no change for that same time period. Between 6 and 14 percent of sites had increases of up to 25 percent. Five percent of sites at 1 month, 18 percent at 12 months, and

35 percent at 24 months had reductions up to 35 percent in the percent of vehicles traveling 15 mph or more over the posted or advisory speed.

The majority of sites (48 percent for 1 month and 41 percent for the 12- and 24-month after periods) had decreases from 35 to 70 percent. Eighteen to 33 percent had reductions of more than 70 percent in the fraction of vehicles traveling 15 mph or more over the posted or advisory speed.

Figure 14 shows results for the percent of vehicles exceeding the posted or advisory speed by 20 mph or more. One or two sites showed increases in the percent of vehicles exceeding the speed limit by 20 mph or more for the 1- and 12-month after periods, respectively. Two sites for the 24-month after period had increases from more than 1 to 10 percent. Five to nine sites (23 to 53 percent) had decreases from 35 to 70 percent.

As noted, large reductions in the number of vehicles traveling over the posted or advisory speed occurred for all of the after periods at the CC. The majority of sites had reductions up to 35 percent in the fraction of vehicles traveling 5 mph or more over the posted or advisory speed. The majority of sites had decreases up 70 percent in the fraction of vehicles traveling 10 mph or more over the posted or advisory speed. Most sites had reductions of 35 percent or more in the fraction of vehicles traveling 15 or 20 mph or more over the posted or advisory speed. These results indicate the signs were effective in reducing high-end speeds as well as average and 85th percentile speeds.

Comparison of Mean and 85th Percentile Speed Changes Over Time

Data were collected over a period of 2 years to assess whether regular drivers become habituated to the signs, which might lessen their effectiveness. Table 1 showed the average change in mean and 85th percentile speeds at the PC. The average change in mean speed at 1 month after was -1.82 mph, and the average changes (-2.57 and -1.97 mph) at 12 and 24 months were greater than at the 1-month after period. The average changes (-2.19 and -2.17 mph) in 85th percentile speeds at the PC were similar for the 1- and 24-month after periods, and the decrease (-2.86 mph) was greater at 12 months than at 1 month. These data anecdotally suggest that the signs remained effective over time.

To test that assumption, a Wilcoxon-signed rank test was used to test differences among the 1-, 12-, and 24-month after periods. The Wilcoxon-signed rank test is a non-parametric test and was used given the data were not normally distributed. The test compares the absolute value of the differences between observations, which are ranked from smallest to largest.

The individual changes in mean and 85th percentile speeds for sites at the PC were compared using the Wilcoxon-signed rank test. Results of the analysis indicated no statistically significant differences among changes in mean speeds at the PC for any of the time periods. The following shows the test statistics:

- 1 and 12 months ($p = 0.29$).
- 1 and 24 months ($p = 0.43$).
- 12 and 24 months ($p = 0.43$).

Similarly, no statistically significant differences in the change in 85th percentile speeds at the PC were noted with the following test statistics:

- 1 and 12 months ($p = 0.45$).
- 1 and 24 months ($p = 0.60$).
- 12 and 24 months ($p = 0.36$).

As shown in table 11, the average change in mean speed at 1, 12, and 24 months at the CC was -2.08, -1.65, and -1.76 mph, respectively. The average change in 85th percentile speed at the CC was -2.52, -1.55, and -1.89 mph for the 1-, 12-, and 24-month after periods, respectively. In both instances, the average decrease in speeds at the CC at 1 month after was slightly greater than for the 12- or 24-month after period.

To test whether the differences were statistically significant, the individual changes in mean and 85th percentile speeds for sites at the CC were compared using the Wilcoxon-signed rank test. As shown by the following test statistics, there were no statistically significant differences among changes in mean speeds across sites over the three after periods:

- 1 and 12 months ($p = 0.87$).
- 1 and 24 months ($p = 0.99$).
- 12 and 24 months ($p = 0.88$).

Results were similar for changes in 85th percentile speeds at the CC. As the following statistics show, there were no statistically significant differences in changes in 85th percentile speeds across sites:

- 1 and 12 months ($p = 0.53$).
- 1 and 24 months ($p = 0.50$).
- 12 and 24 months ($p = 0.98$).

As indicated, changes in mean and 85th percentile speeds appeared to be consistent across the three after periods. This suggests the signs may have a long-term impact on speed.

Summary of Results by Sign Type

Drivers may respond differently to different sign messages. In addition, different signs may be more effective in different situations. However, given only 22 sites were included in this project, testing a range of signs with different driver messages was beyond the project scope.

In addition, given the project intent was not to compare different sign types, the experiment was not designed for comparison. However, there was some value in evaluating the data by sign type to assess whether there was evidence of differences by sign type, which may lead to further research. As a result, data were disaggregated by sign type, and general comparisons were conducted.

As indicated, the experiment was not set up to test differences by sign type, and the sample size is low. Consequently, caution should be used in interpreting the results.

Figure 15 through figure 17 show the percent of sites that showed a change in average speed of a certain magnitude for each after period at the PC. Results are presented by type of sign (curve advisory versus speed sign).

At 1 month, about 10 percent of sites with both sign types had an increase of more than 1 mph in average speed. The majority of sites with curve signs (58 percent) had little change in average speed while 22 percent of sites with speed signs had little change. Seventeen percent of sites with curve signs had decreases of 1 to 4 mph, and another 17 percent had decreases of more than 4 percent, while 33 percent of sites with speed signs had decreases of 1 to 4 mph, and 33 percent had decreases of more than 4 mph.

At 12 months, 23 percent of sites with curve signs had little change in mean speed while 62 percent of sites with curve signs, and 78 percent of sites with speed signs had a decrease in average speeds between 1 and 4 mph. Fifteen percent of sites with curve signs and 22 percent of sites with speed signs had decreases of 4 mph or more.

Results for the 24-month after period are very similar to those for the 12-month after period.

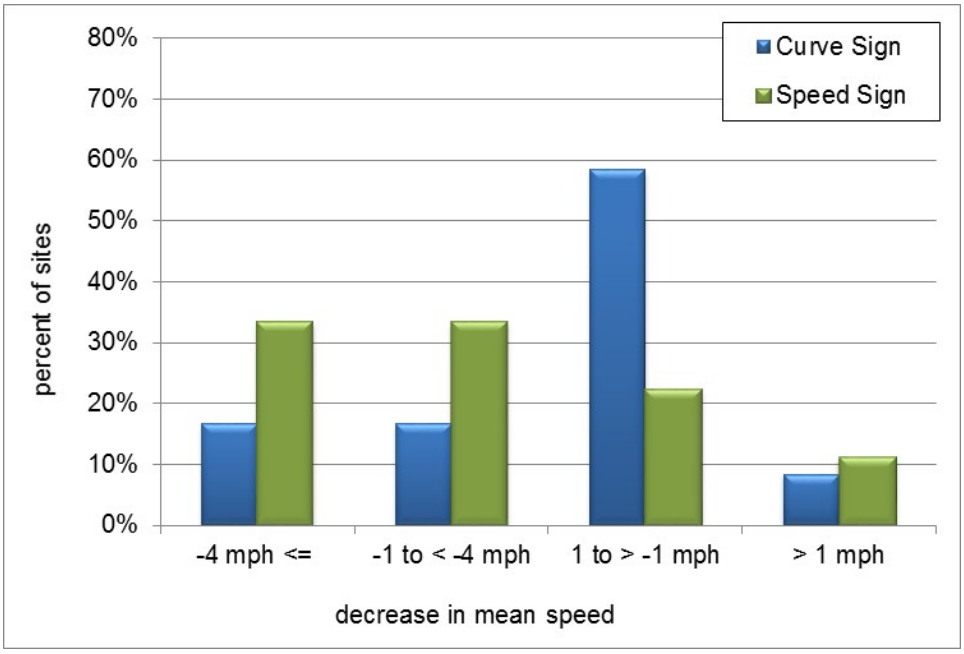


Figure 15. Chart. Changes in mean speed at the PC by sign type about 1 month after sign installation.

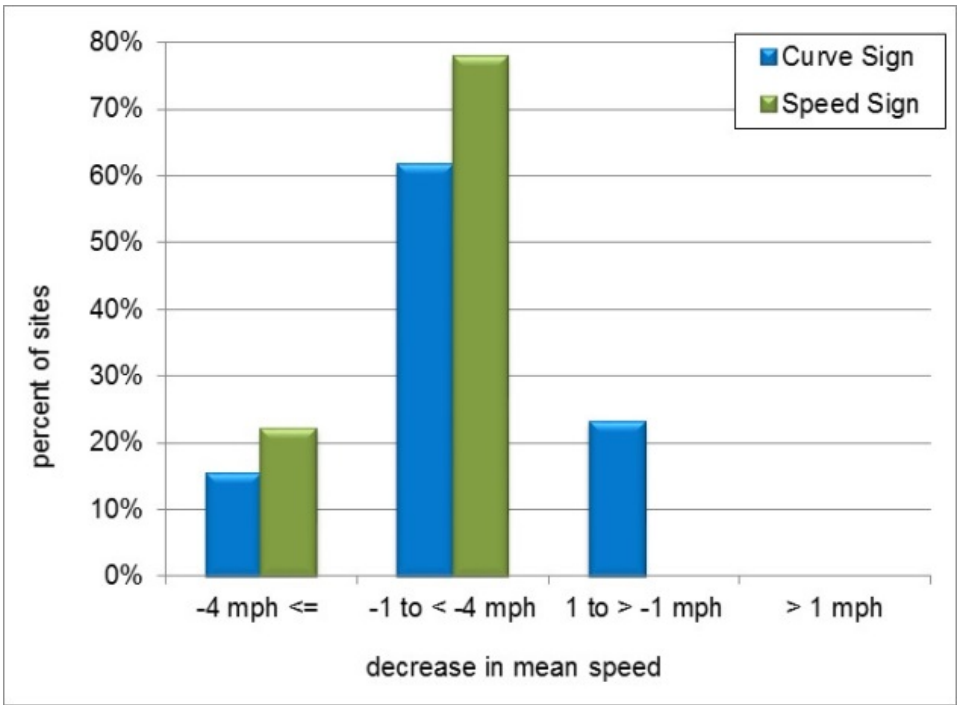


Figure 16. Chart. Changes in mean speed at the PC by sign type about 12 months after sign installation.

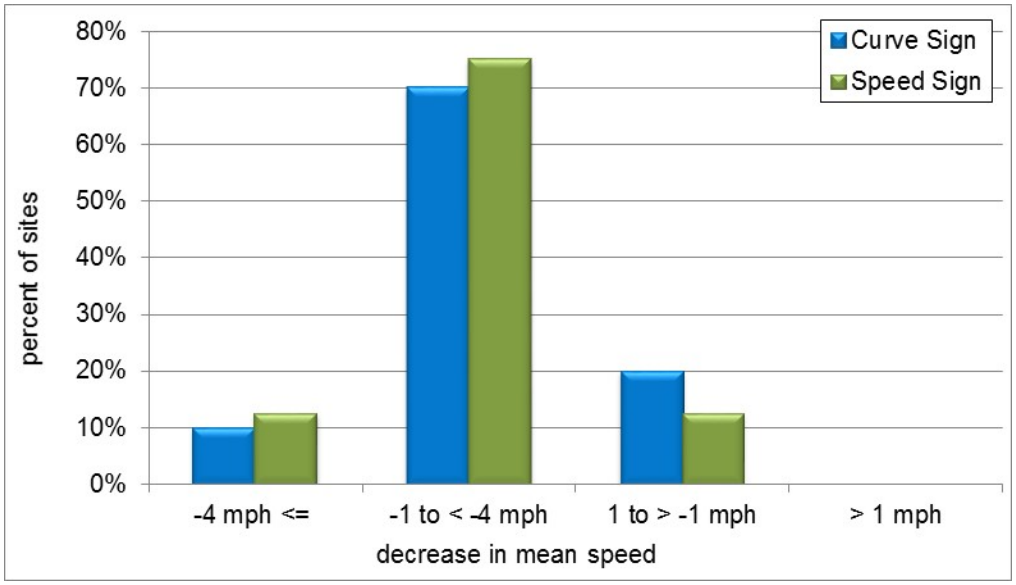


Figure 17. Chart. Changes in mean speed at the PC by sign type about 24 months after sign installation.

Figure 18 through figure 20 illustrate the percent of sites with changes in 85th percentile speed of a certain magnitude at each after period by sign type at the PC. Results are presented by sign type.

About 10 percent of sites for both sign types experienced an increase in 85th percentile speed of more than 1 mph. Approximately one-third of sites with curve signs experienced no change, while one-third of sites with both sign types had decreases between 1 and 4 mph. One-quarter of sites with curve signs and more than 50 percent of sites with speed signs had decreases of more than 4 mph.

About 31 percent of sites with a curve sign showed little change in 85th percentile speeds. The majority of sites with both types of signs (38 percent of sites with curve signs and 56 percent of sites with speed signs) had decreases in 85th percentile speeds between 1 and 4 mph. Thirty-one percent of sites with curve signs and 44 percent of sites with speed signs experienced decreases in 85th percentile speeds of 4 mph or more.

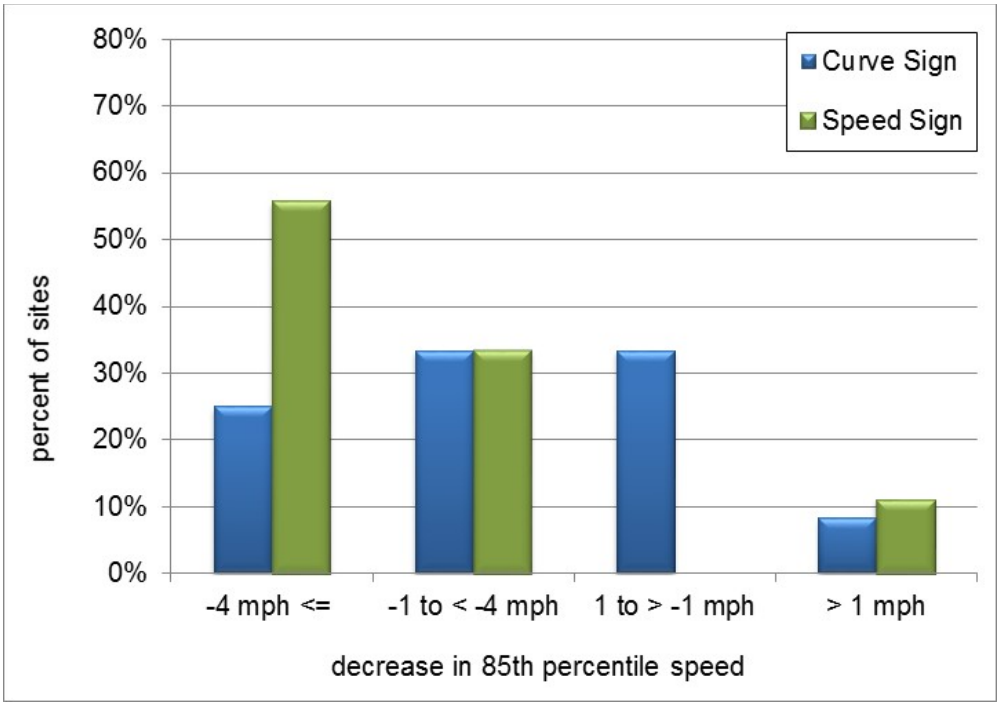


Figure 18. Chart. Changes in 85th percentile speed at the PC by sign type about 1 month after sign installation.

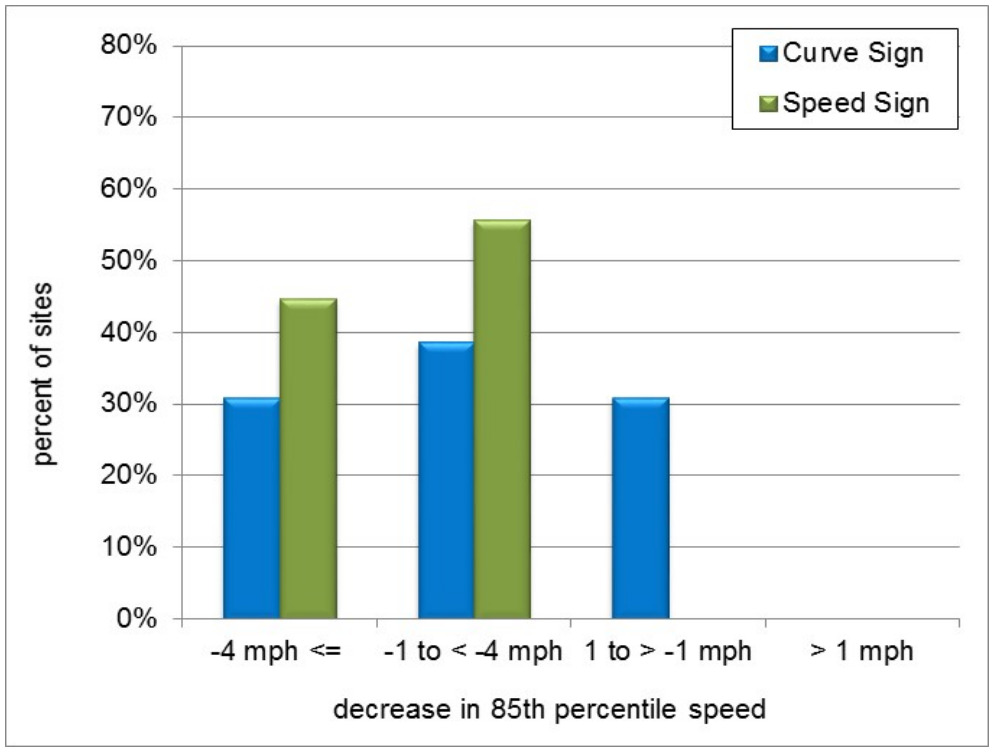


Figure 19. Chart. Changes in 85th percentile speed at the PC by sign type about 12months after sign installation.

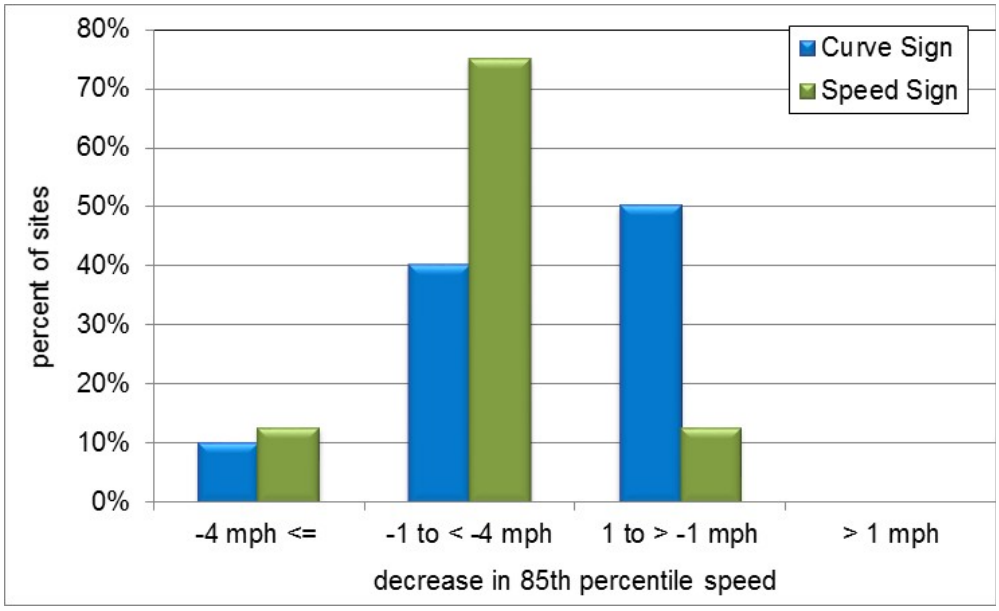


Figure 20. Chart. Changes in 85th percentile speed at the PC by sign type about 24 months after sign installation.

At 24 months, 50 percent of curve signs had little change in 85th percentile speeds while 13 percent of speed signs had no change. Forty percent of curve signs had decreases in 85th

percentile speeds that were 1 up to 4 mph, and 75 percent of speed signs saw the same decrease. Ten percent of curve signs and 13 percent of speed signs had decreases of 4 mph or more.

Sites with speed signs appeared to be slightly more effective based on the data shown in figure 9 and figure 10. To test that assumption, the researchers conducted a statistical test to evaluate differences between sign types for both average speed differences and differences in 85th percentile speeds.

The data were not normally distributed, so the Wilcoxon-signed rank test, a non-parametric test, was used. Results at 1 month showed no statistically significant difference in either average speed ($p = 0.39$) or 85th percentile speed ($p = 0.22$).

Similarly, results for 12 months showed no statistically significant difference in either average speed ($p = 0.20$) or 85th percentile speed ($p = 0.15$). Results for the 24-month after period were similar, with no statistical difference in mean ($p = 0.66$) or 85th percentile speeds (0.29). Consequently, at the PC, there was no evidence to suggest that one sign type was more effective than the other was.

Figure 21 through figure 23 show information for mean speeds at the CC by sign type for 1 month, 12 months, and 24 months after installation of the signs.

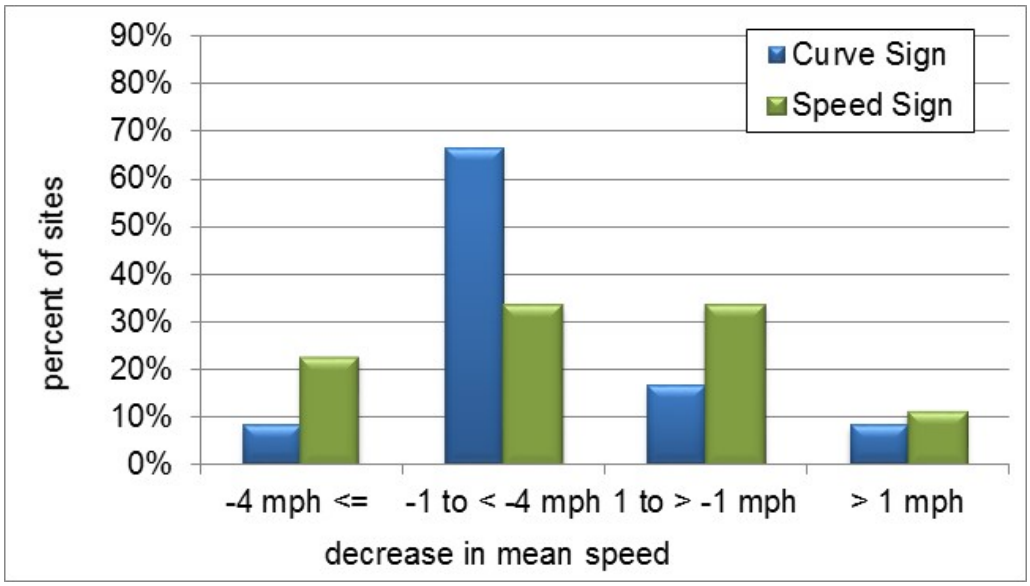


Figure 21. Chart. Changes in mean speed at the CC by sign type about 1 month after sign installation.

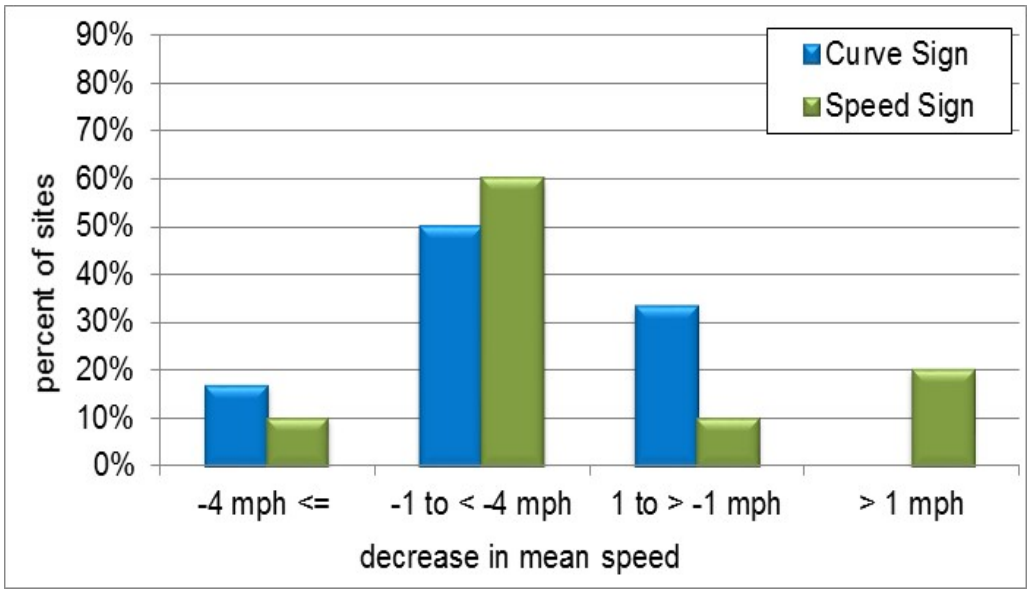


Figure 22. Chart. Changes in mean speed at the CC by sign type about 12 months after sign installation.

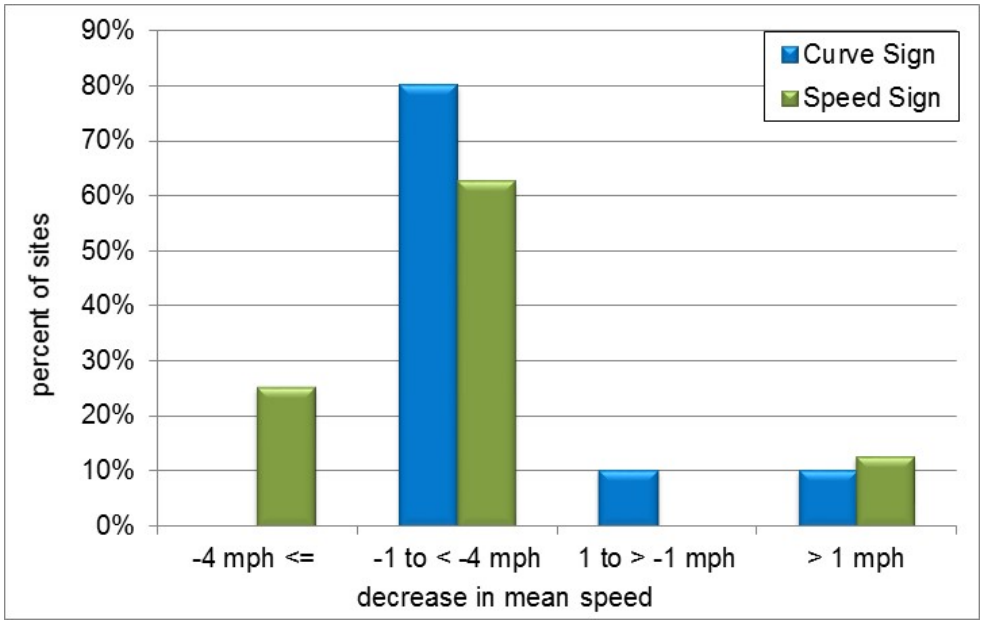


Figure 23. Chart. Changes in mean speed at the CC by sign type about 24 months after sign installation.

At 1 month, about 10 percent of both sites with curve and speed signs had increases of 1 mph or more while 17 percent of sites with curve signs and 33 percent of sites with speed signs had little change in mean speed (defined as changes between -1 and 1 mph). The majority of sites with curve signs (67 percent) and 33 percent of sites with speed signs had decreases from 1 to 4 mph. A small number of sites with curve signs (8 percent) and 22 percent of sites with speed signs had decreases in mean speed of 4 mph or more.

At 12 months, 20 percent of sites with speed signs had an increase in mean speed of 1 mph or more. Almost one-third of sites with curve signs and 10 percent of sites with speed signs had little change in mean speeds. The majority of sites for both the curve signs (50 percent) and speed signs (60 percent) experienced decreases in mean speeds between 1 and 4 mph while 17 percent of sites with curve signs and 10 percent of sites with speed signs had decreases of 4 mph or more.

As stated, figure 24 through figure 26 also show changes in mean speed by sign type for the 24-month after period. Both the curve and speed signs had increases of more than 1 mph in mean speeds while 10 percent of curve signs had little change in mean speeds. Eighty percent of curve signs and 63 percent of speed signs had decreases between 1 and 4 mph. One-quarter of the speed signs had decreases of 4 mph or more at the 24-month after period.

Differences in 85th percentile speeds between sign types for data collected at the CC are shown in figure 24 through figure 26 for 1, 12, and 24 months after installation of the signs.

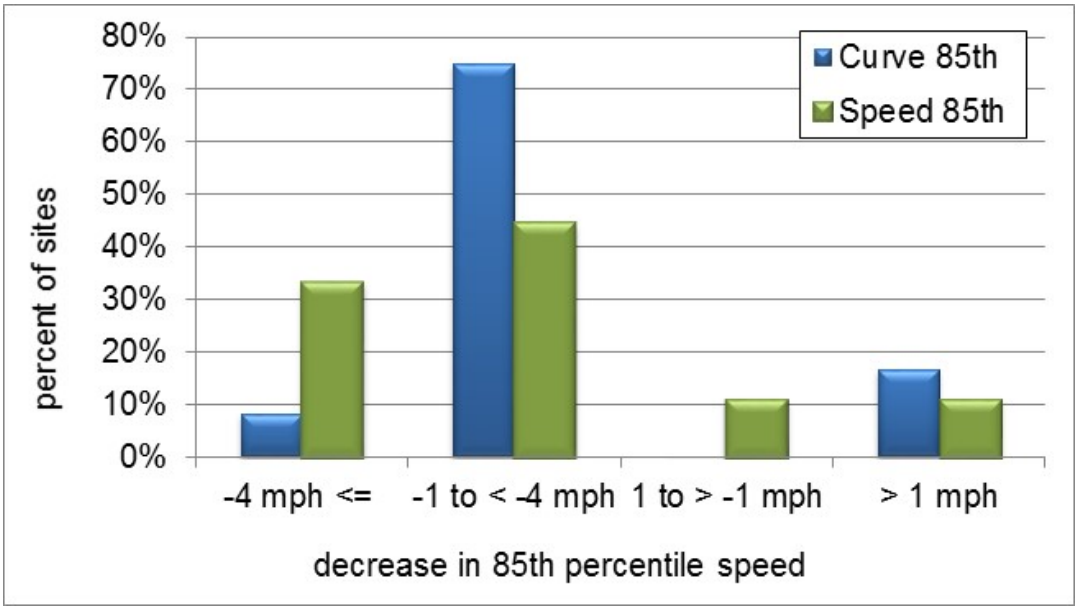


Figure 24. Chart. Changes in 85th percentile speed at the CC by sign type about 1 months after sign installation.

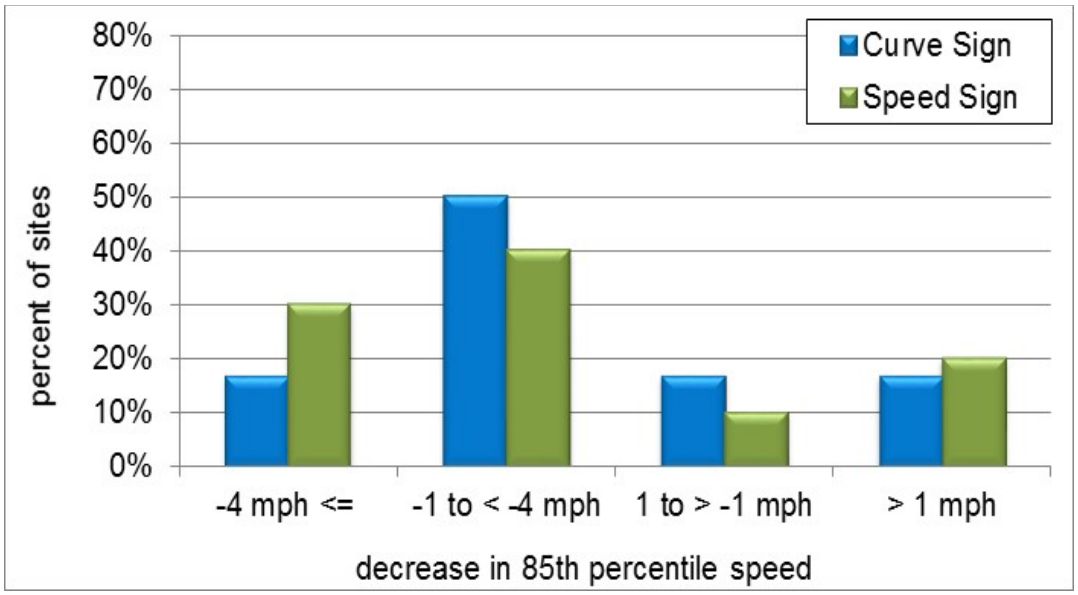


Figure 25. Chart. Changes in 85th percentile speed at the CC by sign type about 12 months after sign installation.

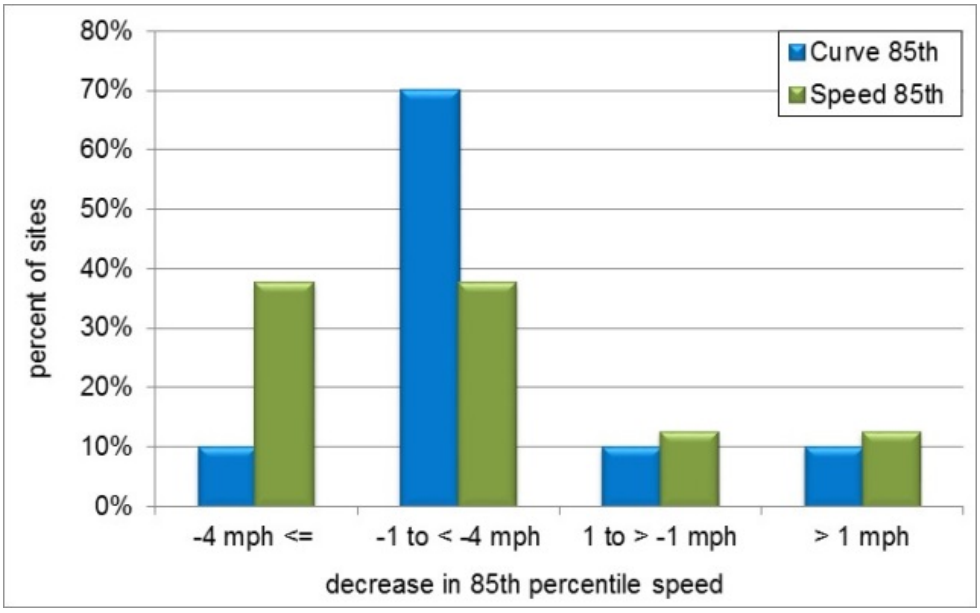


Figure 26. Chart. Changes in 85th percentile speed at the CC by sign type about 24 months after sign installation.

Seventeen percent of sites with curve signs and 11 percent of sites with speed signs at 1 month after had increases in 85th percentile speeds that were more than 1 mph. Another 11 percent of sites with speed signs had no change in 85th percentile speeds (defined as a change between -1 and 1 mph).

The majority of sites for both sign types (75 percent for curve signs and 44 percent for speed signs) had decreases in 85th percentile speeds between 1 and 4 mph. A small number of sites

with curve signs (8 percent) and 33 percent of sites with speed signs had decreases that were 4 mph or more.

Similarly, at 12 months, a similar number of sites (17 percent for curve sign sites and 20 percent for speed sign sites) had increases in 85th percentile speeds that were more than 1 mph while 17 percent of sites with curve signs and 10 percent of sites with speed signs experienced little change. The majority of sites (50 percent of curve signs and 40 percent of speed signs) also experienced decreases between 1 and 4 mph. Seventeen percent of sites with curve signs and 30 percent of sites with speed signs had decreases in 85th percentile speeds that were 4 mph or more.

Figure 26 also shows changes in 85th percentile speeds for the 24-month after period. About 10 percent of sites for both curve and speed signs had increases of more than 1 mph and no change. Eight percent of curve signs and 63 percent of speed signs had decreases of 1 to 4 mph, and 10 percent of curve signs and 38 percent of speed signs had decreases of more than 4 mph.

Similar to results at the PC, sites with speed signs appeared to be slightly more effective based on the information provided in figure 24 through figure 26. A Wilcoxon-signed rank test was also used to test differences between sign types for both average speed differences and differences in 85th percentile speeds.

Results for 1 month after showed no statistically significant difference in either average speed ($p = 0.64$) or 85th percentile speed ($p = 0.11$) by sign type. Similarly, results for 12 months after showed no statistically significant difference in either average speed ($p = 0.63$) or 85th percentile speed ($p = 0.35$). At 24 months, results showed no statistically significant difference ($p = 0.69$) in mean or 85th percentile speed ($p = 0.92$).

Results suggest there is no evidence of a difference in effectiveness between sign types at the CC. However, results should be used with caution given the small sample size.

SUMMARY OF CRASH ANALYSES

A crash analysis was conducted in addition to the speed analysis. Crash data were collected for up to 4 years before and up to 3 years after installation of the signs. To select treatment and control sites in early stages of the project, crash data were requested for 3 years before installation of the signs from the corresponding State or county agency for all sites except Iowa. The team had access to the Iowa crash data and was able to extract all of the necessary crash variables.

Once the signs had been installed for at least 2 years in States other than Iowa, the team contacted the corresponding State or county agency again and requested crash data for the intervening period from the original data request up to 2 years after installation of the signs. In some cases, more than 2 years had elapsed, and the agency provided more than 2 years of after data.

Data were evaluated for several different scenarios, including the following:

- Total crashes for both directions of travel.
- Total crashes by direction.
- Single-vehicle (SV) crashes for both directions of travel.
- SV crashes by direction.

Crashes were modeled in the direction of the DSFS sign given it was thought that the sign was most likely to reduce crashes for vehicles traveling in that direction. However, crashes for both directions were also modeled, given slowing vehicles in one direction may have some impact on vehicles in the opposite direction, particularly multivehicle crashes involving vehicles from both directions. Total crashes were modeled as well as single-vehicle crashes. Not all States had the same variables in their crash records so lane departure crashes could not be identified consistently. As a result, SV crashes were modeled, given they are overwhelmingly lane departures.

Crashes were modeled by quarter rather than by year because the after period was limited to about 2 years and use of quarters allowed the quarter in which installation occurred to be excluded from the analysis without having to exclude the entire installation year. In addition, the signs were not functioning at several sites for various periods, so the quarter in which the signs were nonfunctional could also be excluded from the analysis without discarding the entire year.

Two different analyses were conducted. A simple descriptive statistical analysis compared reductions in crashes from the before to after period for treatment versus control sites. Before and after data are compared for each site in chapter 7.

A summary of data aggregated by treatment and control site is provided in table 21. As shown, total crashes in both directions decreased by 0.08 crashes per quarter for the control site, while crashes per quarter at the treatment sites decreased by 0.22 (a 17-percent versus 40-percent reduction). SV crashes for both directions decreased by 0.07 crashes per quarter at the control site and by 0.21 at the treatment sites (a 19-percent versus 47-percent reduction). Decreases at treatment sites were 2.75 and 3.0 times greater than at control sites.

Total crashes in the direction of the outside of the curve increased by 0.02 crashes per quarter for control sites and decreased by 0.12 crashes per quarter in the direction of the sign for the treatment sites (an increase of 9 percent compared with a decrease of 35 percent). Similarly, SV crashes decreased by 0.01 crashes per quarter at the control sites compared with a decrease of 0.14 at treatment sites (a decrease of 4 percent compared with a decrease of 49 percent). Decreases at treatments sites were 6 to 14 times greater than at control sites.

Table 21. Decrease in crashes using simple descriptive statistics.

Site	Before (crashes/quarter)		After (crashes/quarter)		Change (crashes/quarter)	
	Total	SV	Total	SV	Total	SV
Crashes for both directions						
Control	0.48	0.38	0.40	0.31	-0.08 (-17%)	-0.07 (-19%)
Treatment	0.55	0.45	0.33	0.24	-0.22 (-40%)	-0.21 (-47%)
Crashes in direction of sign or outside of curve						
Control	0.28	0.22	0.30	0.22	0.02 (+9%)	-0.01 (-4%)
Treatment	0.35	0.29	0.23	0.15	-0.12 (-35%)	-0.14 (-49%)

SV = Single vehicle

Descriptive statistics are provided to indicate overall trends. Caution should be used in applying the results, given data were not normalized by season and more quarters of a particular season may have been present in the before period than the after period. However, results show a trend that a much greater decrease in crashes per quarter occurred for treatment sites compared with control sites.

A before-and-after analysis was also conducted using a Full Bayes Model to develop crash modification factors (CMF). Predictive models were developed using data from control sites for all periods and before data for treatment sites. The models accounted for season, repeated measures at the same site, and differences in the length of sites. The models were then used to calculate the number of crashes for the after period for treatment sites that would have been expected had no treatment been applied. CMFs were calculated by dividing the observed crashes by the predicted values. Table 22 shows results and 95-percent confidence intervals (CI).

Table 22. Results for calculation of crash modification factors for DSFS.

Crash Type	Direction Type	Observed Crashes	Estimated Crashes	CMF (STDE)	95-percent CI
Total	both	52.1	54.6	0.95 (0.01)	0.93, 0.97
Total	one	32.5	34.8	0.93 (0.02)	0.89, 0.97
Single-Vehicle	both	38.6	40.7	0.95 (0.01)	0.93, 0.97
Single-Vehicle	one	22.3	23.4	0.95 (0.02)	0.91, 0.99

CMF = Crash modification factor
STDE = Standard error
CI = Confidence interval

For total crashes in both directions, the CMF was 0.95. In other words, total crashes for both directions are expected to decrease by 5 percent with installation of the DSFS system, and the difference is statistically significant. Total crashes in the direction of the DSFS system are expected to decrease by 7 percent (CMF = 0.93), and the result is statistically significant.

SV crashes in both directions are expected to decrease by 5 percent, and SV crashes in the direction of the sign are also expected to decrease by 5 percent. Both changes are statistically significant. Results of both statistical analyses indicate that the DSFS systems are reasonably effective in reducing crashes.

CHAPTER 1. BACKGROUND

INTRODUCTION

The Federal Highway Administration (FHWA 2009) estimates that 58 percent of roadway fatalities are lane departures, while 40 percent of fatalities are single-vehicle (SV) run-off-road crashes. Addressing lane-departure crashes is therefore a priority for national, State, and local agencies. Horizontal curves are of particular interest because they have been correlated with overall increased crash occurrence. Curves have approximately three times the crash rate of tangent sections (Glennon et al. 1985).

Curve-related crashes have a number of causes, including roadway and driver factors. The frequency and severity of curve-related crashes have been correlated to roadway geometric curve factors, including radius, degree of curve, length of curve, type of curve transition, lane and shoulder widths, and preceding tangent length.

A primary driver factor is excessive speed. Factors that contribute to excessive speed include driver workload and distraction, fatigue, sight distance, misperception of the degree of roadway curvature, and situational complexity. The National Highway Traffic Safety Administration (NHTSA 2008) reports that approximately 31 percent of fatal crashes are speed related. A large number of run-off-road fatal crashes on curves are speed related.

The amount of speed reduction needed to traverse a curve has an impact on the frequency and severity of crashes on curves. Large differences between the posted speed limit and speed appropriate to negotiate the horizontal alignment has been suggested as a major cause of crashes on rural two-lane roadways (Luediger et al. 1988). Higher crash rates are experienced on horizontal curves that require greater speed reductions (Anderson et al. 1999).

Driver speed is a major factor in whether drivers will be able to negotiate a curve successfully. Dynamic speed feedback sign (DSFS) systems are one type of traffic control device that has been used to reduce vehicle speeds successfully and, subsequently, crashes, in applications such as traffic calming on urban roads. DSFS systems consist of a speed-measuring device, which may be loop detectors or radar, and a message sign that displays feedback to those drivers who exceed a predetermined speed threshold. The feedback may be the driver's actual speed, a message such as SLOW DOWN, or activation of some warning device, such as beacons or a curve warning sign.

To better understand the effectiveness of DSFS systems in reducing speeds on curves, the Center for Transportation Research and Education (CTRE) at Iowa State University conducted a national field evaluation of these systems on horizontal curves on rural two-lane roadways. The project was sponsored by the FHWA, the Midwest Transportation Consortium, the Iowa Department of Transportation (Iowa DOT), the Iowa Highway Research Board, and the Texas Department of Transportation. The Texas Transportation Institute and Portland State University were partners in the research.

Project Scope and Objectives

Project objectives included the following:

- Conduct a national demonstration project to evaluate DSFS systems in terms of speed and crash reduction on curves on two-lane rural roadways.
- Provide traffic safety engineers and other professionals with additional tools to manage speeds more effectively and decrease crashes on horizontal curves on rural roadways.

The project scope included the following:

- Select a group of geographically representative States to participate in the study.
- Select high-crash curve sites within participating States to serve as treatment and control sites.
- Select types of DSFS systems to be evaluated.
- Collect speed and volume data before and at regular periods after installation of the DSFS system at treatment sites.
- Compare the effectiveness of the DSFS system in reducing speed on curves at treatment sites.
- Conduct statistical analyses to compare the impact of the DSFS system on reducing crashes at using treatment and control sites.
- Report results.

Researchers selected seven States either during the Request for Proposals stage of the project or after the project commenced. A total of 22 DSFS systems were installed in the seven States over a 22-month period. This report presents a summary of how sites were selected, describes how DSFS system types were selected, describes the speed and volume data collection methodology, and presents final results of speed and crash analyses.

Background

This section provides information about the relationship between roadway geometry, vehicle speeds, and crashes on horizontal curves, and the effectiveness of various applications of DSFS systems installed to date.

Relationship Between Curve Crash Rate and Geometry

As previously mentioned, curves have about three times the crash rate of tangent sections (Glennon et al. 1985). Preston (2009) reported that 25 to 50 percent of severe road departure crashes in Minnesota occurred on curves, even though curves account for only 10 percent of the system mileage. Shankar et al. (1998) evaluated divided State highways without median barriers

in Washington State and found a relationship between the number of horizontal curves per kilometer and median crossover crashes. Farmer and Lund (2002) evaluated SV fatal and injury rollover crashes using Fatality Analysis Reporting System (FARS) data and data from Florida, Pennsylvania, and Texas. Using logistic regression, Farmer and Lund found that the odds of having a rollover on a curved section were 1.42 to 2.15 times that of having a rollover on a straight section.

The majority of crashes on curves involve lane departures. A total of 76 percent of curve-related fatal crashes are single vehicles leaving the roadway and striking a fixed object or overturning. Another 11 percent of curve-related crashes are head-on collisions (AASHTO 2008).

The frequency and severity of curve-related crashes have been correlated to a number of geometric factors, including radius, degree of curve, length of curve, type of curve transition, lane and shoulder widths, preceding tangent length, and required speed reduction.

Luediger et al. (1988) found that crash rates increased as the degree of curve increased, even when traffic warning devices were used to warn drivers of the curve. Miaou and Lum (1993) found that truck crash involvement increased as horizontal curvature increased, depending on the length of curve. Council (1998) found that the presence of spirals on horizontal curves reduced crash probability on level terrain but did not find the same effect for hilly or mountainous terrain. Vogt and Bared (1998) evaluated two-lane rural road segments in Minnesota and Washington State using Highway Safety Information System (HSIS) data and found a positive correlation between injury crashes and the degree of horizontal curve.

Zegeer et al. (1991) evaluated curves on two-lane roads in Washington State using a linear regression model. Researchers found that the degree of curve was positively correlated with crashes while total surface width and presence of spirals were negatively correlated. Zegeer et al. (1992) also evaluated 10,900 horizontal curves on two-lane roads in Washington State using a weighted linear regression model. They found that crash likelihood increased as the degree and length of curve increased. Mohamedshah et al. (1993), however, found a negative correlation between crashes and degree of curve for two-lane roadways.

Preston (2009) examined severe road departure crashes and found that 90 percent of fatal crashes and 75 percent of injury crashes occurred on curves with a radius of less than 1,500 ft. Milton and Mannering (1998) evaluated 4,386 km of highway in Washington State using a negative binomial model and reported that an increase in radius was associated with decreases in crash frequency. They also found that a shorter tangent length between horizontal curves was associated with decreases in crash frequency. They speculated that drivers might be traveling at lower speeds and were therefore more likely to be paying attention when tangent lengths between curves were short.

Alternatively, Deng et al. (2006) evaluated head-on crashes on 729 segments of two-lane roads in Connecticut using an ordered probit model. They included geometric characteristics in the analysis but did not find that the presence of horizontal or vertical curves was significant.

Taylor et al. (2002) evaluated the relationship between speed and crashes on rural single-carriageway roads in England. The authors collected data from 174 road sections with 60 mph

speed limits in a wide range of conditions. Data collected included injury crash data, traffic volume, speed data, and roadway geometry. Speed and flow were measured at each site for 1 or 2 days, and various speed metrics, including mean speed, 85th percentile speed, and standard deviation (SD) of speed, were calculated.

The authors found that crashes were more highly correlated with mean speed than any other speed metric. They also found that crash frequency increased with mean speed. In general, a 10-percent increase in mean speed resulted in a 26-percent increase in the frequency of injury crashes. Results indicated that total crashes increased by 13 percent with each additional curve per kilometer. SV crashes increased by 34 percent per additional sharp curve per kilometer.

Relationship Between Curve Crash Rate and Speed of Curve Negotiation

Although curve-related crashes are correlated to geometric factors, driver factors, such as speeding, also contribute to curve-crash frequency and outcome. Driver factors include driver workload, driver expectancy, and speeding.

Speeding, defined by FHWA as "exceeding the posted speed limit or driving too fast for conditions," in general is problematic. Council et al. (2005) evaluated FARS, General Estimates System, and HSIS data to assess the impact of speeding on fatal crashes. Using 2005 FARS data, they found that 29.5 percent of fatal crashes were speed related. They conducted several different types of analyses and found the SV run-off-road crashes were more likely to be speed related than multivehicle crashes. Crashes on curves were more likely to be speed related than tangent section and nighttime crashes. In addition, FARS data indicated that 54 percent of speed-related rollover/ overturn, jackknife, or fixed object crashes were on curves (Council et al. 2005).

Turner and Tate (2009) collected data for 488 curves on sections of State highways in New Zealand and found that speed was a contributing factor in 35 percent of fatal and 28 percent of serious crashes on rural roads in New Zealand (in 2003).

FHWA estimates that approximately 56 percent of run-off-road fatal crashes on curves are speed related. The vehicle speed reduction from the tangent section required for traversing a curve has an impact on the frequency and severity of crashes in curves. Abrupt changes in operating speed resulting from changes in horizontal alignment are suggested to be a major cause of crashes on rural two-lane roadways (Luediger et al. 1988).

Anderson and Krammes (2000) developed a model comparing mean speed reduction and mean crash rate for 1,126 horizontal curves on rural two-lane roadways. They report that the relationship between mean crash rate and required speed reduction to negotiate the curve is roughly linear. This finding is also supported by Fink and Krammes (1995), who indicate that curves requiring no speed reduction did not have significantly different mean crash rates than their preceding roadway tangents.

Thompson and Perkins (1983) evaluated crash data for 3 years at 25 rural, isolated curves. They developed models using regression analysis and found that one of the strongest predictors was speed differential between posted and advisory speed.

Driver errors on horizontal curves are often due to the inappropriate selection of speed and the inability to maintain lane position. Drivers' speed selection at curves depends on both explicit attentional cues and implicit perceptual cues (Charlton 2007). A driver's speed prior to entering a curve has a significant effect on their ability to negotiate the curve successfully (Preston and Schoenecker 1999). Inappropriate speed selection and lane positioning can be a result of a driver failing to notice an upcoming curve or misperceiving the roadway curvature.

Driver workload plays an important role in driver speed maintenance. Distracting tasks, such as radio-tuning or cellular telephone conversations, can draw a driver's attention away from speed monitoring, detection of headway changes, lane keeping, and detection of potential hazards (Charlton 2007). Other factors include sight distance issues, fatigue, or complexity of the driving situation (Charlton and DePont 2007, Charlton 2007).

Preston and Schoenecker (1999) evaluated vehicle paths through a curve on a two-lane rural roadway as part of an evaluation of a dynamic curve message sign. The roadway had a posted speed limit of 55 mph and an annual average daily traffic (AADT) of 3,250 vehicles per day (vpd). The researchers collected data over a 4-day period and randomly selected and evaluated 589 vehicles. A total of 340 of the vehicles (58 percent) were traveling over 55 mph, and the rest were traveling at or below the speed limit. The authors evaluated whether each vehicle successfully negotiated the curve. Vehicles that crossed a left or right lane line on one or more occasions were defined as "not successfully navigating the curve."

A logistic regression model was developed to determine the relationship between initial speed and the probability of a vehicle unsuccessfully navigating the curve. Researchers found there was a 20-percent better chance for vehicles that were traveling at or below the speed limit to navigate the curve successfully than for vehicles that were traveling over the speed limit, with the difference being statistically significant at 99 percent. They found that 45 percent of vehicles traveling at or above 65 mph were unable to negotiate the curve compared with 30 percent for vehicles that were traveling under 65 mph, with the difference being statistically significant at the 90-percent confidence interval (CI).

Turner and Tate (2009) evaluated driver behavior on six 20-km rural road sections with curves. Twelve male drivers, 17 to 24 years old, drove each section in a test vehicle with data logging equipment. The researchers found that the speed at which drivers chose to negotiate a curve was more closely related to the radius of the curve than the design speed. In general, radius did not begin to affect negotiation speed until curve radius was less than 300 m. They found that drivers did not lower their speeds from 100 km/h until the curve radius fell below 200 m to 300 m.

Hassan and Easa (2003) found that driver misperception of curvature was greatest when vertical curvature was combined with horizontal curvature. This was particularly a problem when a crest vertical curve was superimposed on a severe horizontal curve, or when a sag vertical curve was combined with a horizontal curve, causing the horizontal curve to appear less severe and resulting in drivers underestimating the curve.

Charlton (2007) conducted a simulator study and evaluated driver speed adjustments on several types of curves with several types of signage. Charlton found that, in general, drivers approached

and entered curves at higher speeds when engaged in cellular telephone tasks than in non-distraction scenarios.

Effectiveness of DSFS Systems

DSFS systems have been used in only a few cases to reduce speeds and warn drivers of upcoming curves. They have been used more extensively for a number of other related applications. A summary of information about application of DSFS systems on curves and in related situations is provided below.

Bertini et al. (2006) studied the effectiveness of a DSFS system on Interstate 5 near Myrtle Creek, OR. The system consisted of two displays that provided different messages to drivers based on the speed detected, as shown in table 23.

Table 23. Advisory messages for Interstate 5 dynamic speed-activated feedback sign system.

Sign Panel	Sign Messages		
	Detected Vehicle Speeds Less Than 50 mph	**Detected Vehicle Speeds 50–70 mph**	**Detected Vehicle Speeds Over 70 mph**
1	CAUTION	SLOW DOWN	SLOW DOWN
2	SHARP CURVES AHEAD	YOUR SPEED IS XX MPH	YOUR SPEED IS OVER 70 MPH

The curve has an advisory speed of 45 mph with an AADT of 16,750 vpd. Before the DSFS system was in place, there was what they termed “dual overhead horizontal alignment/advisory speed combination sign assemblies with four flashing beacons.” The DSFS system was put in place alongside one of the existing signs in both the northbound (NB) and southbound (SB) directions. Each system consisted of the actual dynamic message sign, a radar unit, a controller unit, and computer software. Figure 27 through figure 30 show the system.

Source: Oregon Department of Transportation. See Bertini et al. 2006.

Figure 27. Photo. Interstate 5 DSFS systems in Oregon (Northbound before).

Source: Oregon Department of Transportation. See Bertini et al. 2006.

Figure 28. Photo. Interstate 5 DSFS systems in Oregon (Northbound after).

Source: Oregon Department of Transportation. See Bertini et al. 2006.

Figure 29. Photo. Interstate 5 DSFS systems in Oregon (Southbound before).

Source: Oregon Department of Transportation. See Bertini et al. 2006.

Figure 30. Photo. Interstate 5 DSFS systems in Oregon (Southbound after).

Researchers collected speed data using a laser gun. Results indicated that, after installation of the DSFS system, passenger vehicle speeds were reduced by 2.6 mph and commercial truck speeds were reduced by 1.9 mph, with the results being statistically significant at the 95-percent confidence level. The distribution of speeds shifted to the left after installation of the signs, and the differences were found to be statistically significant based on a 95-percent confidence level using the chi-square test.

Results of a driver survey indicated that 95 percent of drivers surveyed noticed the DSFS system, and 76 percent said they slowed down because of the system.

Another type of DSFS system, a vehicle-activated curve warning sign, was tested on curves in the United Kingdom (Winnett and Wheeler 2002). Three curve warning signs were placed on two-lane roads in Norfolk, Wiltshire, and West Sussex. The signs, shown in figure 31, were placed 50 to 100 m before the apex of a curve.

Figure 31. Photo. DSFS in Norfolk, UK.

The signs were blank when the driver was under a specified speed threshold and displayed the curve sign when a driver exceeded the threshold. The speed threshold was set at the 50th percentile speed for the sign location because the researchers wanted to target the upper half of driver speeds. Once activated, the bend warning display was shown for 4 s. The researchers had calculated this time as sufficient for drivers to register and understand the message based on previous research.

Speed data were collected for a minimum of 7 days before the signs were installed, and again 1 month and 1 year after installation. Data were collected at the 1 year after point to determine whether habituation occurs (i.e., drivers become immune to treatments and stop responding). Data were collected using pneumatic tubes at two sites and a radar gun at the third site. Mean speeds were reduced by 2.1 mph at West Sussex, 3.0 mph at Wiltshire, and 6.9 mph at Norfolk.

Crash data were available for two sites, and the researchers found that crashes decreased 54 percent at the Norfolk bend site and 100 percent at the Wiltshire Bend site. A public survey found that drivers approved of the signs.

The City of Bellevue, WA, installed and evaluated 31 DSFS systems, including two used as curve advisory warnings (figure 32). Both were on urban arterials with 35 mph speed limits and 25 mph advisory speeds. Speeds were collected before and between 18 months and 2 years after installation of the signs. One sign showed a 3.3 mph reduction in 85th percentile speed, and the other showed a 3.5 mph reduction.

©City of Bellevue Transportation Department, 2009

Figure 32. Photo. DSFS in Bellevue, WA.

Preston and Schoenecker (1999) also evaluated the safety effect of a DSFS system on County Highway 54 in Minnesota, which is a two-lane rural roadway with a speed limit of 55 mph and an AADT of 3,250 vpd. The curve has an advisory speed of 40 mph. The DSFS system had a changeable message sign and radar unit. A field test was conducted over a 4-day period with a unit that consisted of a closed circuit television camera, a video cassette recorder, and a personal computer. A portable trailer housed the entire system.

The sign showed the following display:

- CURVE AHEAD (from 6 to 10 a.m., 11 a.m. to 2 p.m., and 4 to 7 p.m.).
- No message during other times of the day unless activated.

During all times of the day, when the radar unit detected a vehicle traveling 53 mph or more, the camera activated and recorded the vehicle for 18 s. Using a random number generator, the computer either continued displaying the message CURVE AHEAD or no message, depending on time of day, or displayed the message CURVE AHEAD—REDUCE SPEED.

The team randomly selected 589 of the vehicles captured during data collection and evaluated whether each vehicle successfully negotiated the curve. Successful negotiation was defined as a vehicle remaining within the lane lines as it traversed the curve. Vehicles that crossed a left or right lane line on one or more occasions were defined as "not successfully navigating the curve."

The team found that approximately 35 percent of the drivers who received the message were unable to negotiate the curve successfully. Vehicles that received the CURVE AHEAD sign were more likely to negotiate the curve successfully, but the difference was not statistically significant. Only 26 percent of vehicles that received the CURVE AHEAD—REDUCE SPEED

sign were unable to negotiate the curve successfully, and the difference was statistically significant at the 90-percent level of confidence.

Mattox et al. (2006) looked at the effectiveness of a DSFS system on secondary highways in South Carolina. This system consisted of a radar device and a 4 ft by 4 ft yellow sign with 6-inch lettering reading YOU ARE SPEEDING IF FLASHING. In addition, there were two 1 ft by 1 ft orange flags and a type B flashing beacon light. Teams collected data in a before-and-after study upstream of the sign, at the sign, and then downstream of the sign. Results showed a significant reduction in speed at the sign and downstream of the sign. Overall mean speed and 85th percentile speeds were reduced by approximately 3 mph.

A report by the California Department of Transportation (Caltrans) (2010) provided a summary of the effectiveness of safety treatments in one California district. A changeable message sign was installed at five locations along Interstate 5 to reduce truck collisions. Caltrans reported that truck crashes decreased from 71 to 91 percent at four of the sites, while truck crashes increased by 140 percent at the fifth site.

A study by the 3M Company evaluated driver speed back signs in the United Kingdom (updated 2006). Signs were tested at various locations in Doncaster, including semi-rural roadways. The signs displayed the approaching drivers' speed. The sites had speed limits of 40 mph, and reductions up to 7 mph in 85th percentile speeds were noted.

Tribbett et al. (2000) evaluated dynamic curve warning systems for advance notification of alignment changes and speed advisories at five sites in the Sacramento River Canyon on Interstate 5. The roadway has high traffic volumes (7,650 to 9,300 vpd), mountainous terrain, and a number of heavy vehicle crashes. The signs were a 10 ft by 7 ft full matrix light-emitting diode (LED) panel that could be programmed to display a variety of messages. Messages used by the researchers included curve warning (shown in figure 33) and driver speed feedback.

©Patrick McGowen. See Tribbett et al.

Figure 33. Photo. Speed warning sign in the Sacramento River Canyon.

The researchers collected speed data using stopwatches. Data were collected before installation of the signs and at several times after the signs were installed. However, the researchers did not indicate when these after periods were. Speed results at the point of curvature (PC) include the following:

- Site 1: Statistically significant decreases in mean truck speeds from 2.4 to 5.4 mph and decreases in mean passenger car speeds from 3.0 to 4.5 mph.

- Site 2: No statistically significant changes in truck or passenger car speeds for any time periods.

- Site 3: Statistically significant decreases in mean truck speeds from 1.9 to 3.7 mph and increases in passenger cars from 5.2 to 7.8 mph.

- Site 4: No statistically significant change in mean truck speed and a 1.4 mph decrease for passenger cars for one time period that was statistically significant.

- Site 5: Statistically significant change in mean truck speed of 4.5 mph for one time period and decrease in mean passenger car speeds from 2 to 3 mph.

The researchers also compared 5 years of crash data before installation of the signs and 6 months after. However, owing to the very short after period, the results were determined to be unreliable.

CHAPTER 2. SELECTION OF TREATMENT AND CRASH ANALYSIS CONTROL SITES FOR DSFS SYSTEMS

The intent of the project was to select sites in States that represented geographic diversity across the United States and that were willing to participate in DSFS system installation. Travel considerations were also important because the Iowa-based team made initial visits to potential sites plus subsequent data-collection trips to all selected sites in the participating States.

Seven States participated in this demonstration project: Arizona, Florida, Iowa, Ohio, Oregon, Texas, and Washington. As a result, DSFS systems were tested in the Northwest, Southwest, Midwest, and Southeast regions of the United States, but none were tested in the Northeast.

Each participating State was asked to identify high-crash curve sites and provide initial information about the sites. For the purposes of identifying initial sites, the definition of high-crash was left up to the discretion of each State or agency.

The team then narrowed the initial list to a set of potential sites. Additional information was obtained for the potential sites, and site visits were made to each State. After the site visits, the team selected a set of final treatment and crash analysis control sites in each participating State.

DSFS systems were installed at treatment sites. Control sites, without DSFS systems, were used to conduct crash analyses. The general methodology used to select sites in each State is described in the following sections.

INITIAL REVIEW

A request for initial data was made to each State. The States were requested to provide at least 20 high-crash curve sites on rural two-lane roadways. It was left to the discretion of each agency to determine what it thought were high-crash locations. Rural was defined as 1 or more miles outside an incorporated area. Each curve was required to meet the following criteria:

- No rehabilitation or reconstruction activities that change the geometry of the roadway scheduled during the 2-year project.
- No geometric or cross-section changes made for 3 years prior to the study.
- Posted speed limit on preceding tangent section 50 mph or greater.

Each State was also requested to provide the following information about the potential sites:

- Crash frequency.
- Traffic volume (AADT and percent trucks).
- Geometry (lane width, shoulder width, and type).
- Speed limit (posted/advisory).

Different amounts and levels of detail were provided by the various States. Washington, Oregon, Arizona, and Ohio provided potential sites. Florida, Texas, and Iowa provided roadway and

crash data, and the team selected potential sites. The team then followed up with all the States for additional information about the selected sites.

Once an initial list of high-crash curve sites for each State was obtained, the team located each of the curves using Google Earth™ or aerial images provided by the agency to determine whether there was anything about the site that made it inappropriate. A site was considered inappropriate and removed from further consideration if it was close to a major development, railroad, or major access points, including intersections other than low-volume intersections.

After the team removed inappropriate sites from the list, additional information about the remaining sites was requested from each State, if not already available. This included the following: 1) presence of posted speed advisory on curve, 2) information about crashes (speed-related, severity, etc.), 3) expert opinion about safety and speed problems, and 4) the existence of unusual traffic or other conditions.

Once this information was obtained, the team reviewed the list of potential sites. The sites were ranked in terms of number of crashes. A threshold was determined for each State to indicate what constituted high-crash locations. This varied from State to State because the number of years of crash data provided by each State was not consistent. In many cases, the crash information covered more than one curve, and this was taken into account. Sites with the number of crashes above the threshold were retained and included in the list for site visits.

SITE VISITS

Visits were then made to potential sites in each State. Information was recorded about each site, including layout, conditions, presence of speed and advisory speed signs, general conditions, as well as an indication of whether anything was unusual about the site. Images were also taken of various areas throughout the curve. Information about each site was recorded in a database.

Researchers conducted a preliminary radar gun speed study at each site to determine whether a speeding problem existed. The team collected data for both directions of traffic unless they were physically unable to collect data for one or both directions owing to adverse topography.

An attempt was made to collect at least 25 speed samples for each direction of traffic at each site. In several cases, a low number of vehicles were observed, and it was difficult for the team to remain at the site long enough to obtain this sample size. Mean speed, by direction, was calculated for all locations. When sample size was sufficient, 85th percentile speed was also calculated. A site was determined to have a speeding problem if at least one of the following conditions existed:

- Mean speed exceeded the advisory speed limit by 5 mph or more, or exceeded the posted speed limit by 5 mph or more if an advisory speed was not present.

- 85th percentile speed exceeded the advisory speed limit by 5 mph or more, or exceeded the posted speed limit by 5 mph or more if an advisory speed was not present.

SELECTION OF FINAL SITES

After the site visits, the team met and reviewed information about each site. Locations that did not have a speeding problem were removed from further consideration. If any other information from the site visit indicated the site was not feasible, it was also removed. This resulted in a final list of sites that were selected using similar criteria. At this point, sites had been selected without making any determination about whether the site would be a treatment or control site.

In most cases, treatment and control sites were quasi-randomly selected from the final list. It was determined that installation of the DSFS system would be challenging at a few sites so it was determined that it was more feasible to use these sites as control sites. For instance, at several sites, there was limited right-of-way to place the DSFS system. Several sites had sheer embankments that offered limited room to place a DSFS system, and several sites had significant drop-offs bordered by guardrail, which would have made data collection dangerous.

In several instances, curve sites were near each other. If one curve was selected as a treatment site and the team felt that placing a DSFS system at one curve would affect behavior on adjacent curves, the adjacent curves were dropped from the list and not used as either a treatment or control site.

Once final treatment sites were selected, one of the two different DSFS systems was randomly assigned. Table 24 lists treatment and control sites by State, and figure 34 through figure 40 show final locations of treatment and control sites. Control sites were selected for use in the crash analysis.

LOCATION OF DSFS SYSTEM AND SELECTION OF SIGN DIRECTION

Given only one DSFS system was available for each treatment site curve, it was necessary to determine in which direction of travel the system would be installed (i.e., eastbound (EB) versus westbound (WB)). If one direction had a higher percent of speed-related and/or single-vehicle run-off-road crashes than the other direction, the DSFS system was placed in this direction.

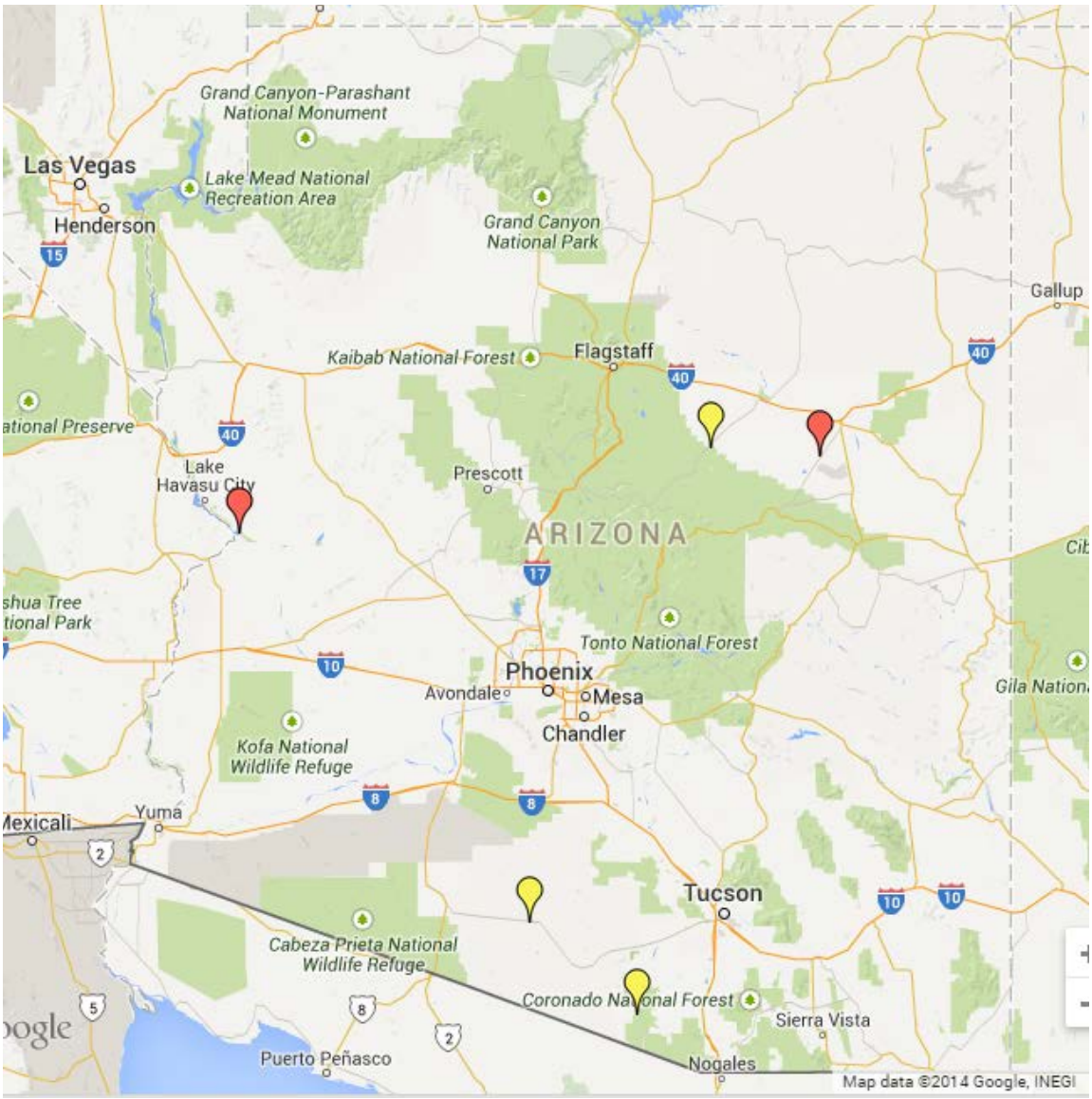
It should be noted that directional information was not available for a number of crashes. If no predominant crash direction was noted, the DSFS system was assigned to whichever direction of travel had the highest speeds based on the initial speed study. The DSFS systems were placed as close to the PC as possible. In all cases, the highest crash direction was the outside of the curve.

Table 24. List of final curve sites selected.

State	ID	Location	Posted Speed (mph)	Advisory Speed (mph)	ADT	Crashes/ year	Type
AZ	2	SR 95	45 NB/55 SB	none NB/45 SB	5,088	2.4	Treatment
	6	SR 377	65	none	1,715	1.4	Treatment
	11	SR 86	55	45	993	1.8	Control
	13	SR 286	55	45	1,357	1.6	Control
	21	SR 87	65	none	610	1.4	Control
FL	6	3 SR 267	55	none	4,300	2.6	Treatment
	8	3 SR 20	55	none	5,400	2.2	Treatment
	32	2 SR 20	55	45	8,100	1.0	Treatment
	4	2 SR 20	60	none	8,100	2.4	Control
	12	2 SR 121	60	none	6,400	1.6	Control
	19	3 SR 97	55	none	4,900	1.0	Control
	20	2 SR 121	60	none	5,400	1.8	Control
	28	3 SR 12	55	none	7,000	1.8	Control
IA	10	US 30	55	none	8,400	5.2	Treatment
	14	IA 136	50	45	1,450	1.2	Treatment
	31	US 67	55	none	3,610	1.2	Treatment
	33	US 69	55	50	1,880	1.0	Treatment
	11	US 6	55	50	3,960	4.2	Control
	15	IA 136	50	45	1,450	0.7	Control
	19	IA 150	55	none	2,160	1.5	Control
	26	IA 141	55	35	830	1.2	Control
	27	IA 76	55	none	2,450	1.2	Control
	1	US 20	55	none	6,200	2.3	Control
	6	E-49	55	40	790	1.0	Control
	11	US 6	55	50	3,960	3.5	Control
	12	US 6	55	none	3,330	2.7	Control
	19	IA 150	55	none	2,160	1.3	Control
	20	IA 150	55	none	2,180	1.3	Control
	27	IA 76	55	none	2,450	1.2	Control
	40	US 61	55	45	7,200	2.2	Control
	41	US 275	55	40	3,360	1.2	Control
	43	E-34	55	40	3,410	3.0	Control
	48	US 275	55	none	3,500	1.6	Control
	50	E-35	55	none	3,960	2.0	Control
	52	US 34	55	50	3,780	1.0	Control
	55	Old Hwy 141	50	40	1,350	1.0	Control
	56	US 52	55	none	3,200	2.5	Control
OH	6	Alkire Rd	55	30	2,403	1.7	Treatment
	8	Norton Rd	55	35	6,391	1.7	Treatment
	14	Pontius Rd	55	30	2,225	4.3	Treatment
	1	Walnut St	55	25	775	0.7	Control
	2	Elliott Rd	55	15	400	0.7	Control
	9	Lambert Rd	55	15	733	0.7	Control
	10	Lambert Rd	55	30	1205	0.7	Control
OR	4	US 101	55	45	2,600	2.8	Treatment
	5	OR 42	55	35	3,000	2.4	Treatment
	9	OR 238	55	30	2,900	2.2	Treatment
	12	OR 126	55	40	4,700	1.6	Treatment
	3	OR 38	55	35	3,700	0.8	Control
	6	US 199	55	45	7,700	3.2	Control

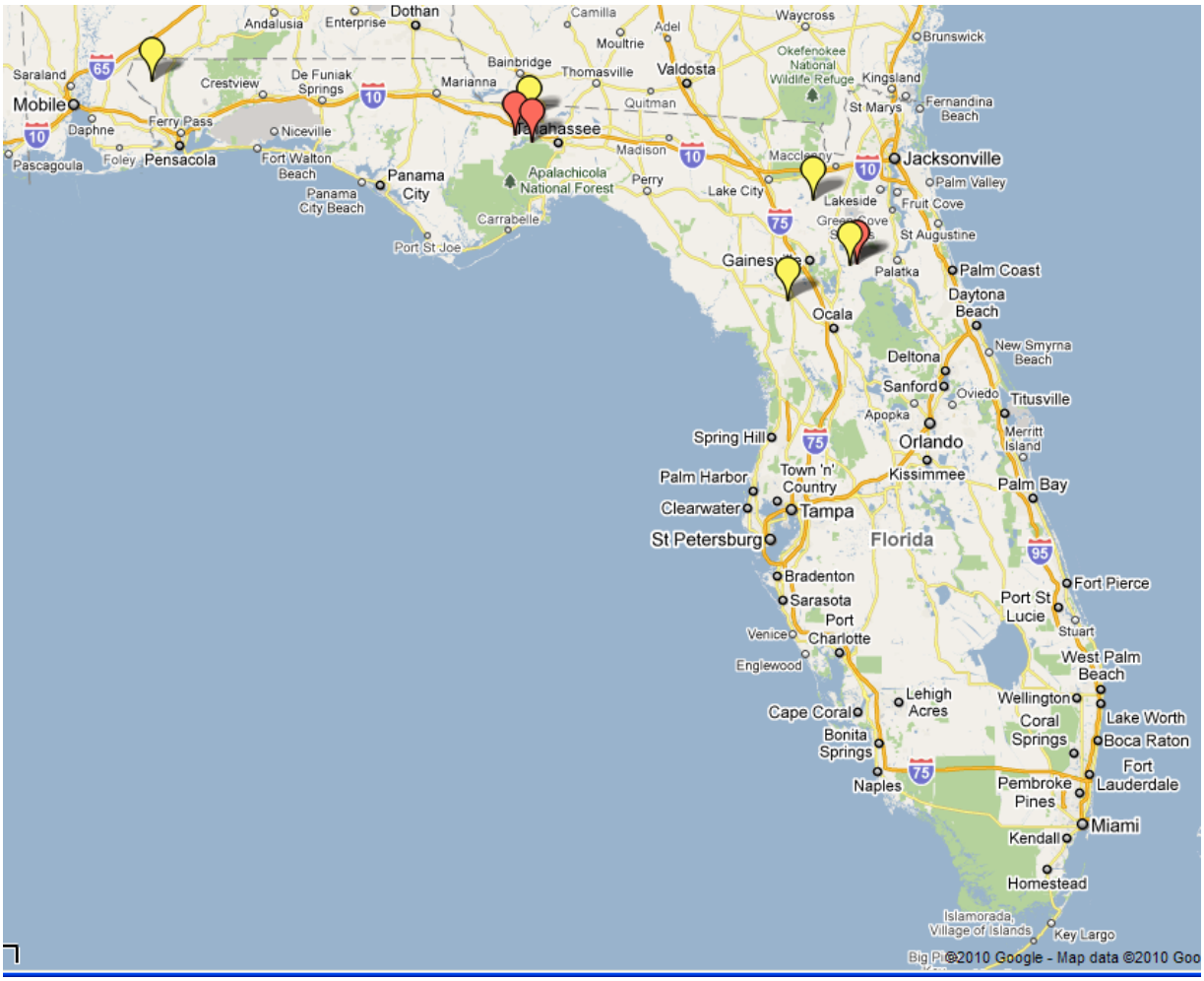
State	ID	Location	Posted Speed (mph)	Advisory Speed (mph)	ADT	Crashes/ year	Type
	7	US 199	55	40	7,700	3.4	Control
	8	OR 138	55	30	750	1.0	Control
	10	US 20	55	30	2,400	1.8	Control
TX	4	FM 755	65 Truck 60 day Truck 55 night	50	970	2.0	Treatment
	30	SH 359	70 Truck 70 day Truck 65 night	none	3,490	1.3	Treatment
	38	FM 481	65 Truck 60 day Truck 55 night	50	890	1.3	Treatment
	39	US 90	70	none	3,160	1.3	Treatment
	2	FM 88	60	none	4,330	1.0	Control
	7	FM 755	65 Truck 60 day Truck 55 night	none	980	1.3	Control
	10	FM 490	65 Truck 60	none	1,800	0.7	Control
	12	FM 800	55	50	1,560	1.7	Control
	33	US 83	75 day 65 night Truck 70 day Truck 65 night	none	4,020	1.3	Control
	34	US 90	70 day 65 night	none	3,500	0.7	Control
WA	15	US 101	50	40	3,778	3.5*	Treatment
	18	SR 7	50	40 NB/35 SB	1,976	3.3	Treatment
	17	SR 510	50	40 WB	7,070	2.8	Control
	1	US 97	60	40 NB	5,200	4.8*	Control
	4	US 2	60	50	4,400	4.8*	Control
Average for All Sites					**3,428**	**1.9**	
Average for Treatment Sites					**3,565**	**2.2**	
Average for Crash Control Sites					**3,362**	**1.8**	

*Crashes were over several curves
ADT = Average daily traffic
NB = Northbound
SB = Southbound



Original image: ©2014 Google®; map annotations provided by CTRE. See reference Google 2014a.
Red markers indicate curve test sites.
Yellow markers indicate curve control sites.

Figure 34. Map. Location of treatment and crash analysis control sites in Arizona.

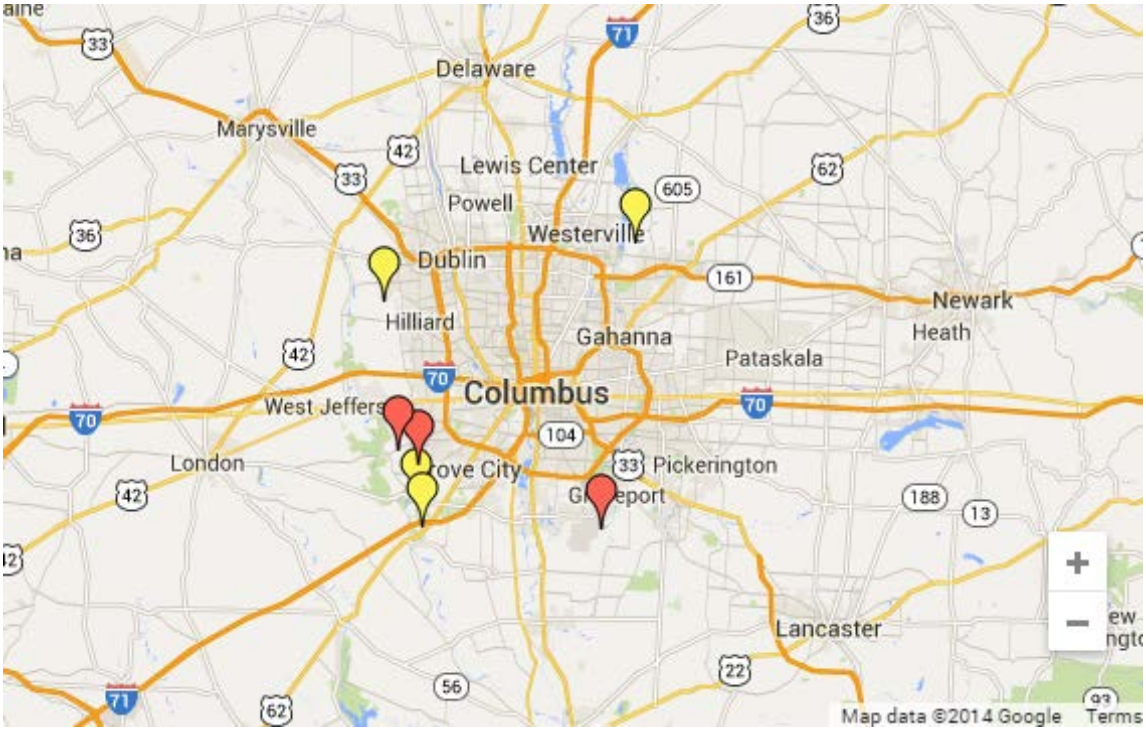


Original image: ©2014 Google®; map annotations provided by CTRE. See reference Google 2014b.
Red markers indicate curve test sites.
Yellow markers indicate curve control sites.

Figure 35. Map. Location of treatment and crash analysis control sites in Florida.

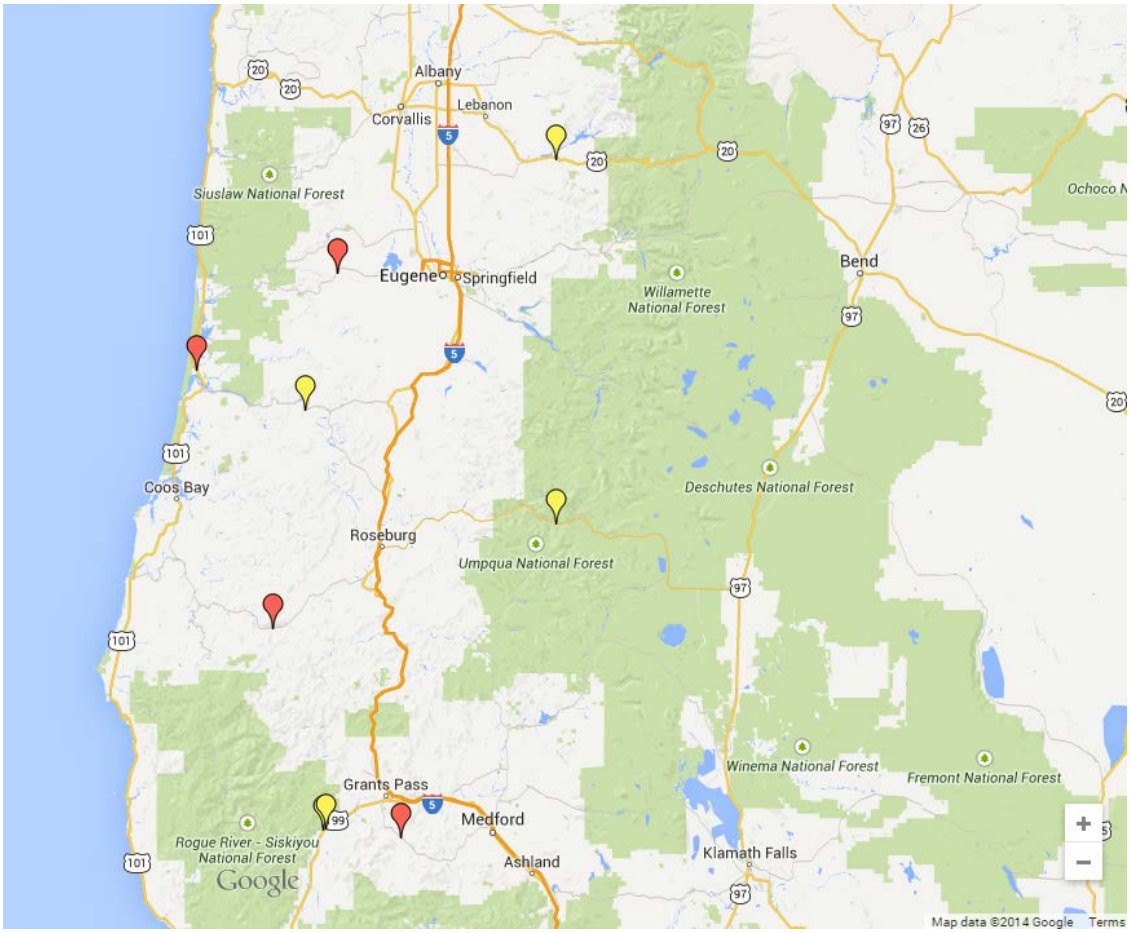
Original image: ©2014 Google®; map annotations provided by CTRE. See reference Google 2014c.
Red markers indicate curve test sites.
Yellow markers indicate curve control sites.

Figure 36. Map. Location of treatment and crash analysis control sites in Iowa.



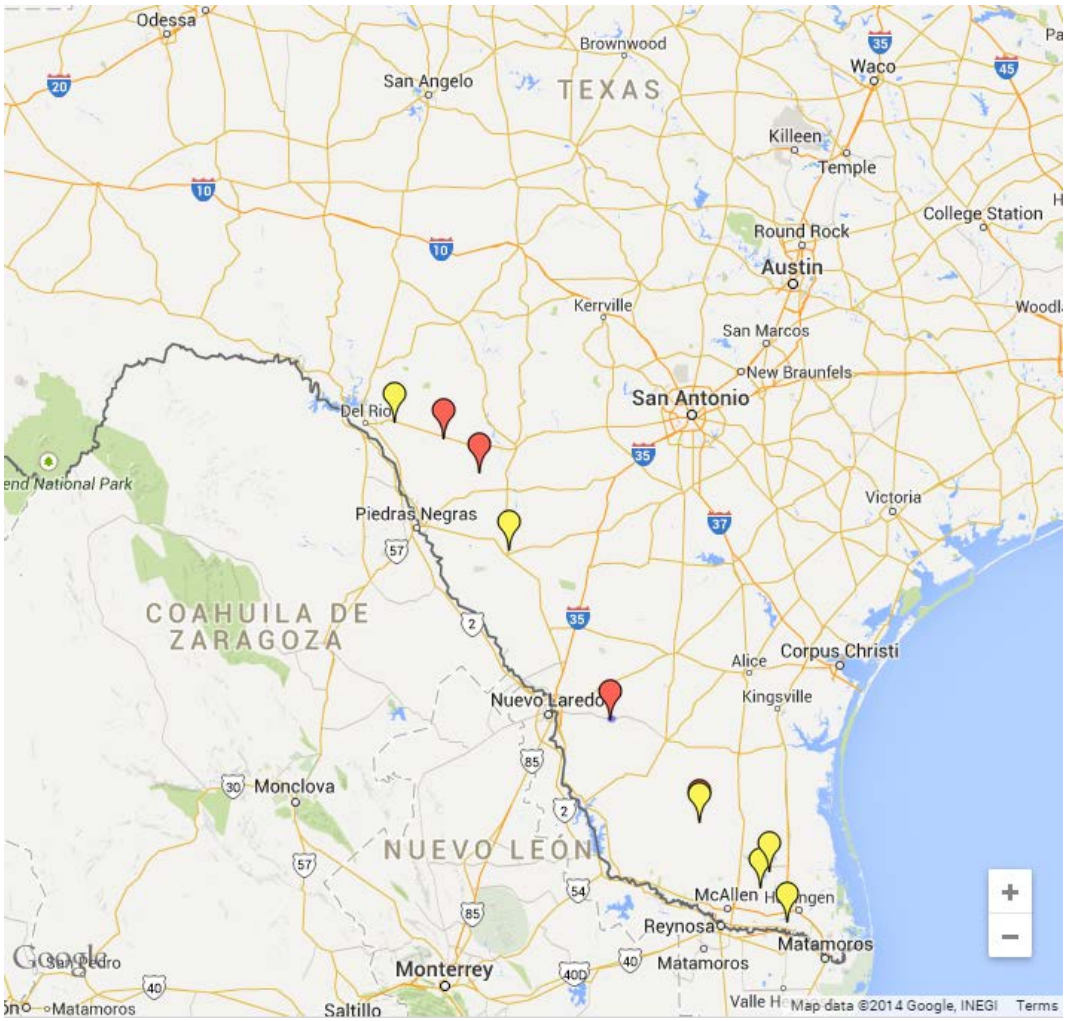
Original image: ©2014 Google®; map annotations provided by CTRE. See reference Google 2014d.
Red markers indicate curve test sites.
Yellow markers indicate curve control sites.

Figure 37. Map. Location of treatment and crash analysis control sites in Franklin County, OH.



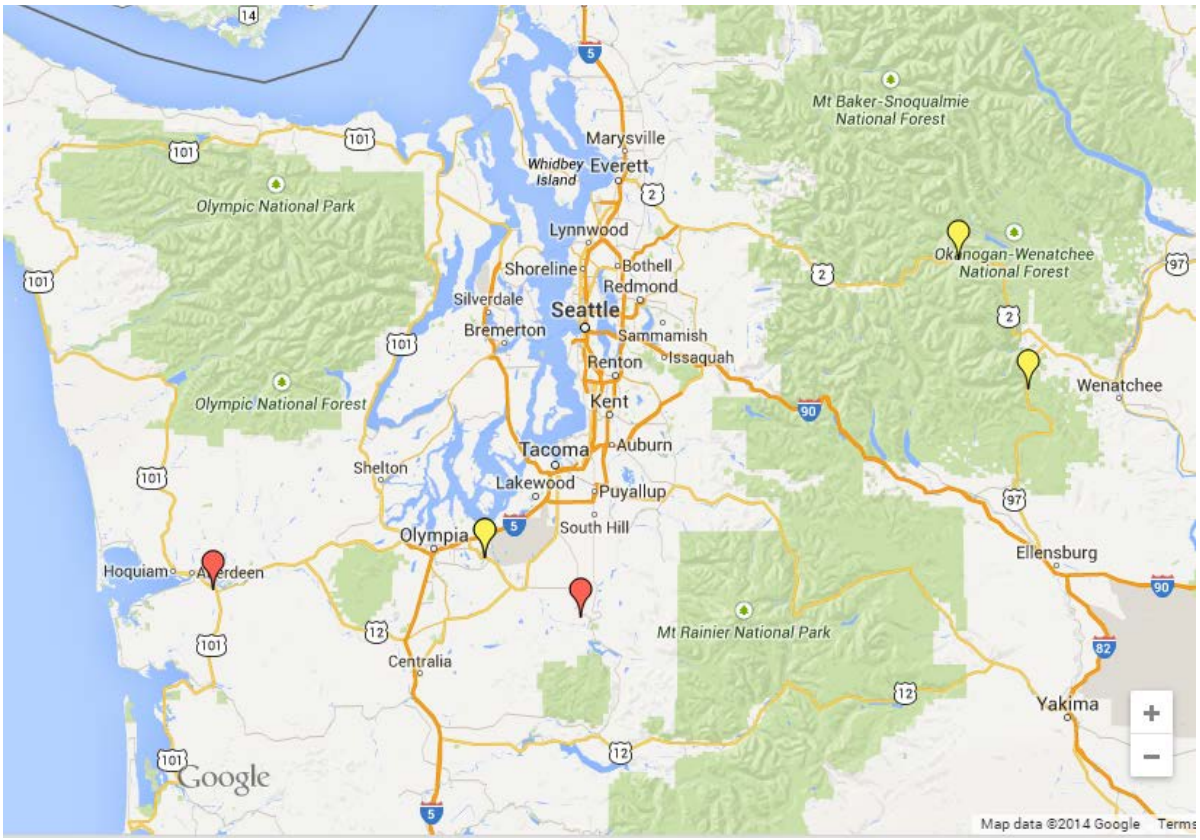
Original image: ©2014 Google®; map annotations provided by CTRE. See reference Google 2014e.
Red markers indicate curve test sites.
Yellow markers indicate curve control sites.

Figure 38. Map. Location of treatment and crash analysis control sites in Oregon.



Original image: ©2014 Google®; map annotations provided by CTRE. See reference Google 2014f.
Red markers indicate curve test sites.
Yellow markers indicate curve control sites.

Figure 39. Map. Location of treatment and crash analysis control sites in Texas.



Original image: ©2014 Google®; map annotations provided by CTRE. See reference Google 2014g.
Red markers indicate curve test sites.
Yellow markers indicate curve control sites.

Figure 40. Map. Location of treatment and crash analysis control sites in Washington.

CHAPTER 3. SELECTION OF DSFS SYSTEMS, SPEED THRESHOLDS, AND SIGN PLACEMENT

DSFS systems consist of a speed-measuring device, which may include loop detectors or radar, and a message sign, which provides feedback to drivers who are exceeding a set speed threshold. The feedback may be the driver's actual speed, another message such as SLOW DOWN, or activation of warning devices such as beacons or a curve warning sign. The sign is dynamic in the sense that it interacts with each vehicle based on that vehicle's speed.

In addition to the methods used to select the DSFS system for a given site, this chapter also discusses the selection of speed thresholds and sign placement.

DSFS SYSTEM SELECTION

While it would have been possible to create a DSFS system specifically for this project, for practical reasons it was decided to select and use one or more of the many commercially available DSFS systems. The team researched DSFS systems through the Internet, displays at conferences, and existing contacts.

When selecting DSFS systems, the team focused on the type of feedback provided by the variable message sign; therefore, this chapter generally refers to sign selection rather than DSFS system selection. The most common variable message sign simply displays a vehicle's speed when it is exceeding a set threshold. The sign can also activate a flashing beacon when the speed threshold is exceeded. Several signs can also display a static message. Common messages include SLOW DOWN or TOO FAST. More complex signs allow programming of a message, with the message being limited only by the number of alphanumeric characters that can be displayed on the sign.

To select final DSFS systems, the research team developed a set of minimum criteria:

- Can be permanently mounted on a standard wood or metal pole.
- Can display a warning and/or a simple message (e.g., XX mph, TOO FAST, etc.).
- Is durable enough to survive the 2-year study period and perform in different climates.
- Has self-contained power (e.g., alternating current or solar).
- Costs less than $10,000 per sign (including installation, support, and maintenance).
- Meets all applicable *Manual on Uniform Traffic Control Devices* (MUTCD) requirements or can be approved by MUTCD.
- Provides repeatable and accurate speed measurements.
- Projects a clear, bright, non-glare, easily readable message to motorists.

Other desirable characteristics included the following:

- Acceptable sign performance (based on references).
- Sufficient quantity of signs deployed to determine sign performance.
- Ability to store and transmit data.
- Reasonable installation and mounting requirements for proper operation and viewing.
- Programmable display by calendar or remote input.
- Ease of maintenance.

After this list of required and desirable characteristics was prepared, the research team contacted vendors for specifications, application guidelines, and costs. The information provided was used to develop a matrix that ranked signs by required or desirable criteria.

Signs that met the minimum criteria were categorized by the sign message type. No DSFS systems were identified that had only a flashing beacon. Figure 41 shows signs that were categorized into one of four categories.

Figure 41. Photo. Types of dynamic speed-activated feedback signs.

The various sign categories had the capability to present a number of message types. In some cases, several vendors were available for a specific sign category, and for some categories a single vendor was available.

All signs in Category 1 display a static SPEED LIMIT with the vehicle speed (XX). Category 2 can display a static YOUR SPEED and then either the speed (XX) or SLOW DOWN. Category 3 can display the same messages as categories 1 and 2 with the added function of being able to display YOUR SPEED and SPEED LIMIT dynamically, rather than statically, as well as the ability to display TOO FAST. Category 4 signs can display the same messages as categories 1, 2, and 3, but can also be programmed to display any alphanumeric message that fits within two lines and has five or fewer characters per line. Category 4 can display a curve warning symbol with the text SLOW DOWN or TOO FAST.

One or several messages could be combined to create a particular message type. A number of different message types were available depending on the sign category. Given the range of messages that could be displayed by the four categories of signs, a large number of message types could be considered. Category 4 signs can display virtually any message that has one or

two lines of text each with five characters or fewer. The team decided to use message types that had been considered in other studies or used terminology that would be familiar to drivers. The team determined that the following messages fit that description and considered message types that were combinations of the following messages:

- YOUR SPEED XX.
- SPEED LIMIT XX.
- SLOW DOWN.
- TOO FAST.
- SLOW CURVE.
- CURVE SLOW.
- CURVE AHEAD.
- Curve warning symbol plus SLOW DOWN.
- Curve warning symbol plus TOO FAST.

Because several message types were available, the team debated whether to test only one message type, such as SPEED LIMIT XX followed by SLOW DOWN, or whether to test several message types. Message types would be assigned to an equal number of signs. So if four message types were selected, about five sites would have been assigned each message type.

The main advantage of having a single message type is sample size for both the speed and crash evaluation. Only 20 to 24 signs were to be installed, so each message type selected would decrease the available number of samples. Multiple message types would increase the number of factors that had to be considered in the crash analysis and would decrease the number of available samples within each sign message cohort. As a result, having too many messages would affect the ability to detect whether the signs were effective overall and whether a particular message was effective.

The main disadvantage to having a single message type is that if it proved not to be effective, it would be difficult to determine whether DSFS systems on curves in general are ineffective or whether the particular message type was ineffective.

The main advantage of testing two or more message types is that it would be possible to determine whether a particular message was more effective than others and would reduce the probability that study results were influenced by selection of the wrong message type. Another advantage is that one message type might not be appropriate for every situation. The main disadvantage of multiple message types is the decrease in sample size, as described in the previous paragraph.

The team carefully considered the available message types and the advantages and disadvantages of having several sign message types. It was decided that two message types would overcome the disadvantages of having only one message but would maximize sample size.

The first message type selected was the dynamic display of YOUR SPEED XX or SPEED LIMIT XX, with the message determined by the speed threshold. Figure 42 illustrates message type 1.

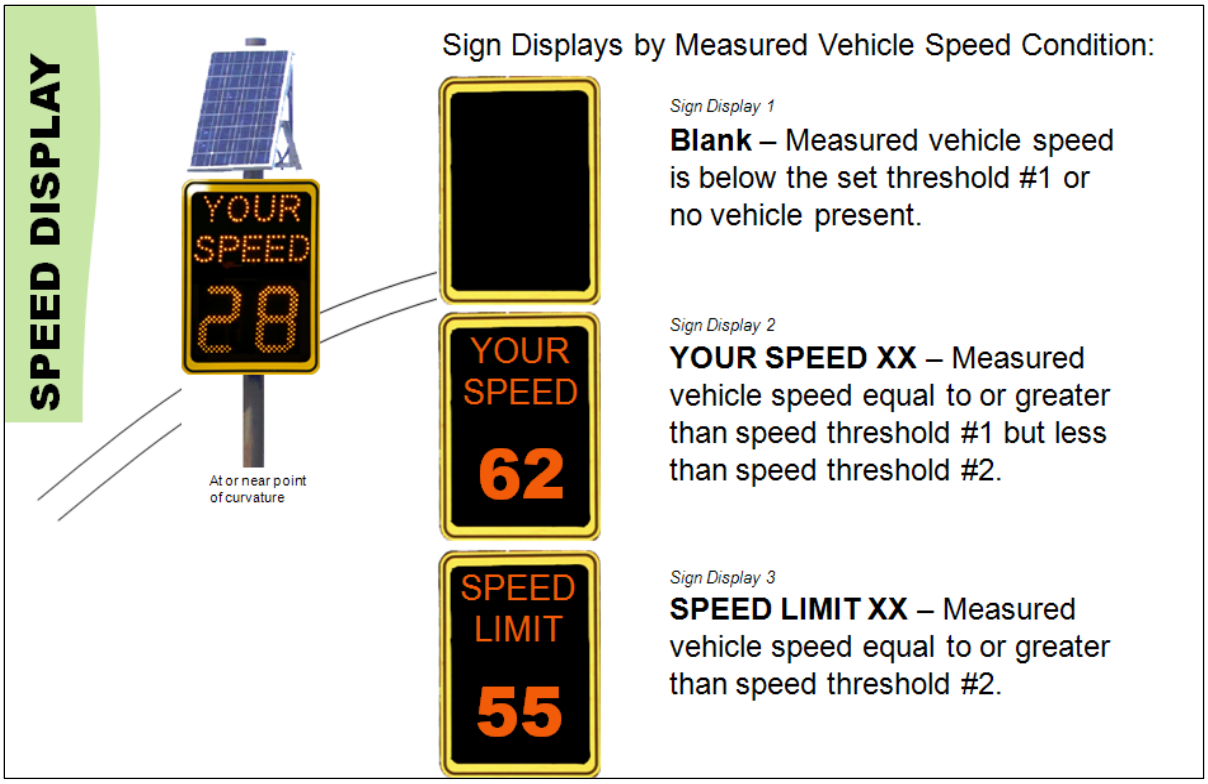


Figure 42. Illustration. Dynamic speed display.

Only sign categories 3 and 4 had the capability to display message type 1. Category 4 signs can be programmed to display this message type but are typically much more expensive than sign category 3 because they have full alphanumeric capabilities. As a result, only signs from category 3 were evaluated.

Message type 1 is hereafter referred to as "dynamic speed display." This message type is also referred to as sign type 1 because each message type had a unique vendor, and in some cases, it was easier to categorize the sites by type of sign placed than by message type.

The second message type selected displays an advance curve warning symbol (message type 2 is hereafter referred to as "dynamic curve display"). This message type has been used in Europe but has had limited application in the United States. Figure 43 shows the dynamic curve.

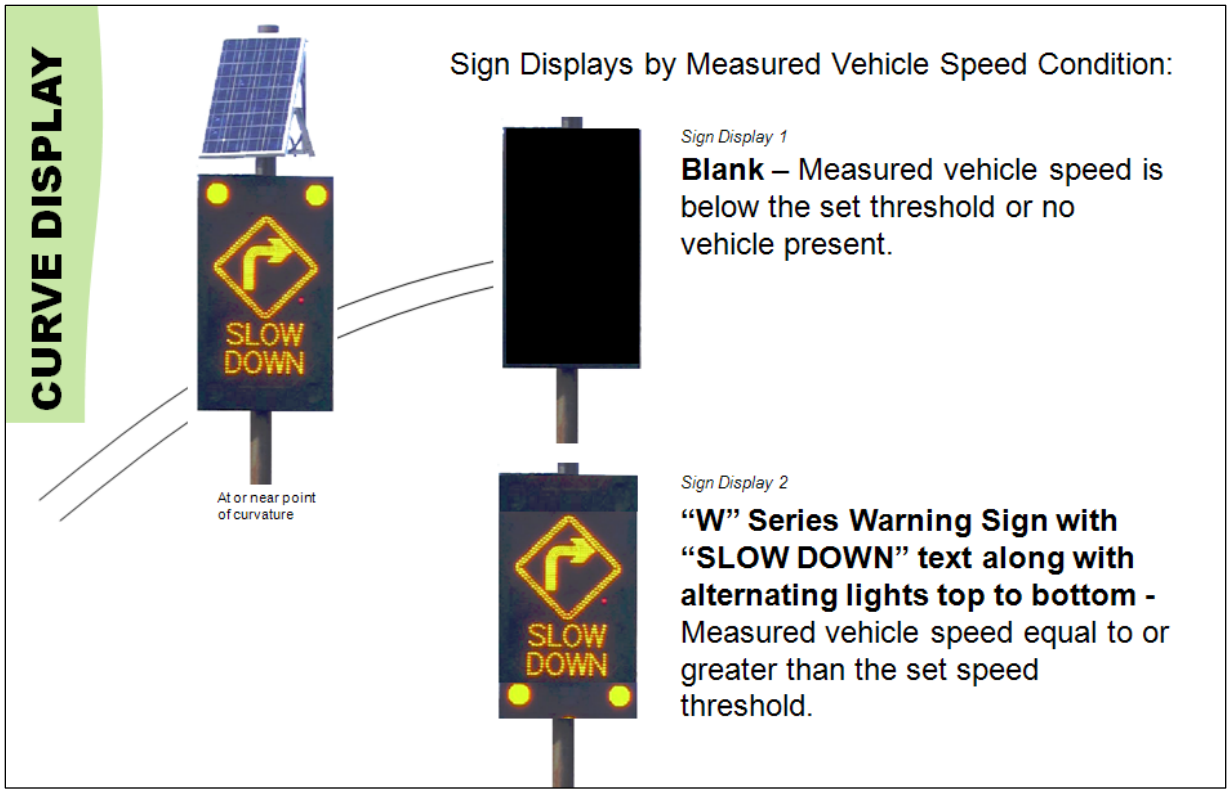


Figure 43. Illustration. Curve warning display.

When activated, the sign displays a standard curve warning symbol as specified by the MUTCD and SLOW DOWN. The sign also has two lights on the top and bottom of the sign that blink in alternative pattern while the curve warning symbol is displayed. The only manufacturer that produces this type of sign is Dorman Varitext. This message type is also referred to as sign type 2 for the reasons given in the preceding paragraph.

In this study, the curve warning display was configured for each site to display the appropriate advance curve warning symbol already depicted at the site (i.e., if a W1-2 sign was displayed in advance of the curve, the curve warning display would also display the W1-2 symbol when activated by a vehicle).

Both vendors provided documentation that their signs were MUTCD compliant, so it was not necessary to obtain MUTCD approval.

The MUTCD describes appropriate sign placement, in advance of the curve at a distance based on posted speed. In this study, the signs were to be placed at the PC rather than upstream, resulting in a concern that the sign placement would violate MUTCD guidelines. Follow-up conversations with the Iowa DOT and FHWA resulted in the conclusion that these signs are in "conjunction" with or "supplemental" to existing advance curve warning signage and, as a result, could be placed at the PC.

The sign selection methodology and final sign types were submitted to and approved by FHWA.

It was determined each State would receive a proportionate number of each message type and the message type would be randomly selected for each site, unless an unusual condition existed at the site that made one message type more appropriate than another.

SIGN MESSAGE THRESHOLD

The speed display is most likely to be effective when targeted at a selected set of drivers who are exceeding a safe speed. It becomes less effective when it is activated by a large number of drivers.

It is commonly accepted that speed displays should have an upper speed threshold above which they no longer display speed, so that drivers do not "test" their speeds against the sign and travel at unsafe speeds. For this study, it was decided that an upper speed threshold for the dynamic speed display sign would be 20 mph over the posted speed limit. The upper threshold was therefore unique for each site.

It was decided that a unique bottom threshold—the lowest speed at which the speed display would be activated—should also be selected for each site. There is no need, of course, to warn drivers who are traveling at or below the posted speed limit or curve advisory speed or even slightly above those speeds because posted and advisory speeds are not always well-determined. The challenge is to set a bottom threshold that activates the speed display only for drivers who are exceeding a safe speed.

Winnett and Wheeler (2002) addressed the bottom threshold issue when they evaluated different speed-activated warning signs, including a rural curve warning system in the United Kingdom. They also felt that the threshold for triggering the sign should be set so that it did not activate for a large percent of drivers. They determined that the threshold for triggering the sign should be set at the 50th percentile speed regardless of the advisory speed. They felt that this indicated the speed at which most drivers felt safe.

As a result, for this project the team selected the 50th percentile speed for the site for the direction of travel toward the sign as the lower speed threshold for activating the speed display. The 50th percentile speed was determined during the "before" data collection. The methodology for collection and analysis of speed data before and after installation of the signs is discussed in chapter 6.

Based on the upper and lower speed thresholds, the sign face for the speed display shows the following for each situation:

- 0 to 50th percentile speed at the PC for the site in the direction of travel toward the sign: blank sign.

- 50th percentile speed to 20 mph over the posted speed limit: YOUR SPEED followed by the vehicle's speed XX in mph.

- 20 mph over the posted speed limit and higher: SPEED LIMIT XX. The actual speed limit is displayed in lieu of the XX.

Based on the upper and lower speed thresholds, the sign face for the curve warning display shows the following for each situation:

- 0 to 50th percentile speed at the PC for the site in the direction of travel toward the sign: blank sign.

- 50th percentile speed or higher at the PC: curve warning sign plus alternating lights and the words SLOW DOWN.

The sign message for both signs activates when a vehicle is detected traveling over the lower speed threshold. The corresponding message is displayed as long as the radar unit in the sign detects that the vehicle is still traveling over the designated threshold.

CHAPTER 4. SIGN INSTALLATION

After a list of final sites was selected by the team and approved by FHWA, signs were ordered from the respective vendors and shipped to the respective States. Before installation, the team made site visits to collect "before" speed data. Within a month, the team returned to install the signs. Whenever possible, all signs were installed for a State at the same time to avoid additional trips.

Originally, 24 sites were selected and signs were scheduled to be installed at all sites by December 2008. As discussed in the following paragraphs, several challenges, delays, and setbacks occurred that reduced the number of sites and significantly prolonged the installation schedule. Ultimately, 22 signs were installed.

One State that had volunteered to participate during the proposal stage dropped out of the study. That State had submitted initial locations, and the team had made site visits, selected final sites, and conducted "before" data collection before the State decided to withdraw from the study. In addition, Texas, which was originally scheduled to have 12 signs installed in four districts, decided owing to budget cuts to proceed with only 4 signs in two districts.

Franklin County in Ohio and the Oregon Department of Transportation heard about the study and contacted the team about participating. Three sites were then selected in Ohio and four in Oregon, and site visits were made. To compensate for the sites that dropped out, in addition to adding Ohio and Oregon, the team added one additional site in Florida and two additional sites in Iowa. Even though Texas was one of the original States on board, signs were installed there last, owing to procurement problems and other delays. All of the issues described above affected the original project schedule.

The first set of signs was installed in July 2008, and the last four signs were installed in Texas on April 8 and 9, 2010. Table 25 shows the installation dates.

Table 25. Sign installation information.

State	Number of Signs Installed	Installation Dates
Arizona	2	September 2008
Florida	3	December 2008
Iowa	2	November 2008
	2	April 2009
Ohio	3	June 2009
Oregon	2	October 2009
	2	January 2010
Texas	4	April 2010
Washington	2	July 2008

CHAPTER 5. METHODOLOGY FOR SPEED AND VOLUME DATA COLLECTION

The goal of this project was to evaluate the reduction in speeds attributable to DSFS systems. Therefore, collection of traffic speed and volume data was integral to the project. An initial speed study using a radar gun was conducted during the first visit at each site as a preliminary step to ensure that a speeding problem existed. A full-scale before-and-after speed study was then conducted. Speed and volume data were collected at test sites only. Given the control sites were selected for use in only the crash analysis, no speed and/or volume data were collected at those sites after the initial site visit.

EQUIPMENT

Pneumatic road tubes (or road tubes) and counters were used for the collection of speed and volume data. The research team had used the pneumatic road tubes and counters for numerous projects. The advantage of the road tubes is that they are fairly accurate, can collect individual vehicle speeds (allowing for spot-checking of the data), are relatively low cost, and can be placed without cutting the pavement. The team has also found that they are practical, given that other technologies, such as video, are more cumbersome, less accurate, or more expensive.

The counters used were Trax I automatic traffic recorders manufactured by JAMAR Technologies, Inc. The units can collect individual speeds, headways, vehicle class, and volume.

For each data collection period, the counters were set up to record time, vehicle speed, and vehicle class for individual vehicles. Other metrics, such as volume, headway, and average speed, can be calculated from these data. Given time on the counters can “drift,” clocks were checked and reset each time they were used.

The CTRE team collected speed and volume data for all sites.

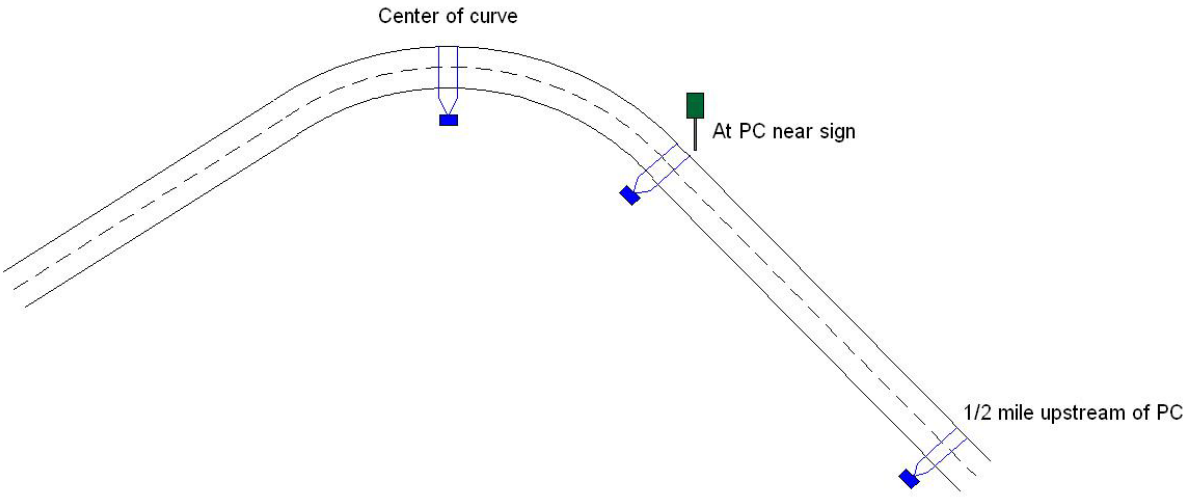
DATA COLLECTION PERIODS

Speed and volume data were collected at each treatment location using the pneumatic road tubes. Data collected about 1 month before the sign installation is referred to as before data. Data were then collected about 1 month after the signs were installed, referred to as 1 month after. Data were collected again about 1 year and 2 years after sign installation (referred to as 12 months after and 24 months after, respectively).

Data were collected over a long period of time after installation of the signs so it could be determined whether the effectiveness of DSFS systems decreases over time as drivers habituate to the signs.

DATA COLLECTION PROTOCOL AND DATA QUALITY ASSURANCE

Speed and volume data were collected at three locations for each data collection period. The dynamic speed-activated feedback sign was placed near the PC for one direction of travel. Data were collected approximately 0.5 miles upstream of the PC, at the PC, and at the center of curve (CC), as shown in figure 44.



PC = Point of curvature

Figure 44. Illustration. Speed data collection locations at each site.

Signs were expected to affect driver behavior shortly upstream of and throughout the curve. As a result, the effectiveness of the signs was evaluated by the change in speed at the PC and at the CC. Speed data were collected 0.5 miles upstream of the signs to monitor fluctuations that may have occurred that were not related to the DSFS system, given drivers at the upstream location had not yet encountered the speed feedback signs. Data were collected at the upstream location to determine whether speeds increased or decreased independent of the signs.

Speed patterns can vary as a result of weather, time of year, and so forth, so the purpose of the upstream data collection locations was to measure any changes in speed that may have occurred independent of the sign installation. It was expected that drivers a 0.5 miles upstream of the curve would not be affected by the sign and would not adjust their behavior.

Although data are evaluated only in the direction of the sign, the road tubes are laid across both lanes of travel, and the counter records both directions of travel given it is not feasible to only lay road tubes across one lane.

In most cases, data were collected for at least 2 days (48 h) during the week (Monday through Friday). A data collection period of 48 h was selected to ensure that a large sample size would result; this would ensure that the data were normally distributed so that appropriate statistical tests, such as the *t*-test, could be applied. In addition, collection of data over 2 or more days might minimize any unusual occurrences for which the team was not able to control.

During data collection, the equipment was spot checked to determine whether any problems had occurred. Common problems include the pneumatic tubes being pulled up from the pavement, the tubes being damaged in some way, or the counters malfunctioning. Damage to the road tubes is typically caused by the tubes getting caught on a tire. On other team projects, the tubes were sometimes intentionally cut or removed.

Data were checked in the field during data collection to spot problems early, and the full data sets were checked when data collection was complete. Data were checked for the following situations, which, based on the team's experience, indicate problems with the counters:

- Large number of low speeds (≤ 5 mph).
- Large number of high speeds (90 mph and higher) (this usually indicates a problem with road tube layout).
- Large number of vehicles with vehicle classification = 14 (class 14 vehicles are vehicles the counter cannot identify).

When problems were noted during data collection, the team typically fixed the problem while in the field and extended the data collection. In a few cases, the team made a return trip. In a very few cases, it was not realistic to do either of the above, and the data sample was for a period less than 48 h.

DATA REDUCTION

When the data collection period for a site was complete, the data were downloaded and checked. Data were usually collected for more than 48 h and then "trimmed" to exactly 48 h. In a few cases, less than 48 h of data were available, and the data were trimmed to 24 h. It was important to ensure that an even 24 h of data were represented because speeds can vary over different time periods during the day, and including portions of a day for one period and not another could bias the sample toward the over-represented period. Table 26 shows sample raw output from the JAMAR counters.

Table 26. Counter output.

Vehicle Number	Date	Time	Lane	Axles	Spec	Class	Length (inches)	Speed (mph)	Gap (s)
1	5/25/2008	6:25:31 p.m.	1	2	3	3	136	48	31
2	5/25/2008	6:25:32 p.m.	1	2	3	3	124	48	1
3	5/25/2008	6:25:34 p.m.	1	2	2	2	111	45	1
4	5/25/2008	6:25:37 p.m.	2	2	2	2	108	57	37
5	5/25/2008	6:25:37 p.m.	1	0	0	14	0	0	3
6	5/25/2008	6:25:45 p.m.	1	2	2	2	101	33	7
7	5/25/2008	6:28:54 p.m.	2	2	2	2	101	60	196
8	5/25/2008	6:28:58 p.m.	2	2	3	3	126	59	4
9	5/25/2008	6:28:59 p.m.	2	2	2	2	111	55	1
10	5/25/2008	6:29:06 p.m.	2	4	18	8	418	58	6

Spec = Specification

After trimming the data file, data were sorted by direction (i.e., NB and SB). Average daily traffic (ADT) was calculated for each data collection period by dividing the number of vehicles in the trimmed dataset by the number of 24-h periods in the dataset. For instance, if 4,050 vehicles were recorded for a 48-h data collection period, ADT would be equal to 4,050/2 = 2,025 vpd.

Vehicles classified as 14 are vehicles that the counter could not classify. Class 14 vehicles were included in the count for ADT because vehicles actually present are recorded.

A number of speed metrics were then calculated for the direction of travel toward the sign. They include average speed, SD of speed, 50th percentile speed, 85th percentile speed, and number of vehicles traveling 5, 10, 15, or 20 mph over the posted or advisory speed limit. Frequently, a speed of 0 is associated with Class 14 vehicle. Vehicles where Class = 14 were removed from the dataset and not included in the speed metrics.

CHAPTER 6. SPEED ANALYSIS

This chapter describes the speed metrics used to assess the effectiveness of the DSFS system. Speed results across sites are also summarized. Given data were collected for three locations at each of the 22 sites, results for individual sites are reported in appendix A. In addition, nighttime versus daytime speeds were compared for several sites, and passenger vehicle versus heavy truck speeds were compared for several sites. This was done to assess whether differences existed that should be considered, and no major differences were noted. This is also noted in appendix A.

SPEED METRICS

The change in speed from each after data collection period was compared with the before period. A negative result indicates that speeds were reduced from the before to the after period.

A number of speed metrics were calculated for the direction of travel toward the sign. They include average speed; SD of speed; 50th percentile speed; 85th percentile speed; and number of vehicles traveling 5, 10, 15, or 20 mph or more over the posted or advisory speed limit. For simplicity in setting up the pneumatic road tubes, the traffic counters were set up to record both directions of traffic on the two-way roadway. Results were reduced by lane and are presented only for traffic traveling in the direction of the DSFS.

Average or mean speed is the average of all spot speeds at the location in question. Mean speed was calculated using the equation in figure 45.

$$\bar{x} = \frac{1}{N}\sum_{i=1}^{N} x_i$$

Figure 45. Equation. Calculation of mean speed.

Where:

$\bar{x}$ = arithmetic average or mean of observed values.
x_i = ith individual value of statistic.
N = sample size, number of values x_i.

SD indicates the amount of variability for a given speed. It can be used to show how speeds are dispersed around the mean. Higher SDs indicate greater variability in the data.

The 50th percentile speed is the speed at which 50 percent of the vehicles are traveling or below. The 85th percentile speed is the speed at which 85 percent of the vehicles are traveling or below. For example, if the 85th percentile speed is 55 mph, 85 percent of the vehicles were observed at a speed of 55 mph or less.

The fraction of vehicles traveling at or above the posted speed limit or advisory speed by a certain threshold amount was also calculated. If an advisory speed was present, the fraction of vehicles traveling 5, 10, 15, and 20 mph or more over the advisory speed was calculated. If no advisory speed was present, the fraction of vehicles traveling 5, 10, 15, and 20 mph or more over the posted speed limit was calculated. This metric provides a measure of the number of vehicles

traveling at high speeds. In many cases, agencies are more concerned with reducing the number of drivers traveling at excessive speeds than with simply reducing average speeds.

The mean, SD, 85th percentile, minimum and maximum speeds, and percent of vehicles traveling at or above 5, 10, 15, and 20 mph over the posted speed limit or advisory speed were calculated at each location for each data collection period. Mean speeds were compared at the 95-percent confidence level using a *t*-test (assuming unequal variances). The percent of vehicles traveling at 5, 10, 15, and 20 mph above the posted speed limit or advisory speed (before periods) were compared with those of after periods. A *z*-test was used to detect differences between two population proportions at the 95-percent confidence level (Ott and Longnecker 2001). (See the equation in figure 46.)

$$z = \frac{\hat{\pi}_1 - \hat{\pi}_2}{\sqrt{\frac{\hat{\pi}_1(1-\hat{\pi}_1)}{n_1} + \frac{\hat{\pi}_2(1-\hat{\pi}_2)}{n_2}}}$$

Figure 46. Equation. *z*-test.

Unless indicated otherwise, difference in means and percents over the posted or advisory speed were statistically significant at the 95-percent level of significance.

The percent change between the fraction of vehicles exceeding the posted or advisory speed before and after installation of the signs was also calculated using the equation in figure 47.

$$C_p = \{FR_{(before,x)} - FR_{(after,x,i)}\} \div FR_{(before,\ x)}$$

Figure 47. Equation. Percent change in fraction of vehicles exceeding posted/advisory speed after installation of signs.

Where:

$FR_{(before,x)}$ = fraction of vehicles exceeding the posted or advisory speed by x mph for before period x.
$FR_{(after,x,\ i)}$ = fraction of vehicles exceeding the posted or advisory speed by x mph for after period i.
C_p = percent change.

For example, if the fraction of vehicles traveling 5 mph or more over the posted speed limit was 0.413 for the before period, and the fraction of vehicles traveling 5 mph or more at 1 month after installation is 0.083, the percent change is (0.413 – 0.083)/0.413 = 0.799. Therefore, 79.9 percent fewer vehicles exceeded the posted or advisory speed by 5 mph or more after the sign had been in place for 1 month. The percent change was the metric used to assess differences in the fraction of vehicles that exceeded the posted or advisory speed by 5, 10, 15, or 20 or mph.

ADT was computed for each site. Total volume was averaged by the number of days of data (i.e., total volume for a 48-h count was divided by 2). ADT is presented only for the upstream site given volume was not expected to vary over the study section.

SUMMARY OF SPEED ANALYSIS

Data were collected at 22 sites for four time periods (before, 1 month after, 12 months after, and 24 months after). Data were also collected at three different locations at each site as described in chapter 6. This resulted in a significant amount of information. Consequently, results for individual sites by time period and location are provided in appendix A. Results across sites were summarized and are presented in the following sections.

Results of Mean and 85th Percentile Speed Analysis at Point of Curvature

Table 27 through table 35 summarize results by curve. The change in mean and 85th percentile speed from the before period speed to specific after period speed, in mph, are shown. The percent change (as defined in the Speed Metrics section of this chapter) in the fraction of vehicles exceeding the posted or advisory speed is also presented.

These tables provide the curve identification number, sign type, road name, and posted speed limit for each curve. An S for Sign Type indicates a speed display sign, and a C designates a curve display sign. When an advisory curve speed was displayed, the advisory speed is shown as well.

Table 27 through table 29 show changes in the speed metrics at the PC for data collected about 1 month after installation of the DSFS systems. Changes in mean speeds range from a decrease of 5.6 mph at site AZ-6 to an increase of 3.3 mph at site FL-32. Changes in 85th percentile speeds at the PC 1 month after installation ranged from a decrease of 8 mph to an increase of 4 mph.

Table 27. Summary of results at the PC 1 month after sign installation (part 1).

Curve		AZ-6	AZ-2	FL-6	FL-32	FL-8	IA-10	IA-31	IA-33
Sign Type		C	S	C	S	S	C	S	C
Road		SR 377	SR 95	SR 267	SR 20	SR 20	US 30	US 67	US 69
Posted		65	55	55	55	55	55	55	55
Curve Advisory		none	45	none	45	none	none	none	50
Change in Mean Speed (mph)		-5.6	-4.4	-0.9	3.3	-1.4	-0.9	-0.8	-0.2
Change in 85th Percentile Speed (mph)		-8	-8	-1	4	-1	-1	-1	0
Percent Change in Fraction of Vehicles Exceeding Posted or Advisory Speed by:	**5 mph**	-79.9%	-18.6%	-20.9%	2.8%	-31.1%	-19.5%	-19.6%	-3.1%
	10 mph	-91.3%	-54.6%	-25.0%	16.0%	-34.8%	-44.2%	-43.1%	-14.3%
	15 mph	-92.5%	-70.8%	-57.1%	71.3%	-44.4%	-37.5%	-42.9%	-24.5%
	20 mph	-96.4%	-70.1%	0.0%	172.9%	0.0%	100.0%	-66.7%	-25.0%

C = Curve display sign
S = Speed display sign

Table 28. Summary of results at the PC 1 month after sign installation (part 2).

Curve		IA-14	OH-6	OH-8	OH-14	OR-4	OR-12	OR-5	OR-9
Sign Type		S	S	C	S	C	C	S	S
Road		Iowa 136	Alkire	Norton	Pontius	US 101	OR 126	US 42	OR 238
Posted		50	55	55	55	55	55	55	55
Curve Advisory		45	30	35	30	45	40	35	30
Change in Mean Speed (mph)		-2.7	-0.5	-0.9	0.9	-0.8	-0.6	-4.1	-3.4
Change in 85th Percentile Speed (mph)		-4	-1	0	0	-1	0	-4	-3
Percent Change in Fraction of Vehicles Exceeding Posted or Advisory Speed by:	**5 mph**	-16.8%	0.2%	-1.5%	0.9%	-2.3%	-1.5%	-6.1%	-16.7%
	10 mph	-57.9%	-2.4%	-8.5%	4.0%	-15.0%	-9.9%	-19.9%	-42.1%
	15 mph	-71.9%	-11.9%	-15.6%	11.4%	-34.6%	-11.6%	-40.2%	-61.0%
	20 mph	-73.0%	-27.1%	-11.8%	34.2%	-53.5%	9.3%*	-64.5%	-62.1%

*Not statistically significant at 95-percent level of significance
C = Curve display sign
S = Speed display sign

Table 29. Summary of results at the PC 1 month after sign installation (part 3).

Curve		TX-38	TX-30	TX-39	WA-15	WA-8
Sign Type		S	C	C	C	S
Road		FM 481	FM 359	US 90	US 101	SR 7
Posted		65	70	70	50	50
Curve Advisory		50	none	none	40	35
Change in Mean Speed (mph)		-5.2	-3.4	1.6	-5.1	-3.2
Change in 85th Percentile Speed (mph)		-4	-5	2	-5	-5
Percent Change in Fraction of Vehicles Exceeding Posted or Advisory Speed by:	**5 mph**	-14.1%	-75.0%	110.5%	-4.3%	-32.0%
	10 mph	-28.5%	-80.0%	75.0%*	-16.2%	-60.5%
	15 mph	-42.3%	-78.9%	0.0%*	-41.4%	-65.6%
	20 mph	-91.3%	-50.0%	-100.0%	-68.2%	-56.0%

*Not statistically significant at 95-percent level of significance
C = Curve display sign
S = Speed display sign

Table 30 through table 32 provide changes in the speed metrics at the PC for data collected about 12 months after installation of the DSFS systems. Decreases in mean speeds range from 6.5 mph to an increase of 0.6 mph. Decreases in 85th percentile speeds range from a decrease of 8 mph to an increase of 1 mph. Signs were functioning for all 22 sites for the 12-month after period.

Table 30. Summary of results at the PC 12 months after sign installation (part 1).

Curve		AZ-6	AZ-2	FL-6	FL-32	FL-8	IA-10	IA-31	IA-33
Sign Type		C	S	C	S	S	C	S	C
Road		SR 377	SR 95	SR 267	SR 20	SR 20	US 30	US 67	US 69
Posted		65	55	55	55	55	55	55	55
Curve Advisory		none	45	none	45	none	none	none	50
Change in Mean Speed (mph)		-3.6	-3.9	-6.5	-2.8	-1.9	-2.5	-1.0	-1.3
Change in 85th Percentile Speed (mph)		-5	-7	-8	-4	-2	-3	-1	0
Percent Change in Fraction of Vehicles Exceeding Posted or Advisory Speed by:	**5 mph**	-44.8%	-16.9%	-95.4%	-3.6%	-45.5%	-53.2%	-30.2%	-13.7%
	10 mph	-78.5%	-48.8%	-96.4%	-24.7%	-50.0%	-76.6%	-45.8%	-19.9%
	15 mph	-83.6%	-58.9%	-100.0%	-64.2%	-44.4%	-62.5%	-42.9%	-28.6%
	20 mph	-89.3%	-57.5%	-100.0%	-77.1%	-50.0%	0.0%*	-33.3%	-37.5%

*Not statistically significant at 95-percent level of significance
C = Curve display sign
S = Speed display sign

Table 31. Summary of results at the PC 12 months after sign installation (part 2).

Curve		IA-14	OH-6	OH-8	OH-14	OR-4	OR-12	OR-5	OR-9
Sign Type		S	S	C	S	C	C	S	S
Road		Iowa 136	Alkire	Norton	Pontius	US 101	OR 126	US 42	OR 238
Posted		50	55	55	55	55	55	55	55
Curve Advisory		45	30	35	30	45	40	35	30
Change in Mean Speed (mph)		-0.8	-2.8	-2.4	0.1	-1.8	-0.2*	-6.1	-2.8
Change in 85th Percentile Speed (mph)		-1	-3	-2	0	-1	1	-6	-3
Percent Change in Fraction of Vehicles Exceeding Posted or Advisory Speed by:	**5 mph**	-2.8%	-7.9%	-3.6%	1.1%	-10.7%	-3.3%	-12.5%	-11.8%
	10 mph	-22.2%	-25.1%	-16.7%	-0.2%*	-26.2%	-10.2%	-32.2%	-35.4%
	15 mph	-31.5%	-41.1%	-36.0%	-4.0%*	-35.8%	-0.5%*	-61.6%	-59.4%
	20 mph	-52.3%	-54.2%	-54.8%	3.3%	-30.2%	44.9%	-81.1%	-72.4%

*Not statistically significant at 95-percent level of significance
C = Curve display sign
S = Speed display sign

Table 32. Summary of results at the PC 12 months after sign installation (part 3).

Curve		OH-6	TX-38	TX-30	TX-4	TX-39	WA-15	WA-8
Sign Type		S	S	C	C	C	C	S
Road		Alkire	FM 481	FM 359	FM 755	US 90	US 101	SR 7
Posted		55	65	70	65	70	50	50
Curve Advisory		30	50	none	50	none	40	35
Change in Mean Speed (mph)		-2.8	-5.6	-1.7	-2.9	0.6	-4.9	-1.7
Change in 85th Percentile Speed (mph)		-3	-4	-3	-4	1	-5	-3
Percent Change in Fraction of Vehicles Exceeding Posted or Advisory Speed by:	**5 mph**	-7.9%	-16.5%	-51.2%	-10.0%	47.4%	-4.7%	-18.5%
	10 mph	-25.1%	-29.8%	-58.2%	-28.3%	25.0%*	-15.9%	-40.4%
	15 mph	-41.1%	-47.3%	-73.7%	-35.6%	200.0%	-43.6%	-41.7%
	20 mph	-54.2%	-70.1%	-100.0%	-68.5%	0.0%*	-71.5%	-44.0%

*Not statistically significant at 95-percent level of significance
C = Curve display sign
S = Speed display sign

Table 33 through table 35 show changes in speed metrics at the PC for the 24-month after period. Results are shown for 18 sites. Signs at two sites in Oregon and two sites in Texas had various issues between the 12- and 24-month after periods. Given a number of other signs had already been repaired, it was determined there were not sufficient project resources to make additional trips to perform maintenance at those sites.

As shown, at the 24-month after period, decreases in mean speeds ranged from 0.8 to 5.7 mph, with one site experiencing an increase in mean speed of 0.5 mph. Decreases in 85th percentile speeds ranged from 1 to 6 mph, with one site having an increase in 85th percentile speed of 1 mph.

Table 33. Summary of results at the PC 24 months after sign installation (part 1).

Curve		AZ-6	AZ-2	FL-6	FL-32	FL-8	IA-10	IA-31	IA-33
Sign Type		C	S	C	S	S	C	S	C
Road		SR 377	SR 95	SR 267	SR 20	SR 20	US 30	US 67	US 69
Posted		65	55	55	55	55	55	55	55
Curve Advisory		none	45	none	45	none	none	None	50
Change in Mean Speed (mph)		-4.7	-1.4	-1.1	-1.1	-1.1	-0.8	-2.4	-2.7
Change in 85th Percentile Speed (mph)		-6	-3	-1	-2	-1	-1	-3	-2
Percent Change in Fraction of Vehicles Exceeding Posted Or Advisory Speed by:	**5 mph**	-60.3%	-7.0%	-32.0%	0.1%*	-22.6%	-21.4%	-57.9%	-35.2%
	10 mph	-86.2%	-15.9%	-60.7%	-7.2%	37.0%	-50.6%	-72.2%	-58.5%
	15 mph	-91.0%	-21.0%	-71.4%	-33.2%	122.2%	-25.0%	-71.4%	-61.2%
	20 mph	-92.9%	-12.6%	-100.0%	-44.8%	150.0%	0.0%*	-66.7%*	-87.5%

*Not statistically significant at 95-percent level of significance
C = Curve display sign
S = Speed display sign

Table 34. Summary of results at the PC 24 months after sign installation (part 2).

Curve		IA-14	OH-6	OH-8	OH-14	OR-12	OR-9
Sign Type		S	S	C	S	C	S
Road		Iowa 136	Alkire	Norton	Pontius	OR 126	OR 238
Posted		50	55	55	55	55	55
Curve Advisory		45	30	35	30	40	30
Change in Mean Speed (mph)		-2.1	-2.4	0.6	-1.9	-1.7	-2.1
Change in 85th Percentile Speed (mph)		-2	-2	1	-2	-1	-2
Change in Fraction of Vehicles Exceeding Posted or Advisory Speed by:	**5 mph**	-13.1%	-6.6%	0.0%*	-3.1%	-6.5%	-9.1%
	10 mph	-38.7%	-19.6%	0.2%*	-15.0%	-18.0%	-27.1%
	15 mph	-52.5%	-38.3%	6.6%	-28.7%	-23.4%	-40.6%
	20 mph	-89.2%	-44.9%	22.0%	-25.0%	-14.4%	-34.5%

*Not statistically significant at 95-percent level of significance
C = Curve display sign
S = Speed display sign

Table 35. Summary of results at the PC 24 months after sign installation (part 3).

Curve		TX-38	TX-30	WA-15
Sign Type		S	C	C
Road		FM 481	FM 359	US 101
Posted		65	70	50
Curve Advisory		50	none	40
Change in Mean Speed (mph)		-5.7	-1.9	-3.6
Change in 85th Percentile Speed (mph)		-5	-3	-3
Percent Change in Fraction of Vehicles Exceeding Posted or Advisory Speed by:	**5 mph**	-0.1%	-57.1%	-4.1%
	10 mph	-0.4%	-54.5%	-11.3%
	15 mph	-0.5%	-47.4%	-26.9%
	20 mph	-0.7%	-16.7%	-51.3%

C = Curve display sign
S = Speed display sign

Decreases in mean and 85th percentile speeds were plotted to show the distribution of change. Figure 48 shows the percent of sites experiencing decreases in mean speeds of a certain magnitude at 1, 12, and 24 months. Figure 49 provides change in 85th percentile speed of a certain magnitude.

As shown, at 1 month, 2 of the 21 sites had increases in mean speeds between 1 and 4 mph, 9 of the sites (43 percent) experienced virtually no change in mean speeds, 5 sites (24 percent) experienced decreases of 1 to 4 mph, and 5 sites had decreases between 4 and 7 mph.

Changes in 85th percentile speeds for the 1-month after periods are shown in figure 49. As indicated, two sites (10 percent) experienced increases between 1 and 7 mph, four sites (19 percent) had little change in 85th percentile speeds, seven sites (33 percent) had decreases between 1 and 4 mph, six sites (29 percent) had decreases of 4 to 7 mph, and two sites (10 percent) had decreases of more than 7 mph.

At 12 months after installation of the signs, no sites experienced significant increases in mean speeds as shown in figure 50. Three of the 22 sites (14 percent) had little change, 15 sites (68 percent) had decreases of 1 to 4 mph, and 4 sites had decreases from 4 to 7 mph. As indicated in figure 49, no sites had increases in 85th percentile speeds at 12 months while 3 of the 22 (18 percent) had little change, 10 sites (45 percent) had decreases of 1 to 4 mph, 6 sites (27 percent) had a decreases of 4 to 7 mph, and 2 sites (9 percent) had decreases of 7 mph or more.

Figure 48 and figure 49 also show results for 24 months after installation of the signs. Data were available for 18 sites given maintenance and vandalism issues had occurred at 4 sites so that data were not collected for them at the 24-month after period.

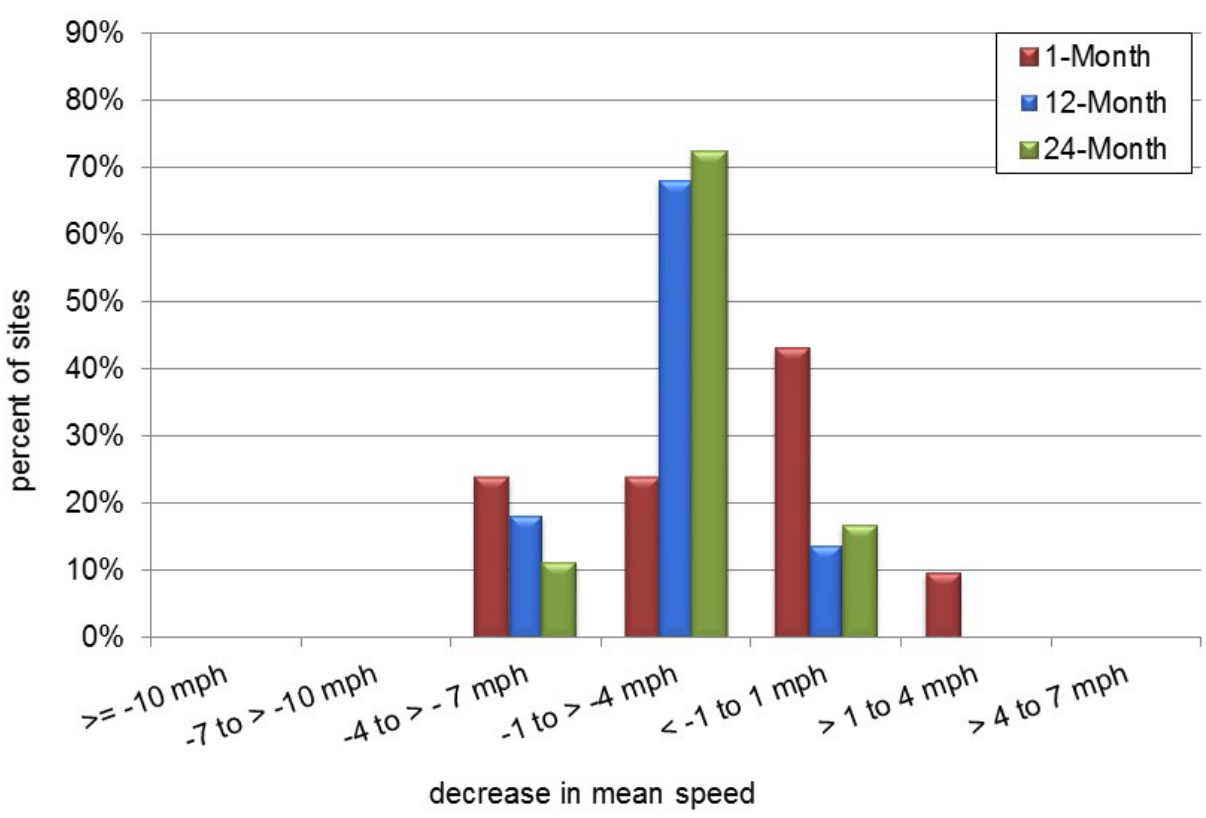


Figure 48. Chart. Percent of sites experiencing a change in mean speed of a certain magnitude at the PC.

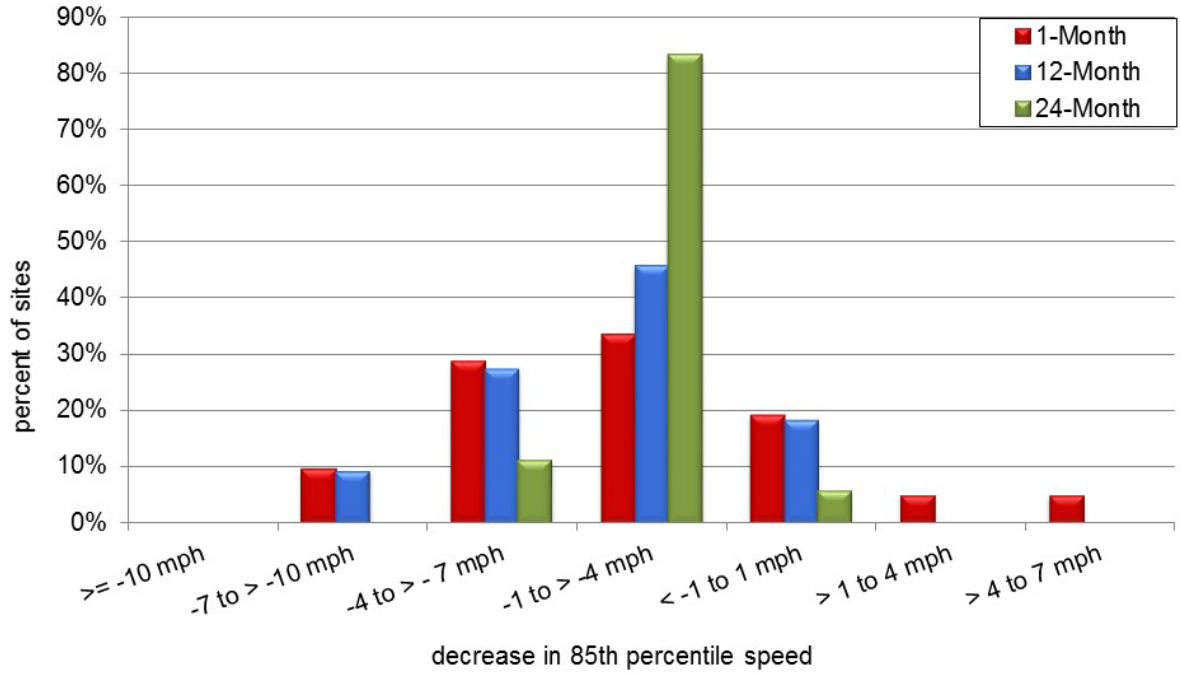


Figure 49. Chart. Percent of sites experiencing a change in 85th percentile speed of a certain magnitude at the PC.

As shown in figure 48, at 24 months, no signs had significant increases in mean speeds, while three sites had little change in mean speeds. The majority (13 sites or 72 percent) had decreases of 1 to 4 mph while 2 sites (11 percent) had a decrease between 4 and 7 mph. As shown in figure 49, at the 24-month after period, 1 site (6 percent) had no relevant changes in 85th percentile speed, 14 sites (83 percent) had decreases of 1 to 4 mph, and 2 sites (11 percent) had decreases of 4 mph or more.

Results of Percent Change in Vehicles Exceeding Posted or Advisory Speed at Point of Curvature

Figure 50 through figure 53 show changes in the percent of vehicles traveling at 5 mph or more, 10 mph or more, 15 mph or more, and 20 mph or more over the posted speed or advisory speed at the PC. Researchers compared the fraction of vehicles a certain threshold over the advisory speed if present; if not present, the posted speed limit was used.

Figure 50 shows the change in percent of vehicles traveling 5 mph or more over the posted or advisory speed at 1, 12, and 24 months.

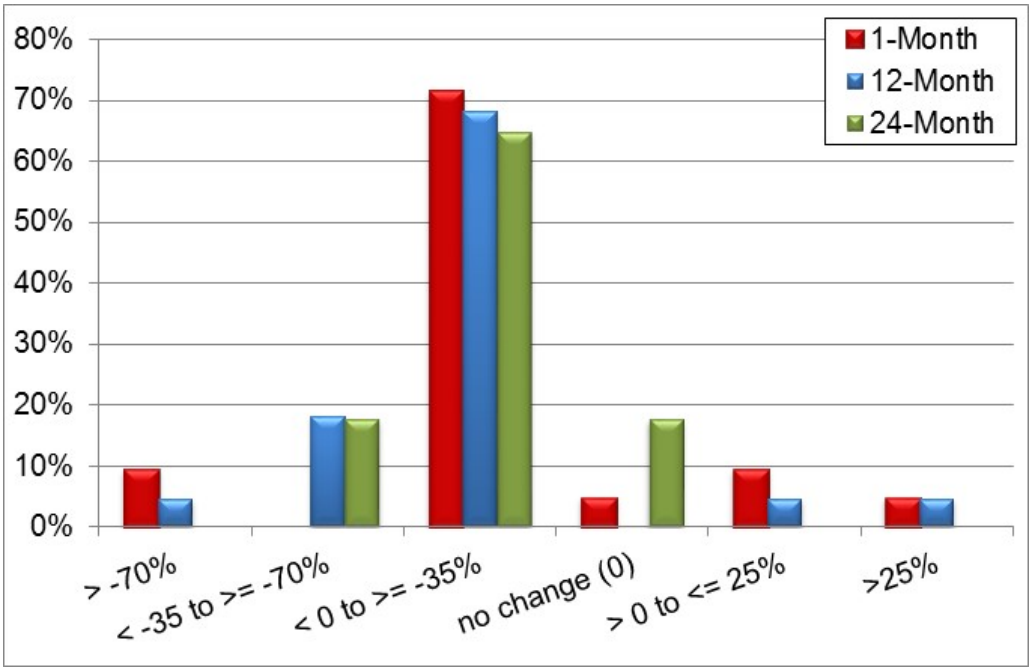


Figure 50. Chart. Changes in percent of vehicles traveling 5 or more mph over posted limit or advisory speed at the PC.

Data for vehicles traveling 5 mph or more over the posted or advisory speed are fairly consistent over the 1-, 12-, and 24-month after periods. As shown, 5 to 10 percent of sites had reductions of 70 percent or more, and about 15 percent of sites had decreases from 35 to 70 percent. The majority of sites for all time periods had decreases up to 35 percent. A small number of sites had little change, with up to 10 percent having increases up to 25 percent and about 5 percent with increases of more than 25 percent.

Figure 51 shows data for the proportion of vehicles traveling 10 mph or more over the posted speed limit or advisory speed. The majority of sites (41 to 55 percent, depending on time period) had decreases of up to 35 percent in the fraction of vehicles traveling 10 mph or more over the posted or advisory speed while 23 to 35 percent of sites had decreases between 35 and 70 percent. Finally, about 10 percent of sites for 1 month, 14 percent for 12 months, and 6 percent for 24 months had decreases of 70 percent or more. At 1 month, 14 percent of sites and at 12 months, 5 percent of sites had increases up to 25 percent in the fraction of vehicles traveling 10 mph or more over the posted or advisory speed. Six percent of vehicles had increases of more than 25 percent for the 24-month after period. Up to 12 percent of sites had no change.

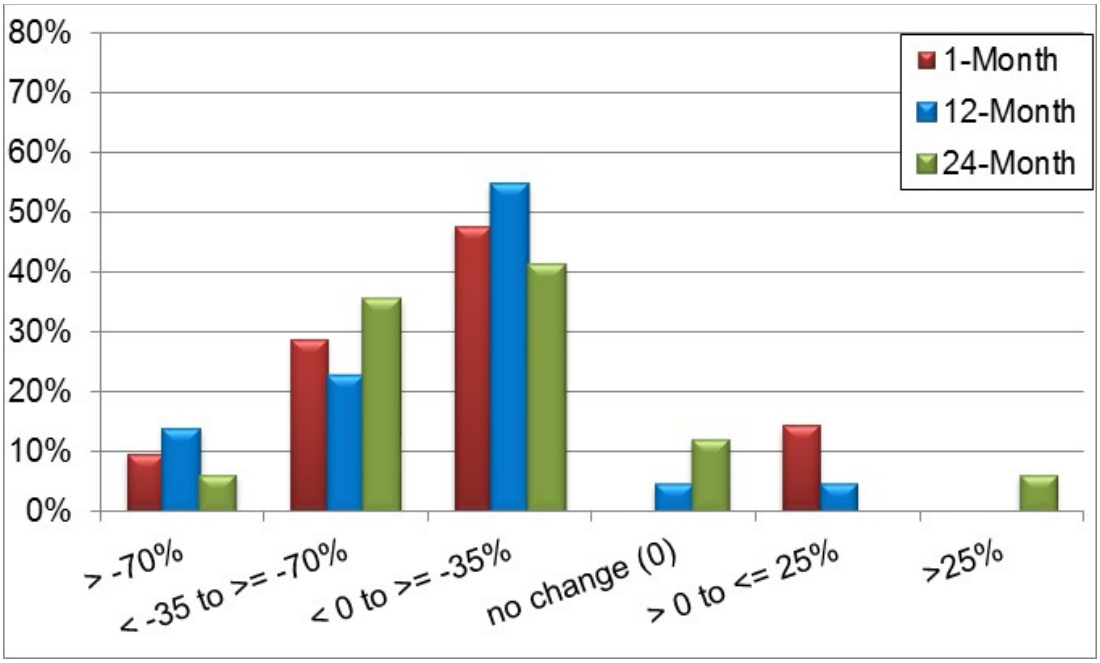


Figure 51. Chart. Changes in percent of vehicles traveling 10 or more mph over posted limit or advisory speed at the PC.

Figure 52 shows changes in the fraction of vehicles traveling 15 mph or more over the posted or advisory speed. Less than 6 percent of sites for any analysis time period had increases or no change in the fraction of vehicles traveling 15 mph or more over the posted or advisory speed. Twenty-four percent of vehicles at 1 month, 18 percent at 12 months, and 41 percent at 24 months, had decreases of up to 35 percent in the percentage of vehicles traveling 15 mph or more over the posted or advisory speed. The majority of sites (43 percent and 64 percent) for 1 and 12 months after and 29 percent for 24 months after had decreases between 35 and 70 percent. Up to 19 percent of sites had decreases of more than 70 percent.

Figure 53 shows results for changes in the percent of vehicles traveling 20 mph or more over the posted or advisory speed. The majority of vehicles (35 percent) at 24 months had decreases up to 35 percent in the fraction of vehicles traveling 20 mph or more over the posted or advisory speed. About 9 and 14 percent of sites experienced decreases in that range for the 1- and 12-month after periods.

The majority of sites (38 percent) for 1 month and (41 percent) for 12 months had decreases of 35 to 70 percent in the vehicles traveling 20 mph or more over the posted or advisory speed. Between 19 and 32 percent of sites had decreases in the fraction of vehicles traveling 20 mph or more over the posted or advisory speed. A few sites (14 percent for 1 month and about 5 percent for 12 and 24 months) had increases of more than 25 percent. About 5 percent had increases up to 25 percent, and about 6 to 9 percent had no change. About 20 percent of sites at 1 and 24 months and about 30 percent of sites at 12 months had decreases in the percent of vehicles traveling 20 mph or more over the posted or advisory speed.

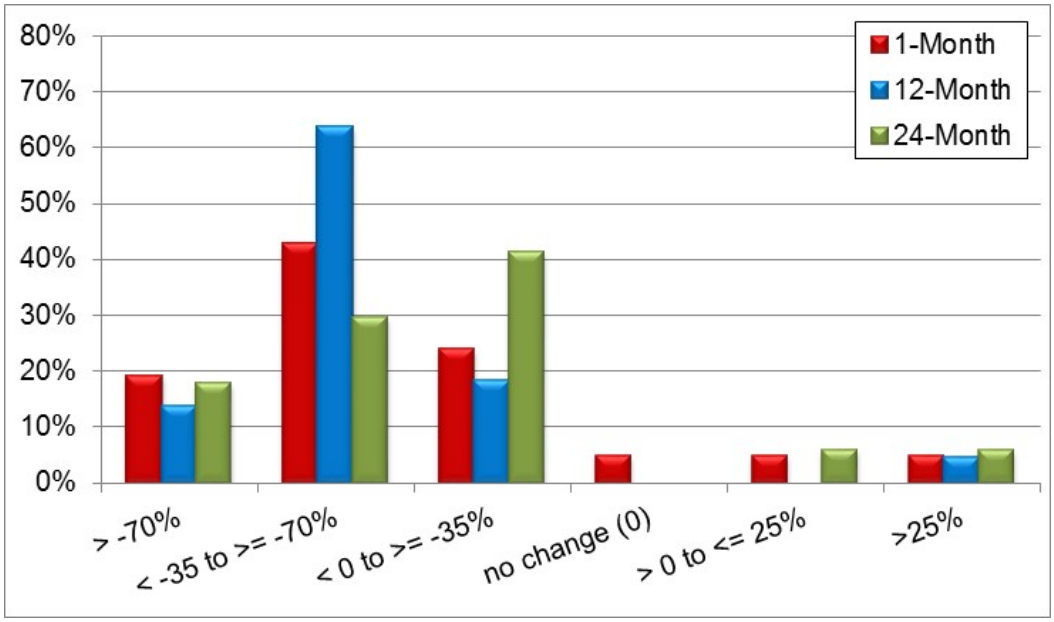


Figure 52. Chart. Changes in percent of vehicles traveling 15 or more mph over posted limit or advisory speed at the PC.

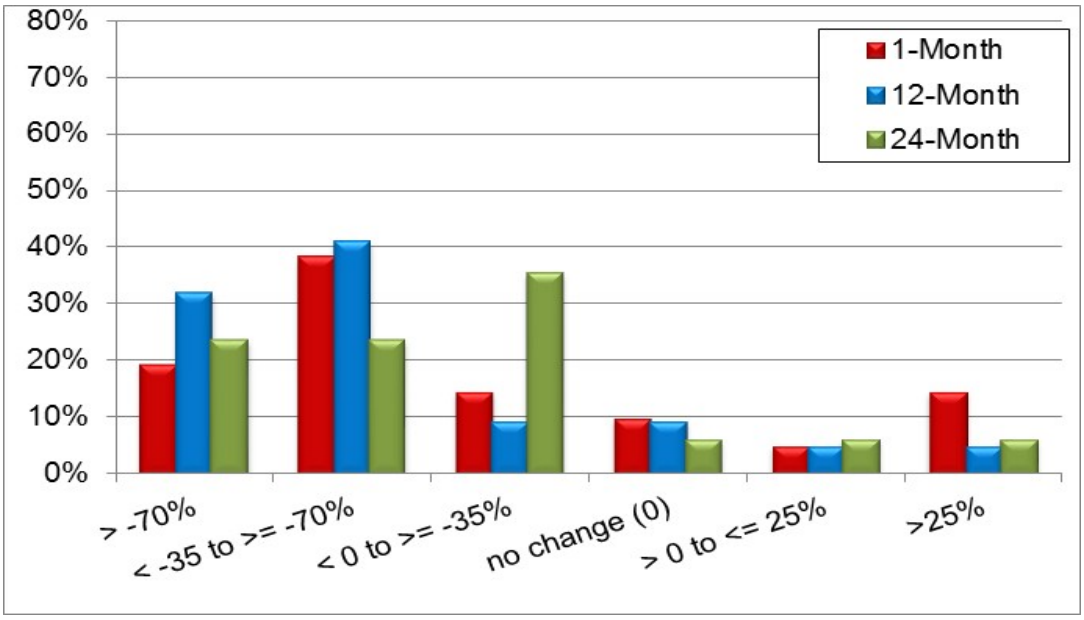


Figure 53. Chart. Changes in percent of vehicles traveling 20 or more mph over posted limit or advisory speed at the PC.

As noted, significant reductions in the number of vehicles traveling over the posted or advisory speeds occurred for all of the after periods at the PC. In most cases, the majority of sites had reductions in the fraction of vehicles exceeding the posted or advisory speed between 35 and 70 percent. This was the case for all of the speed thresholds (5, 10, 15, and 20 mph or more over). In addition, reductions of greater than 70 percent were noted for all time periods and thresholds except for one. This indicates the signs were effective in reducing high-end speeds, as well as average and 85th percentile speeds.

Results of Mean and 85th Percentile Speed Analysis at the Center of the Curve

Table 36 through table 44 summarize overall results by curve at the CC. The changes in mean and 85th percentile speeds from the before period speed to the specific after period speed, in mph, are shown. The percent change (as defined in Speed Metrics) in the fraction of vehicles exceeding the posted or advisory speed is also presented.

These tables provide the curve identification number, sign type, road name, and posted speed limit for each curve. An S for Sign Type indicates a speed display sign, and a C designates a curve display sign. When an advisory curve speed was displayed, the advisory speed is shown as well.

Table 36 through table 38 show results at the CC for individual sites at the 1-month after period. Speed reductions were generally larger at the CC than at the PC. Changes in mean speeds ranged from a decrease of 10.9 mph to an increase of 2.8 mph. Changes in 85th percentile speeds ranged from a decrease of 12 mph to an increase of 6 mph. Data are presented for 21 of the 22 sites. At the 1-month after period, a sign had been knocked down at one of the Texas sites and had not been repaired when data were collected.

Table 36. Summary of results at the CC 1 month after sign installation (part 1).

Curve		AZ-6	AZ-2	FL-6	FL-32	FL-8	IA-10	IA-31	IA-33
Sign Type		C	S	C	S	S	C	S	C
Road		SR 377	SR 95	SR 267	SR 20	SR 20	US 30	US 67	US 69
Posted		65	55	55	55	55	55	55	55
Curve Advisory		none	45	none	45	none	none	none	50
Change in Mean Speed (mph)		-1.7	-5.3	-0.7	-3.7	-2.9	-1.5	-10.9	0.0
Change in 85th Percentile Speed (mph)		-3	-7	-1	-4	-3	-1	-12	1
Percent Change in Fraction of Vehicles Exceeding Posted or Advisory Speed by:	**5 mph**	-52.5%	-41.5%	-17.2%	-7.1%	-65.4%	-25.6%	-96.5%	-2.5%
	10 mph	-70.2%	-73.3%	-28.6%	-21.2%	-78.3%	-58.2%	-99.0%	0.4%
	15 mph	-79.2%	-85.6%	-50.0%	-69.9%	-70.0%	-63.6%	-97.9%	-95.8%
	20 mph	-60.0%	-88.9%	0.0%*	-80.4%	-50.0%	-50.0%	-95.2%	-100.0%

*Not statistically significant at 95-percent level of significance
C = Curve display sign
S = Speed display sign

Table 37. Summary of results at the CC 1 month after sign installation (part 2).

Curve		IA-14	OH-6	OH-8	OH-14	OR-4	OR-12	OR-5	OR-9
Sign Type		S	S	C	S	C	C	S	S
Road		Iowa 136	Alkire	Norton	Pontius	US 101	OR 126	US 42	OR 238
Posted		50	55	55	55	55	55	55	55
Curve Advisory		45	30	35	30	45	40	35	30
Change in Mean Speed (mph)		-0.6	0.4	-3.1	2.8	-5.6	-1.3	-2.7	-2.5
Change in 85th Percentile Speed (mph)		-2	0	-3	6	-6	-1	-3	-3
Percent Change in Fraction of Vehicles Exceeding Posted or Advisory Speed by:	**5 mph**	-1.5%	3.0%	-14.4%	-0.5%*	-43.0%	-3.5%	-23.6%	-34.0%
	10 mph	-28.6%	6.6%	-41.3%	-1.0%*	-78.7%	-19.4%	-44.3%	-62.6%
	15 mph	-40.2%	14.2%	-63.9%	22.0%	-95.3%	-32.5%	-54.7%	-77.8%
	20 mph	-43.8%	-21.4%	-73.7%	210.7%	-96.7%	-46.8%	-46.2%	-50.0%

*Not statistically significant at 95-percent level of significance
C = Curve display sign
S = Speed display sign

Table 38. Summary of results at the CC 1 month after sign installation (part 3).

Curve		TX-38	TX-30	TX-39	WA-15	WA-18
Sign Type		S	C	C	C	S
Road		FM 481	FM 359	US 90	US 101	SR 7
Posted		65	70	70	50	50
Curve Advisory		50	none	none	40	35
Change in Mean Speed (mph)		1.3	-2.3	-1.0	-2.9	0.5
Change in 85th Percentile Speed (mph)		3	-3	-1	-7	-3
Percent Change in Fraction of Vehicles Exceeding Posted or Advisory Speed by:	**5 mph**	-1.8%*	-66.1%	-29.4%	-26.2%	-28.3%
	10 mph	-0.2%*	-59.6%	-33.3%*	-44.7%	-45.6%
	15 mph	13.1%	-68.8%	-100.0%	-59.0%	-38.6%
	20 mph	160.9%	-57.1%	0.0%*	-69.2%	0.0%

*Not statistically significant at 95-percent level of significance
C = Curve display sign
S = Speed display sign

As noted, most sites had significant decreases in the fraction of vehicles traveling 5, 10, 15, or 20 mph or more over the posted or advisory speed. Reductions up to almost 100 percent were reported for the fraction traveling 5, 10, or 15 mph or more over the posted or advisory speed. One site had a 211-percent reduction, and another site had a 161-percent reduction in the fraction of vehicles traveling 20 mph or more over the posted or advisory speed limit.

Table 39 through table 41 provide results for the CC for 12 months after installation of the signs. Results are presented for all 22 sites. Changes in mean speeds ranged from a decrease of 7.9 mph to an increase of 3.7 mph. Changes in 85th percentile speeds ranged from a decrease of 9 mph to an increase of 3 mph.

Table 39. Summary of results for the CC 12 months after sign installation (part 1).

Curve		AZ-6	AZ-2	FL-6	FL-32	FL-8	IA-10	IA-31	IA-33
Sign Type		C	S	C	S	S	C	S	C
Road		SR 377	SR 95	SR 267	SR 20	SR 20	US 30	US 67	US 69
Posted		65	55	55	55	55	55	55	55
Curve Advisory		none	45	none	45	none	none	none	50
Change in Mean Speed (mph)		0.2	-2.9	-1.9	-3.7	-1.1	0.4	-7.9	-2.5
Change in 85th Percentile Speed (mph)		0	-4	-2	-4	-1	3	-9	-2
Percent Change in Fraction of Vehicles Exceeding Posted Or Advisory Speed by:	**5 mph**	4.3%	-17.8%	-41.8%	-6.5%	-29.6%	22.0%	-82.2%	-30.5%
	10 mph	-26.2%	-41.8%	-42.9%	-32.0%	-40.6%	29.6%	-94.8%	-59.6%
	15 mph	-58.3%	-61.0%	-50.0%	-70.2%	-40.0%	9.1%	-96.9%	-70.8%
	20 mph	0.0%	-66.7%	0.0%*	-80.4%	-50.0%	-50.0%	-95.2%	-100.0%

*Not statistically significant at 95-percent level of significance
C = Curve display sign
S = Speed display sign

Table 40. Summary of results for the CC 12 months after sign installation (part 2).

Curve		IA-14	OH-6	OH-8	OH-14	OR-4	OR-12	OR-5	OR-9
Sign Type		S	S	C	S	C	C	S	S
Road		Iowa 136	Alkire	Norton	Pontius	US 101	OR 126	US 42	OR 238
Posted		50	55	55	55	55	55	55	55
Curve Advisory		45	30	35	30	45	40	35	30
Change in Mean Speed (mph)		-2.0	-2.9	-0.2	-2.0	-5.6	-4.4	-2.3	-0.4
Change in 85th Percentile Speed (mph)		-3	-3	0	-2	-5	-4	-3	-1
Percent Change in Fraction of Vehicles Exceeding Posted or Advisory Speed by:	**5 mph**	-17.0%	-13.4%	-0.9%	-2.2%	-41.4%	-26.5%	-20.7%	-6.2%
	10 mph	-44.8%	-35.4%	-8.4%	-16.2%	-67.7%	-54.9%	-42.5%	-10.0%
	15 mph	-64.4%	-49.1%	-3.9%	-33.8%	-86.0%	-72.4%	-52.6%	-18.5%
	20 mph	-75.0%	-71.4%	-7.9%	-48.4%	-93.3%	-87.1%	-15.4%	0.0%

C = Curve display sign
S = Speed display sign

Table 41. Summary of results for the CC 12 months after sign installation (part 3).

Curve		TX-38	TX-30	TX-4	TX-39	WA-15	WA-18
Sign Type		S	C	C	C	C	S
Road		FM 481	FM 359	FM 755	US 90	US 101	SR 7
Posted		65	70	65	70	50	50
Curve Advisory		50	none	50	none	40	35
Change in Mean Speed (mph)		-0.9	-2.8	-1.4	-1.6	-2.0	3.7
Change in 85th% Speed (mph)		0	-3	1	-1	-2	2
Change in Fraction of Vehicles Exceeding Posted or Advisory Speed by:	**5 mph**	-7.7%	-55.0%	4.0%*	-52.9%	-17.4%	6.7%
	10 mph	-14.4%	-72.3%	-0.3%*	-16.7%*	-33.9%	8.9%
	15 mph	-12.7%	-87.5%	10.5%*	0.0%*	-47.4%	136.8%
	20 mph	4.7%	-85.7%	100.0%*	0.0%*	-61.5%	575.0%

*Not statistically significant at 95-percent level of significance
C = Curve display sign
S=Speed display sign

Table 42 through table 44 provide changes in speed metrics for the 24-month after period. Data are presented for 18 sites given 4 sites were no longer functioning. One site had an increase in mean speed of 2.0 mph while the remaining sites had decreases from 0.8 to 7.0 mph. Two sites experienced increases (1 and 2 mph) in 85th percentile speeds, and two sites had no change. The remaining sites had decreases in 85th percentile speed from 1 to 8 mph.

Table 42. Summary of results at the CC 24 months after sign installation (part 1).

Curve		AZ-6	AZ-2	FL-6	FL-32	FL-8	IA-10	IA-31	IA-33
Sign Type		C	S	C	S	S	C	S	C
Road		SR 377	SR 95	SR 267	SR 20	SR 20	US 30	US 67	US 69
Posted		65	55	55	55	55	55	55	55
Curve Advisory		none	45	none	45	none	none	none	50
Change in Mean Speed (mph)		-3.5	-4.1	-0.8	-1.2	-2.1	-2.0	-7.0	-1.3
Change in 85th Percentile Speed (mph)		-4	-5	-1	-1	-2	-2	-8	0
Percent Change in Fraction of Vehicles Exceeding Posted or Advisory Speed by:	**5 mph**	-69.9%	-29.6%	-23.8%	-1.1%	-48.6%	-44.0%	-74.1%	-19.3%
	10 mph	-84.5%	-53.8%	-66.7%	-6.3%	-66.7%	-67.3%	-93.7%	-22.9%
	15 mph	-79.2%	-69.2%	-100.0%	-28.1%	-60.0%	-54.5%	-97.9%	-12.5%*
	20 mph	-60.0%	-66.7%	0.0%*	-40.2%	0.0%	-50.0%	-100.0%	0.0%*

*Not statistically significant at 95-percent level of significance
C = Curve display sign
S = Speed display sign

Table 43. Summary of results at the CC 24 months after sign installation (part 2).

Curve		IA-14	OH-6	OH-8	OH-14	OR-12	OR-9	TX-38
Sign Type		S	S	C	S	C	S	S
Road		Iowa 136	Alkire	Norton	Pontius	OR 126	OR 238	FM 481
Posted		50	55	55	55	55	55	65
Curve Advisory		45	30	35	30	40	30	50
Change in Mean Speed (mph)		-1.5	-3.9	2.0	-1.9	-2.1	-1.1	-1.0
Change in 85th Percentile Speed (mph)		-1	-4	2	-2	-1	-2	0
Percent Change in Fraction of Vehicles Exceeding Posted or Advisory Speed by:	**5 mph**	-9.2%	-19.0%	5.2%	-1.8%	-12.0%	-14.5%	-7.3%
	10 mph	-25.4%	-43.1%	18.5%	-13.6%	-28.5%	-36.5%	-21.9%
	15 mph	-44.8%	-63.6%	60.5%	-32.8%	-35.4%	-40.7%	-12.0%
	20 mph	-68.8%	-73.8%	110.5%	-40.2%	-40.3%	-50.0%	15.6%

C = Curve display sign
S = Speed display sign

Table 44. Summary of results at the CC 24 months after sign installation (part 3).

Curve		TX-30	WA-15
Sign Type		C	C
Road		FM 359	US 101
Posted		70	50
Curve Advisory		none	40
Change in Mean Speed (mph)		-2.4	-1.6
Change in 85th Percentile Speed (mph)		-3	-1
Percent Change in Fraction of Vehicles Exceeding Posted or Advisory Speed by:	**5 mph**	-64.3%	-13.8%
	10 mph	-68.1%	-26.0%
	15 mph	-50.0%	-34.6%
	20 mph	-57.1%	-100.0%

C = Curve display sign
S = Speed display sign

The following figures show the distribution of results. Figure 54 shows the percent of sites experiencing changes in mean speeds of a certain magnitude. As indicated, the majority of sites had decreases in mean speeds from 1 to 4 mph.

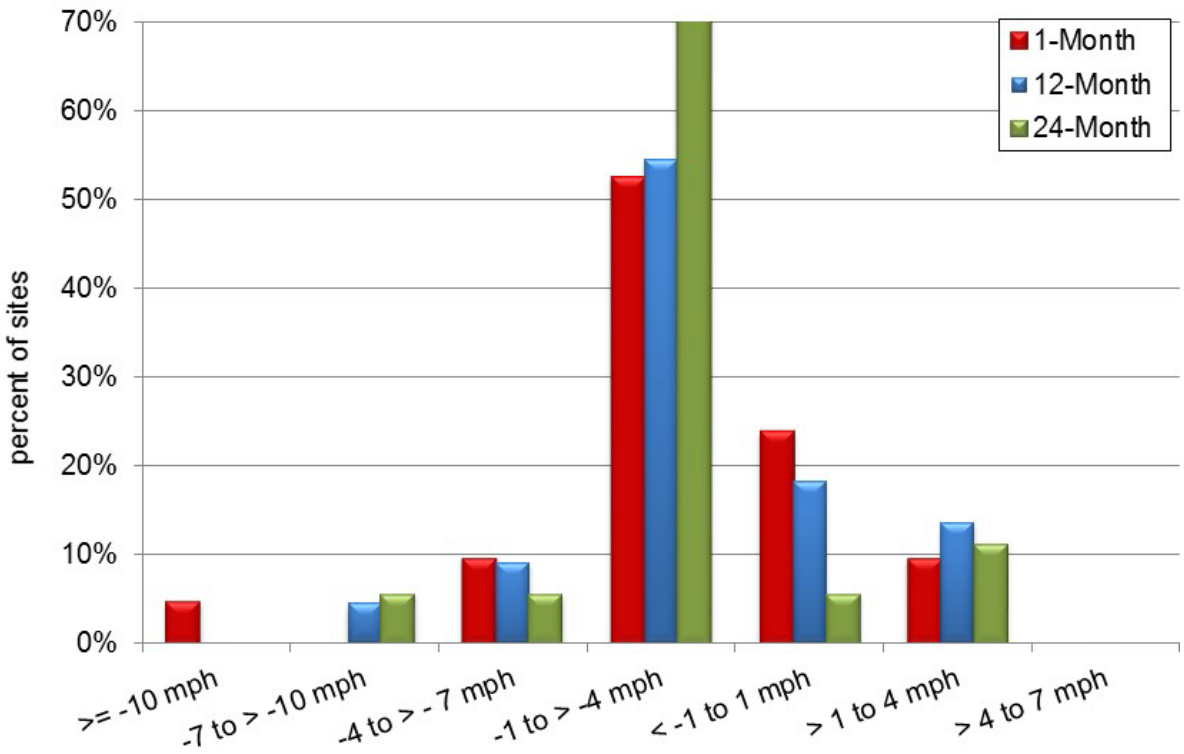


Figure 54. Chart. Percent of sites experiencing a change in mean speed of a certain magnitude at the CC.

At 1 month, 2 of the 21 sites (10 percent) had increases in mean speeds that were greater than 1 to 4 mph, 5 of the sites (24 percent) experienced virtually no change in mean speeds, and 11 sites (52 percent) experienced decreases of 1 up to 4 mph. Finally, three sites (15 percent) had decreases of 4 mph or more.

Similar results occurred for the 12-month and 24-month after periods. At 12 and 24 months, about 14 percent of sites had increases between 1 and 4 mph. Eighteen percent of sites for the 12 month after period and 6 percent for 24 months after had little change. The majority of sites (55 and 72 percent) had decreases in mean speeds from 1 to 4 mph. At 12 months, 9 percent of sites and 6 percent of sites had decreases between 4 and 7 mph, respectively. About 5 percent of sites for both the 12- and 24-month after periods had decreases of more than 7 mph.

Figure 55 shows the change in 85th percentile speeds at the CC at 1, 12, and 24 months. Overall, the majority of sites for all after periods had decreases in mean speeds from 1 to 4 mph.

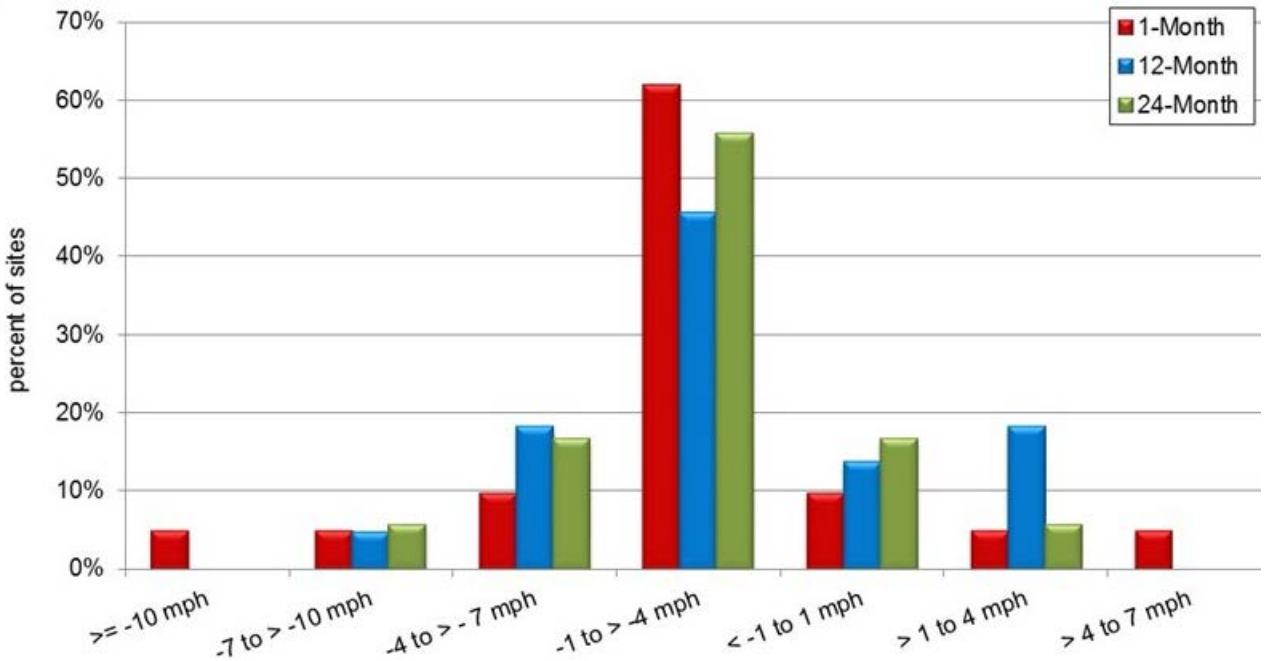


Figure 55. Chart. Percent of sites experiencing a change in 85th percentile speed of a certain magnitude at the CC.

At 1 and 24 months, two sites (about 10 percent) had increases that were more than 1 mph while, at 12 months, four sites (18 percent) saw an increase. Between 6 and 14 percent of sites experienced little change in 85th percentile speeds depending on the after periods.

Thirteen sites (62 percent) at 1 month, 10 sites (45 percent) at 12 months, and 10 sites (56 percent) at 24 months had decreases from 1 to 4 mph. Two sites (10 percent) at 1 month, four sites (18 percent) at 12 months, and three sites (17 percent) at 24 months had decreases from 4 to 7 mph. One site (about 5 percent) for each after period experienced a decrease from 7 to 10 mph, and 1 site (5 percent) at 1 month after had decreases in 85th percentile speeds that were more than 10 mph.

Results of Percent Change in Vehicles Exceeding Posted or Advisory Speed at Center of the Curve

Figure 56 through figure 59 show changes in the percentage of vehicles traveling at 5, 10, 15, or 20 mph or more over the posted speed limit or advisory speed at the CC. The figures show the percentage of sites that experienced a change within a particular range. Data are fairly consistent over the 1-, 12-, and 24-month after periods.

As shown in figure 56, 18 percent and 6 percent of sites had increases in the fraction of vehicles traveling 5 mph or more over the posted or advisory speed at the 12- and 24-month after periods, and 5 percent of sites at the 1-month after period had no change. The majority of sites (67 percent for 1 month, 59 percent for 12 months, and 65 percent for 24 months) had decreases up to 35 percent in the fraction of vehicles traveling 5 mph or more over the posted or advisory speed. About 24 percent of sites had reductions between 35 and 70 percent, and about 5 percent of sites had reductions of 70 percent or more.

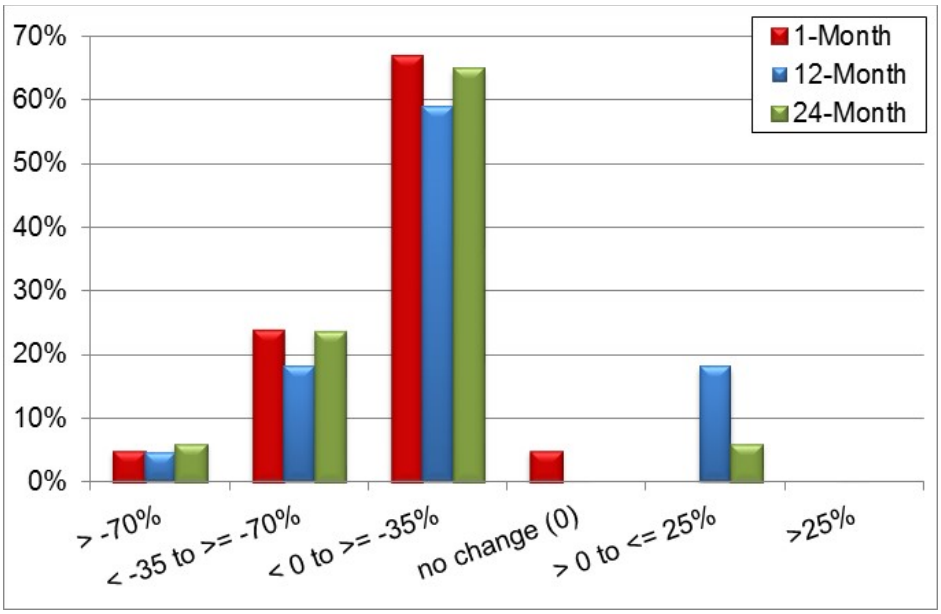


Figure 56. Chart. Changes in percent of vehicles traveling 5 or more over posted limit or advisory speed at the CC.

Figure 57 provides results for the percentage of vehicles traveling at 10 mph or more over the posted speed or advisory speed at the CC. Five to 9 percent of sites at 1 and 12 months, respectively, had increases up to 25 percent, and 10 percent and 5 percent of sites had no change for the 1- and 12-month after periods, respectively. Most sites had reductions in the fraction of vehicles traveling 10 mph or more over the posted or advisory speed up to 35 percent or between 35 and 70 percent.

About 29 percent of sites at 1 month and 41 percent of sites at 12 and 24 months experienced reductions in the fraction of vehicles traveling 10 mph or more over the posted or advisory speed. Thirty-six to 41 percent of sites had reductions between 35 and 70 percent. Finally, about 20 percent of sites at 1 month, 9 percent at 12 months, and 12 percent at 24 months had reductions in the fraction of vehicles traveling 10 mph or more over the posted or advisory speed.

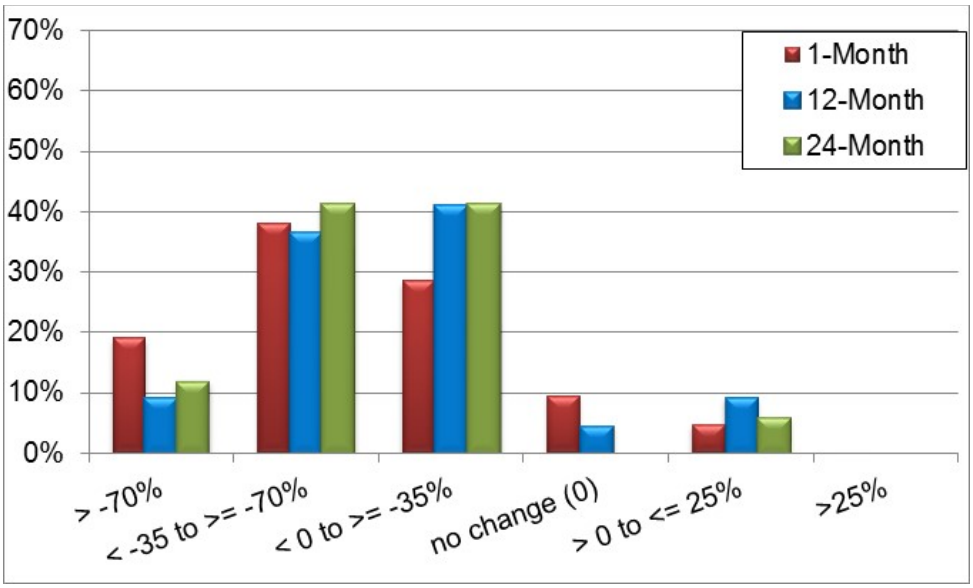


Figure 57. Chart. Changes in percent of vehicles traveling 10 or more over posted limit or advisory speed at the CC.

Similarly, figure 58 shows changes in the fraction of vehicles traveling 15 mph or more over the posted or advisory speed. Five percent of sites at 12 months had increases of more than 25 percent, and 5 percent had no change for that same time period. Between 6 and 14 percent of sites had increases of up to 25 percent.

Five percent of sites at 1 month, 18 percent at 12 months, and 35 percent at 24 months had reductions up to 35 percent in the percentage of vehicles traveling 15 mph or more over the posted or advisory speed. The majority of sites (48 percent for 1 month and 41 percent for the 12- and 2-month after periods) had decreases from 35 to 70 percent. Eighteen to 33 percent had reductions of more than 70 percent in the fraction of vehicles traveling 15 mph or more over the posted or advisory speed.

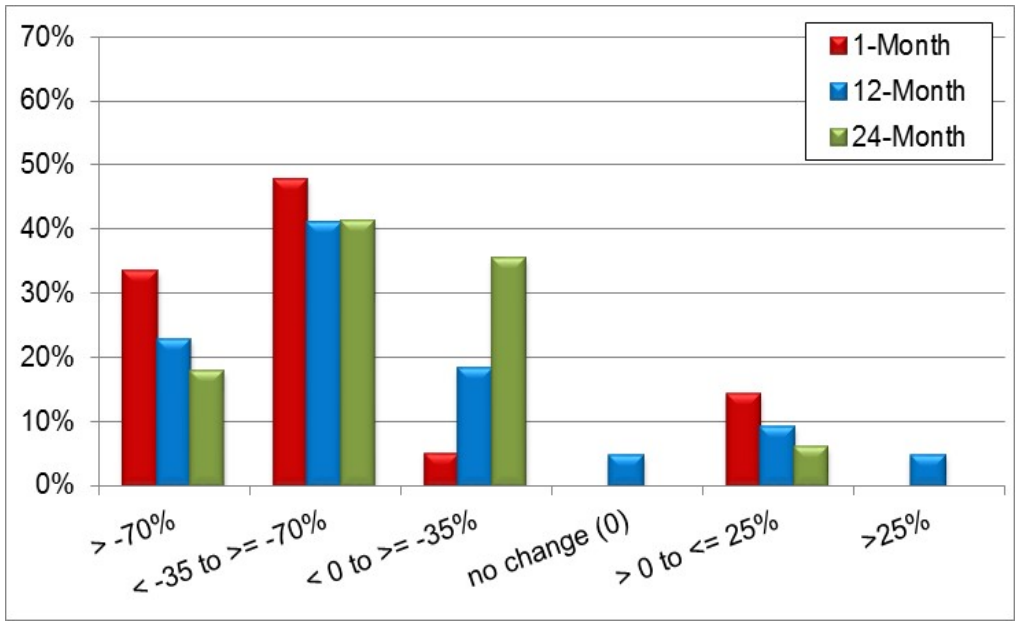


Figure 58. Chart. Changes in percent of vehicles traveling 15 or more over posted limit or advisory speed at the CC.

Figure 59 also shows results for the percent of vehicles exceeding the posted or advisory speed by 20 mph or more. One or two sites showed increases in the percent of vehicles exceeding the speed limit by 20 mph or more for the 1- and 12-month after periods, respectively. Two sites for the 24-month after period had increases from more than 1 to 10 percent. Five to nine sites (23 to 53 percent) had decreases from 35 to 70 percent.

As noted, large reductions in the number of vehicles traveling over the posted or advisory speed occurred for all of the after periods at the CC. The majority of sites had reductions up to 35 percent in the fraction of vehicles traveling 5 mph or more over the posted or advisory speed. The majority of sites had decreases up 70 percent in the fraction of vehicles traveling 10 mph or more over the posted or advisory speed. Most sites had reductions of 35 percent or more in the fraction of vehicles traveling 15 or 20 mph or more over the posted or advisory speed. These results indicate the signs were effective in reducing high-end speeds as well as average and 85th percentile speeds.

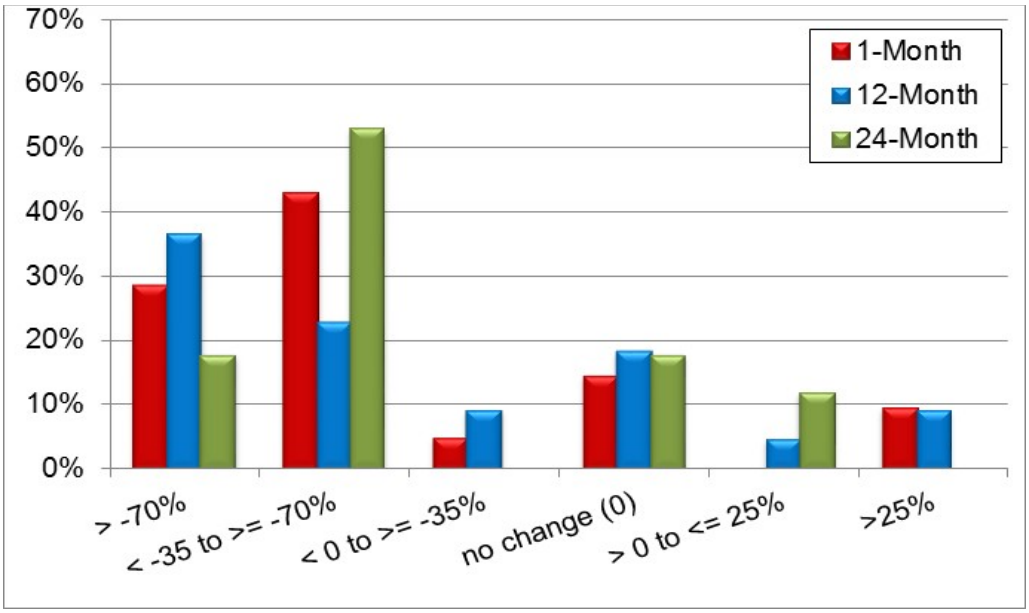


Figure 59. Chart. Changes in percent of vehicles traveling 20 or more over posted limit or advisory speed at the CC.

SUMMARY OF RESULTS BY SIGN TYPE

Results at Point of Curvature

Drivers may respond differently to different sign messages. In addition, different signs may be more effective in different situations. Given only 22 sites were included in this project, testing a range of signs with different driver messages was beyond the project scope. In addition, given the project intent was not to compare different sign types, the experiment was not designed for comparison.

However, there was some value in evaluating the data by sign type to assess whether there was evidence of differences that may lead to further research. As a result, data were disaggregated by sign type, and general comparisons were conducted. As indicated, the experiment was not set up to test differences by sign type, and the sample size is low. Consequently, caution should be used in interpreting the results.

Table 45 provides the average changes in speeds overall by after analysis period at the PC. As shown, the change in mean speed at the 1-month after period was a decrease of 1.8 mph. The average decrease in mean speed at the 12-month after period was even greater than the 1-month after period with a decrease of 2.57 mph. The average speed decrease of 1.97 mph for the 24-month after period was similar to the 1-month period.

Table 45. Average change over sites at PC.

		1 Month			12 Months			24 Months		
		All Sites	Curve Sign Sites	Speed Sign Sites	All Sites	Curve Sign Sites	Speed Sign Sites	All Sites	Curve Sign Sites	Speed Sign Sites
Average Mean Speed (mph)		-1.82	-1.68	-1.95	-2.57	-2.36	-2.54	-1.97	-1.99	-1.96
Average 85th Percentile Speed (mph)		-2.19	-1.90	-2.45	-2.86	-2.40	-2.70	-2.17	-2.00	-2.30
Average Percent Change in Fraction of Vehicle Exceeding Posted or Advisory Speed by:	**5 mph**	-11.8%	-9.8%	-13.7%	-18.6%	-22.1%	-15.0%	-19.8	-27.1%	-13.3%
	10 mph	-29.9%	-30.4%	-29.4%	-34.4%	-36.5%	-32.2%	-29.3%	-42.5%	-17.7%
	15 mph	-36.3%	-39.4%	-33.5%	-36.2%	-27.3%	-45.2%	-29.6%	-42.5%	-18.2%
	20 mph	-28.5%	-29.6%	-27.6%	-49.8%	-46.1%	-53.5%	-30.0%	-42.6%	-18.7%

The average mean speeds of sites with speed signs were higher than those with curve signs at 1 and 12 months, while the average mean speeds for sites with curve signs were slightly higher for the 24-month after period.

The changes in 85th percentile speeds for all sites was a decrease of about 2.2 mph for the 1- and 24-month after periods while the average decrease was 2.9 mph for the 12-month after period. The average changes in 85th percentile speeds were 0.55 mph higher for speed signs than for curve signs at the 1-month after period, and 0.3 mph higher for both the 12- and 24-month after periods.

Also shown in table 45, sites on average had a decrease of 12 percent in the fraction of vehicles traveling 5 mph or more over the posted or average speed limit for the 1-month after period. The fraction of vehicles traveling 10 mph or more over the posted or advisory speed decreased by an average of 30 percent for the 1-month after period and 36 percent for the fraction of vehicles traveling 15 mph or more over the posted or advisory speed. Similarly, the average decrease in vehicles traveling 20 mph or more over the posted or advisory speed was 29 percent.

Results for the 12-month after period were somewhat higher, with average decreases of 19, 34, 36, and 50 percent for the fraction of vehicles traveling 5, 10, 15, and 20 mph or more over the posted or advisory speed, respectively.

Results for the 24-month after period were similar to the 1-month after period.

Sites with speed signs had greater reductions in the fraction of vehicles traveling 5 mph or more over the posted or advisory speed at 1 month after while greater reductions were noted for sites with curve signs at the 12- and 24-month after periods.

Sites with curve signs had slightly greater decreases in the fraction of vehicles traveling 10 mph or more over the posted or advisory speed for 1 and 12 months after and a significantly higher reduction for the 24-month after period.

Sites with speed signs had much greater reductions in the fraction of vehicles traveling 15 mph or more over the posted or advisory speed at the 12-month after period while sites with curve signs had much larger reductions at 24 months. At 1 month after, reductions were similar but slightly higher for sites with curve signs.

Finally, sites with curve signs had slightly higher reductions at 1 month and much higher reductions at 24 months for the fraction of vehicles traveling 20 mph or more over the posted or advisory speed. At 12 months, sites with speed signs had moderately higher reductions.

Figure 60 through figure 62 show the percentage of sites that had a change in average speed of a certain magnitude for each after period at the PC. Results are presented by type of sign (curve advisory versus speed sign).

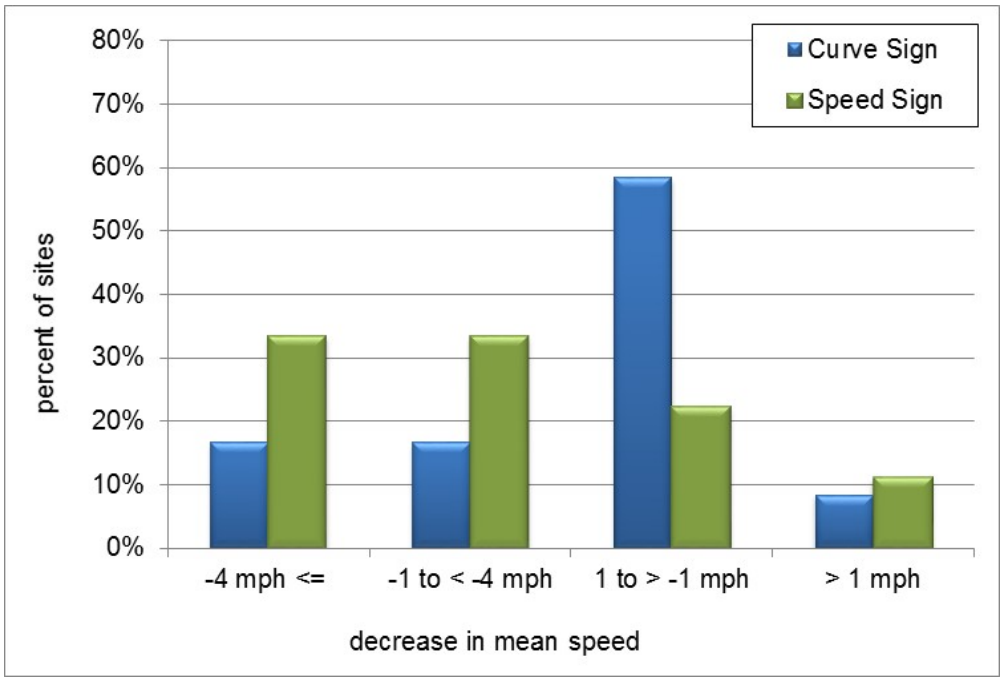


Figure 60. Chart. Changes in mean speed at the PC by sign type about 1 month after sign installation.

At 1 month, about 10 percent of sites with both sign types had increases of more than 1 mph in average speeds. The majority of sites (58 percent) with curve signs had little change in average speeds while 22 percent of sites with speed signs had little change. Seventeen percent of sites with curve signs had decreases of 1 to 4 mph, and another 17 percent had decreases of more than 4 percent, while 33 percent of sites with speed signs had decreases of 1 to 4 mph, and 33 percent had decreases of more than 4 mph.

Figure 61 shows results at 12 months, 23 percent of sites with curve signs had little change in mean speeds while 62 percent of sites with curve signs and 78 percent of sites with speed signs had a decrease in average speeds of between 1 and 4 mph. Fifteen percent of sites with curve signs and 22 percent of sites with speed signs had decreases of 4 mph or more.

Figure 62 shows results for the 24-month after period. As noted the results are very similar to the 12-month after period.

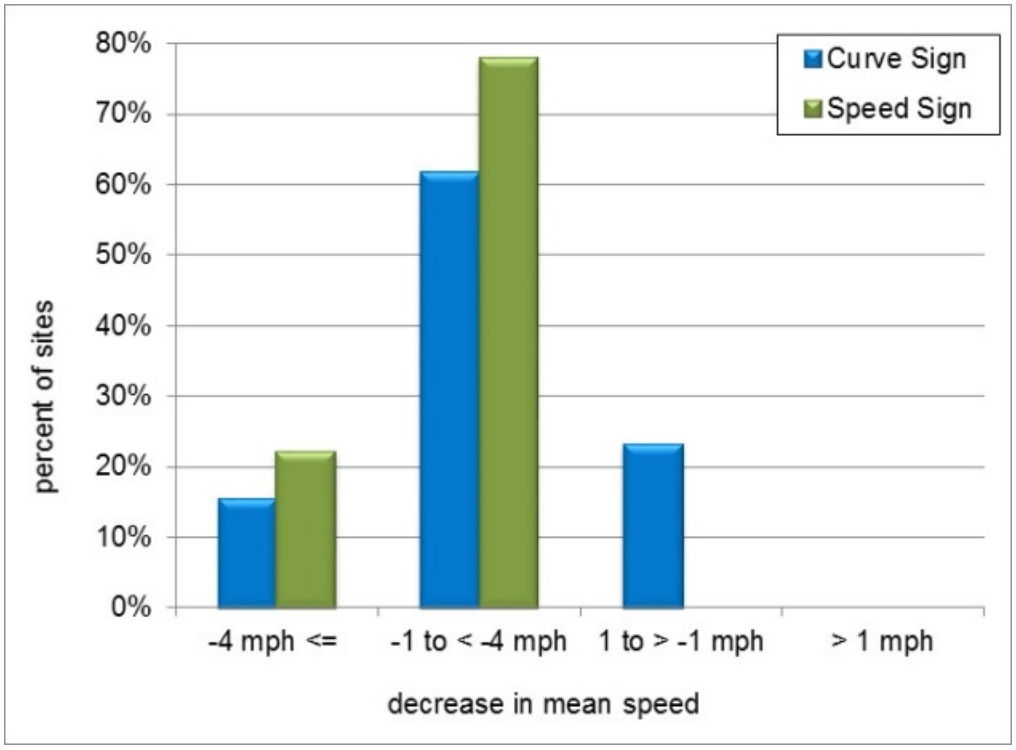


Figure 61. Chart. Changes in mean speed at the PC by sign type about 12 months after sign installation.

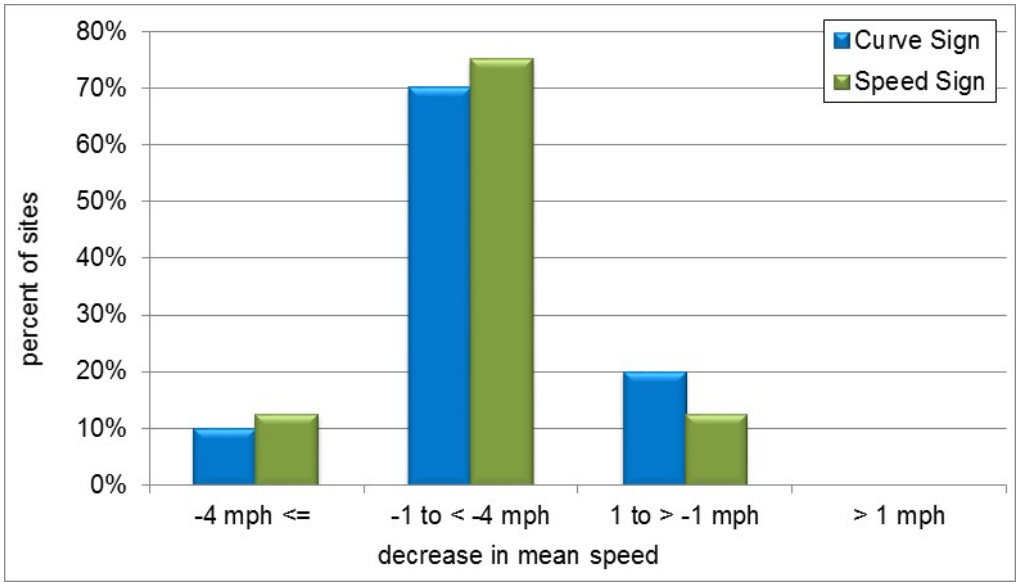


Figure 62. Chart. Changes in mean speed at the PC by sign type about 24 months after sign installation.

Figure 63 through figure 65 illustrates the percent of sites with changes in 85th percentile speeds of a certain magnitude at each after period by sign type at the PC. Results are presented by sign type.

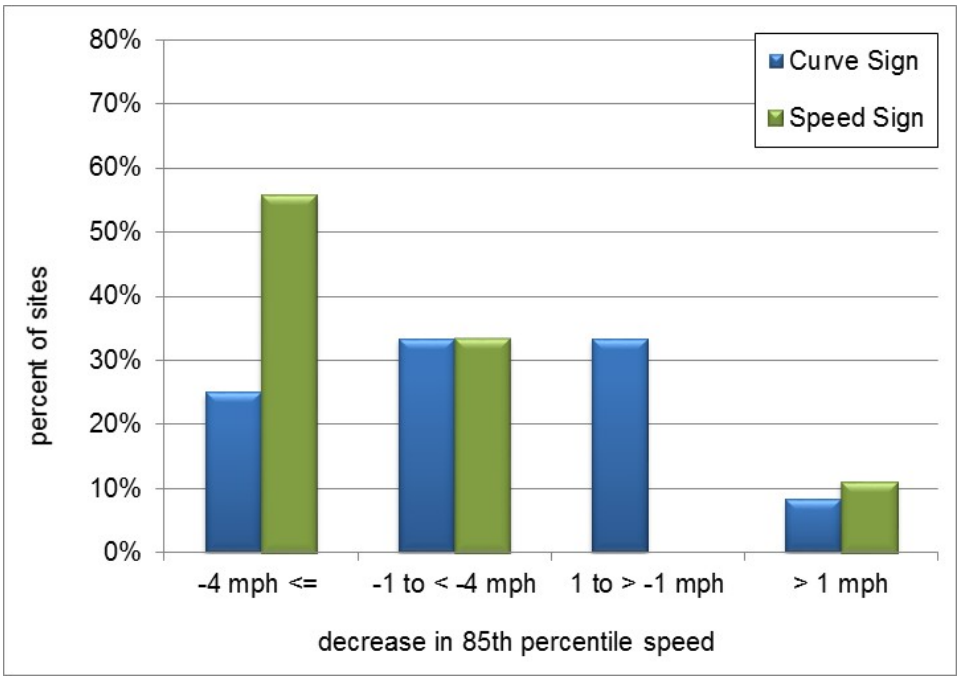


Figure 63. Chart. Changes in 85th percentile speed at the PC by sign type about 1 month after sign installation.

Ten percent of sites for both sign types experienced increases in 85th percentile speeds of more than 1 mph. Approximately one-third of sites with curve signs experienced no change while one-third of sites with both sign types had decreases between 1 and 4 mph. One-quarter of sites with curve signs and more than 50 percent of sites with speed signs had decreases of more than 4 mph.

Figure 64 shows results for the 12-month after period. About 31 percent of sites with a curve sign showed little change in 85th percentile speed. The majority of sites with both types of signs (38 percent of sites with curve signs and 56 percent of sites with speed signs) had decreases in 85th percentile speeds between 1 and 4 mph. Thirty-one percent of sites with curve signs and 44 percent of sites with speed signs experienced decreases in 85th percentile speeds of 4 mph or more.

As shown in figure 65, at 24 months, 50 percent of curve sign sites had little change in 85th percentile speeds while 13 percent of speed sign sites had no change. Forty percent of curve sign sites had decreases in 85th percentile speeds that were 1 to 4 mph, and 75 percent of speed sign sites saw the same decrease. Ten percent of curve sign sites and 13 percent of speed sign sites had decreases of 4 mph or more.

Sites with speed signs appeared to be slightly more effective based on the data described in the previous sections. To test that assumption, the researchers conducted a statistical test to evaluate

differences between sign types for both average speed differences and differences in 85th percentile speeds.

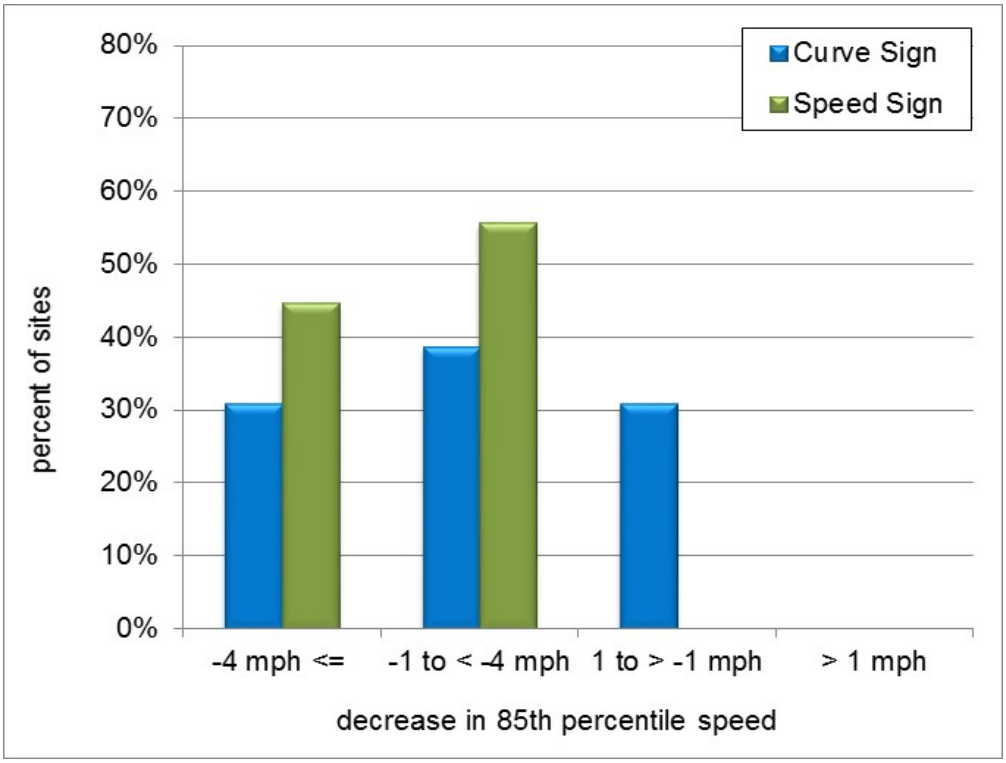


Figure 64. Chart. Changes in 85th percentile speed at the PC by sign type about 12 months after sign installation.

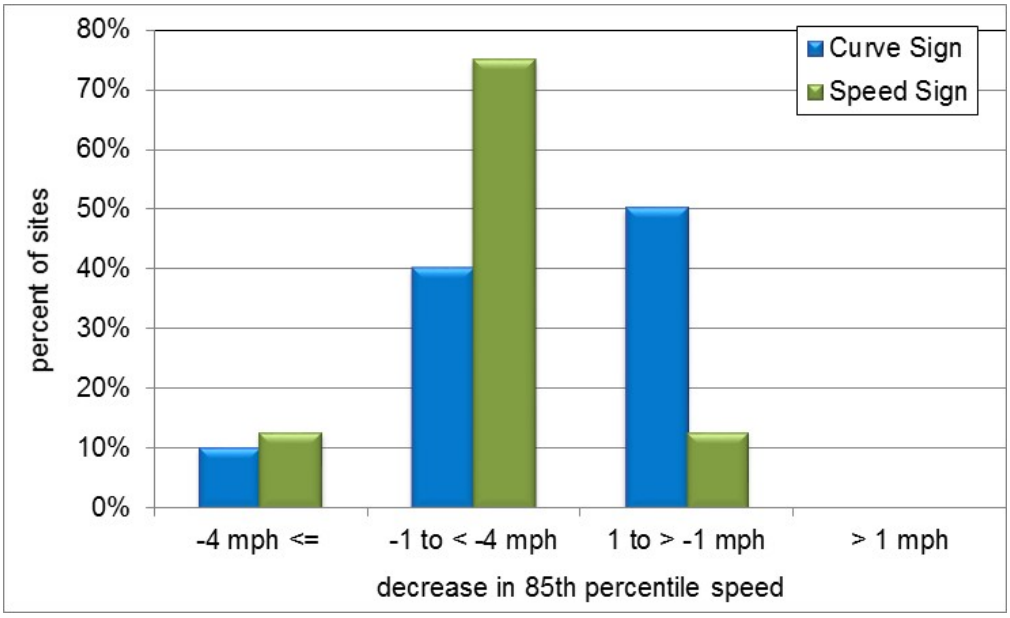


Figure 65. Chart. Changes in 85th percentile speed at the PC by sign type about 24 months after sign installation.

The data were not normally distributed, so the Wilcoxon-signed rank test, a non-parametric test, was used. Results at 1 month showed no statistically significant difference in either average speed (p = 0.39) or 85th percentile speed (p = 0.22).

Similarly, results for 12 months showed no statistically significant difference in either average speed (p = 0.20) or 85th percentile speed (p = 0.15). Results for the 24-month after period were similar, with no statistical difference in mean (p = 0.66) or 85th percentile speeds (0.29). However, results should be used with caution given the sample size is small. Consequently, there was no evidence to suggest that one sign type was more effective than the other was.

Results at the Center of Curve

Table 46 provides the average change in speed metrics over all sites by after analysis period at the CC. Results are shown for all sites as well as by sign type. As shown, the change in mean speed at the 1-month after period was a decrease of 2.1 mph. The average decrease in mean speed at the 12-month and 24-month after periods were smaller than the decrease at 1 month (1.7 and 1.8 mph). The average decrease in mean speed for sites with speed signs was greater than for sites with curve signs for all of the after periods.

Table 46. Average change over sites at CC.

		1 Month			12 Months			24 Months		
		All Sites	Curve Sign Sites	Speed Sign Sites	All Sites	Curve Sign Sites	Speed Sign Sites	All Sites	Curve Sign Sites	Speed Sign Sites
Average Mean Speed (mph)		-2.08	-2.01	-2.15	-1.65	-1.47	-1.84	-1.76	-1.46	-2.00
Average. 85th Percentile Speed (mph)		-2.52	-2.50	-2.55	-1.55	-0.82	-2.27	-1.89	-1.25	-2.40
Average Percent Change in Fraction of Vehicle Exceeding Posted or Advisory Speed by:	**5 mph**	-0.28%	-0.28%	-0.27%	-0.20%	-0.21%	-0.18%	-0.26%	-0.30%	-0.23%
	10 mph	-0.42%	-0.43%	-0.41%	-0.33%	-0.32%	-0.33%	-0.42%	-0.43%	-0.40%
	15 mph	-0.57%	-0.71%	-0.44%	-0.37%	-0.42%	-0.33%	-0.44%	-0.38%	-0.50%
	20 mph	-0.31%	-0.55%	-0.09%	-0.14%	-0.35%	0.07%	-0.37%	-0.25%	-0.47%

The average change in 85th percentile speeds for all sites was a decrease of 2.5 mph for 1 month, 1.6 mph for 12 months, and 1.9 mph for 24 months. The average decrease in 85th percentile speed was slightly higher for the 1-month after period for speed sign sites versus curve sign sites while the decrease at 12 and 24 months was much higher for speed sign sites than for curve sign sites (2.27 versus 0.82 and 2.4 versus 1.25, respectively).

The average change in the fraction of vehicles traveling 5 mph or more over the posted or advisory speed was similar for both curve- and speed-sign sites at 1 month, with curve signs having a slightly higher reduction at 12 months and a moderately higher reduction at 24 months. Both sign types produced similar reductions in the fraction of vehicles traveling 10 mph or more

over for all after periods. The reduction in the fraction of vehicles traveling 15 mph or more over the posted or advisory speed was much greater for sites with curve signs at the 1-month after period and was moderately higher for the 12-month after period. Sites with speed signs had greater reductions in the fraction of vehicles traveling 15 mph or more over the posted or advisory speed at 24 months. Results were similar for the fraction of vehicles traveling 20 mph or more over the posted or advisory speed with much greater reductions for curve signs than for speed signs at 1 and 12 months and much higher reductions for speed signs at 24 months.

The simple comparison of reductions in the fraction of vehicles traveling a certain threshold over the posted or advisory speed by sign type does not offer strong evidence that either sign type was more effective.

Figure 66 through figure 68 shows information for mean speeds at the CC by type of sign for 1 month, 12 months, and 24 months after installation of the signs.

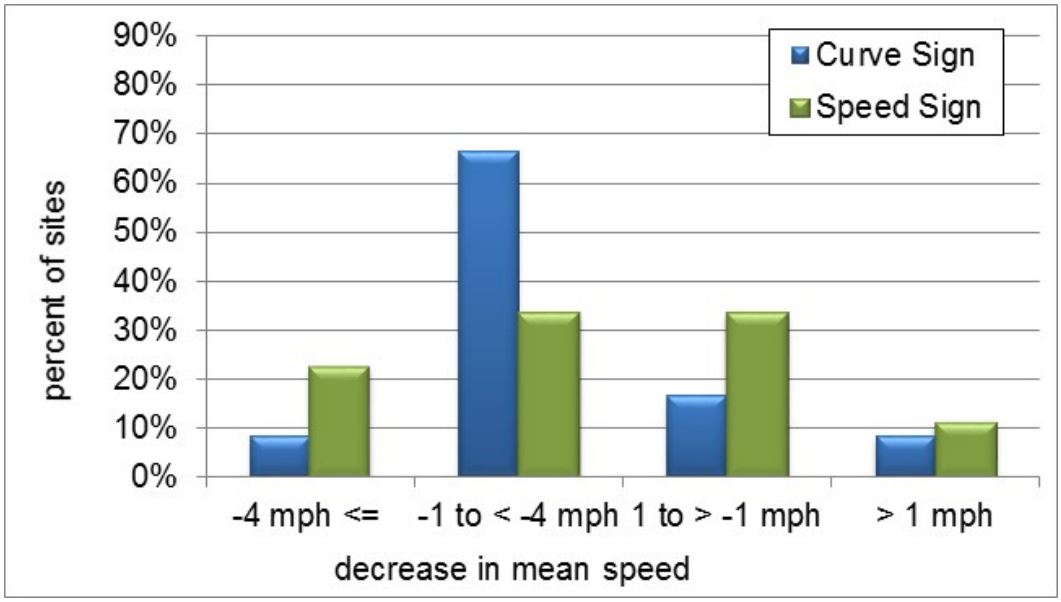


Figure 66. Chart. Changes in mean speed at the CC by sign type about 1 months after sign installation.

At 1 month, about 10 percent of both the sites with curve and speed signs had increases of 1 mph or more, while 17 percent of sites with curve signs and 33 percent of sites with speed signs had little change in mean speed (defined as changes between -1 and 1 mph). The majority of sites with curve signs (67 percent) and 33 percent of sites with speed signs had decreases from 1 to 4 mph. A small number of sites with curve signs (8 percent) and 22 percent of sites with speed signs had decreases in mean speeds of 4 mph or more.

At 12 months (figure 67), 20 percent of sites with speed signs had increases in mean speeds of 1 mph or more. Almost one-third of sites with curve signs and 10 percent of sites with speed signs had little change in mean speeds. The majority of sites for both the curve signs (50 percent) and speed signs (60 percent) experienced decreases in mean speeds between 1 and 4 mph, while 17 percent of sites with curve signs and 10 percent of sites with speed signs had decreases of 4 mph or more.

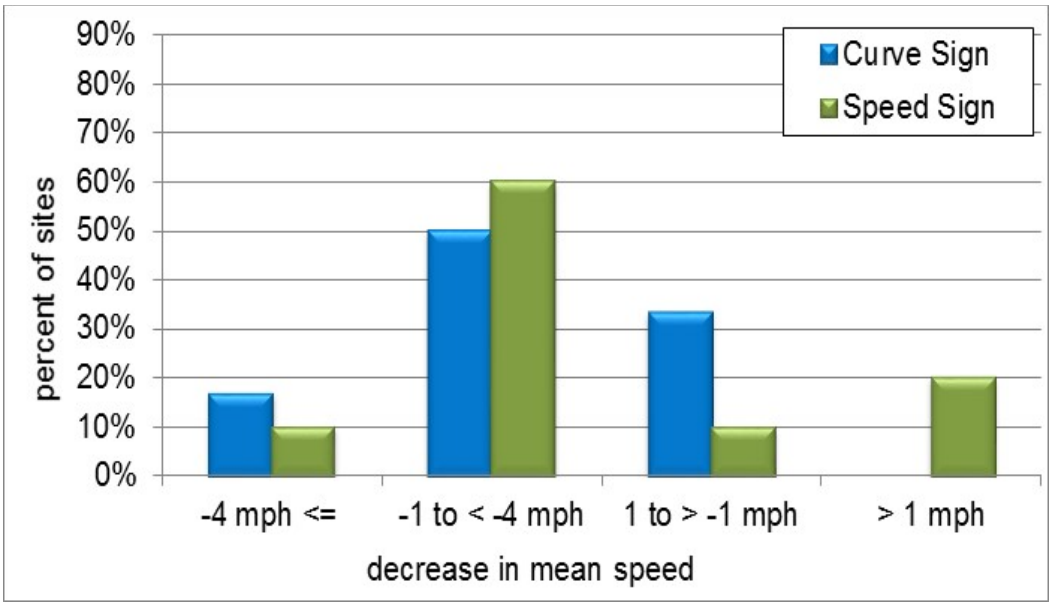


Figure 67. Chart. Changes in mean speed at the CC by sign type about 12 months after sign installation.

Figure 68 also shows changes in mean speeds by sign type for the 24-month after period. Both the curve and speed signs had increases of more than 1 mph in mean speeds, while 10 percent of curve signs had little change in mean speeds. Eighty percent of curve signs and 63 percent of speed signs had decreases between 1 and 4 mph. One-quarter of the speed signs had decreases of 4 mph or more at the 24-month after period.

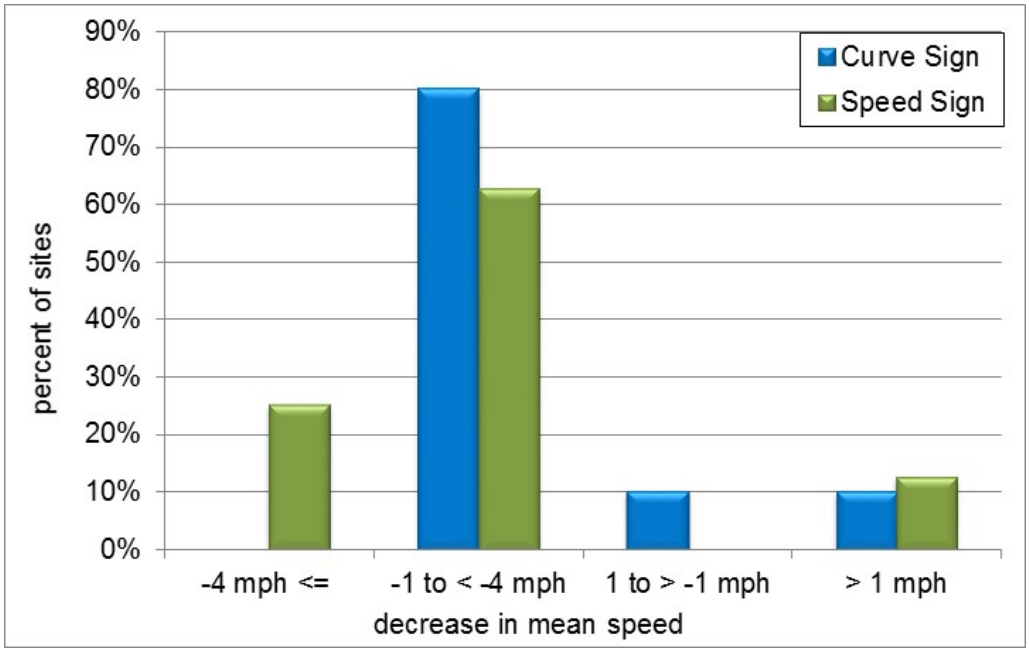


Figure 68. Chart. Changes in mean speed at the CC by sign type about 24 months after sign installation.

Differences in 85th percentile speeds between sign types for data collected at the CC are shown in figure 69 through figure 71 for 1, 12, and 24 months after installation of the signs.

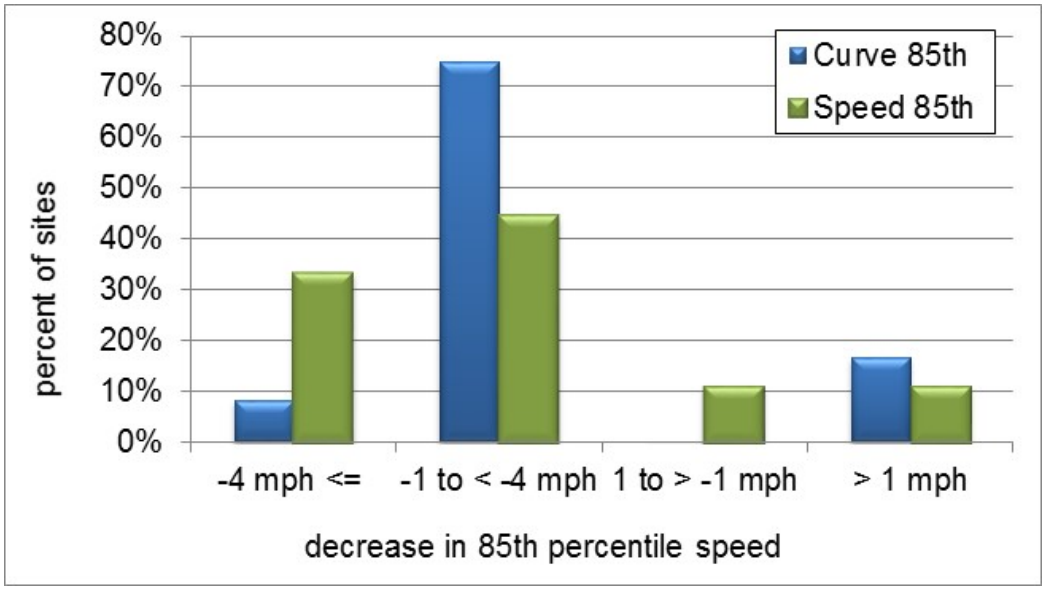


Figure 69. Chart. Changes in 85th percentile speed at the CC by sign type 1 month after sign installation.

Seventeen percent of sites with curve signs and 11 percent of sites with speed signs at 1 month after had increases in 85th percentile speeds that were more than 1 mph. Another 11 percent of sites with speed signs had no change in 85th percentile speeds (defined as a change between -1 and 1 mph).

The majority of sites for both sign types (75 percent for curve signs and 44 percent for speed signs) had decreases in 85th percentile speeds between 1 and 4 mph. A small number of sites with curve signs (8 percent) and 33 percent of sites with speed signs had decreases that were 4 mph or more.

At 12 months (figure 70) after, similar numbers of sites (17 percent for curve sign sites and 20 percent for speed sign sites) had increases in 85th percentile speeds that were more than 1 mph, while 17 percent of sites with curve signs and 10 percent of sites with speed signs experienced little change. The majority of sites (50 percent of curve signs and 40 percent of speed signs) also experienced decreases between 1 and 4 mph. Seventeen percent of sites with curve signs and 30 percent of sites with speed signs had decreases in 85th percentile speeds that were 4 mph or more.

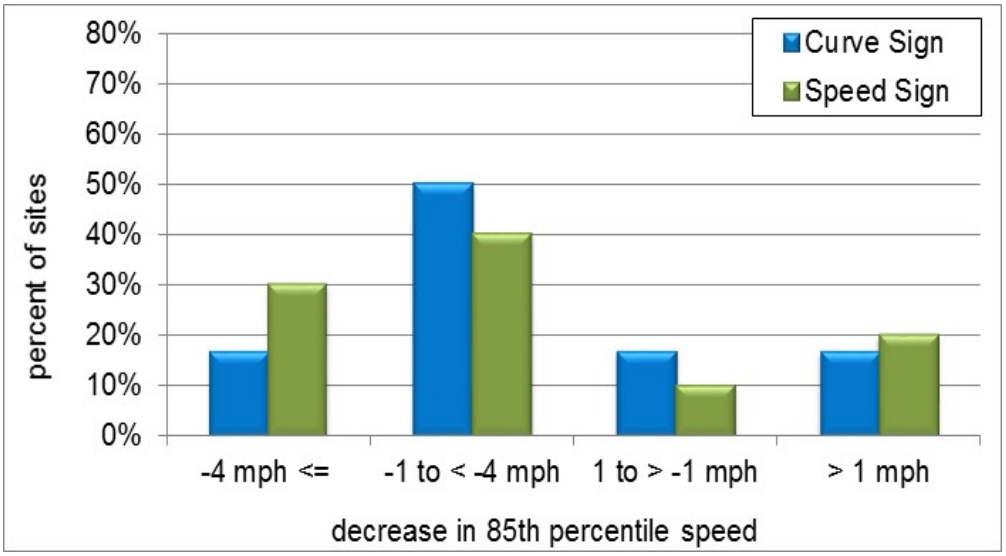


Figure 70. Chart. Changes in 85th percentile speed at the CC by sign type 12 months after sign installation.

Figure 71 also shows changes in 85th percentile speeds for the 24-month after period. About 10 percent of sites for both curve and speed signs had increases of more than 1 mph and no change. Eight percent of curve signs and 63 percent of speed signs had decreases of 1 to 4 mph, and 10 percent of curve signs and 38 percent of speed signs had decreases of more than 4 mph.

Similar to results at the PC, sites with speed signs appeared to be slightly more effective based on the information provided in figure 66 through figure 71. A Wilcoxon-signed rank test was also used to evaluate differences between sign types for both average speed differences and differences in 85th percentile speeds.

Results for 1 month after showed no statistically significant difference in either average speed ($p = 0.64$) or 85th percentile speed ($p = 0.11$) by sign type. Similarly, results for 12 months after showed no statistically significant difference in either average speed ($p = 0.63$) or 85th percentile speed ($p = 0.35$). At 24 months, results showed no difference ($p = 0.69$) in mean or 85th percentile speed ($p = 0.92$). Results suggest that there is no evidence of a difference in effectiveness between sign types at the CC. However, results should be used with caution given the sample size is small.

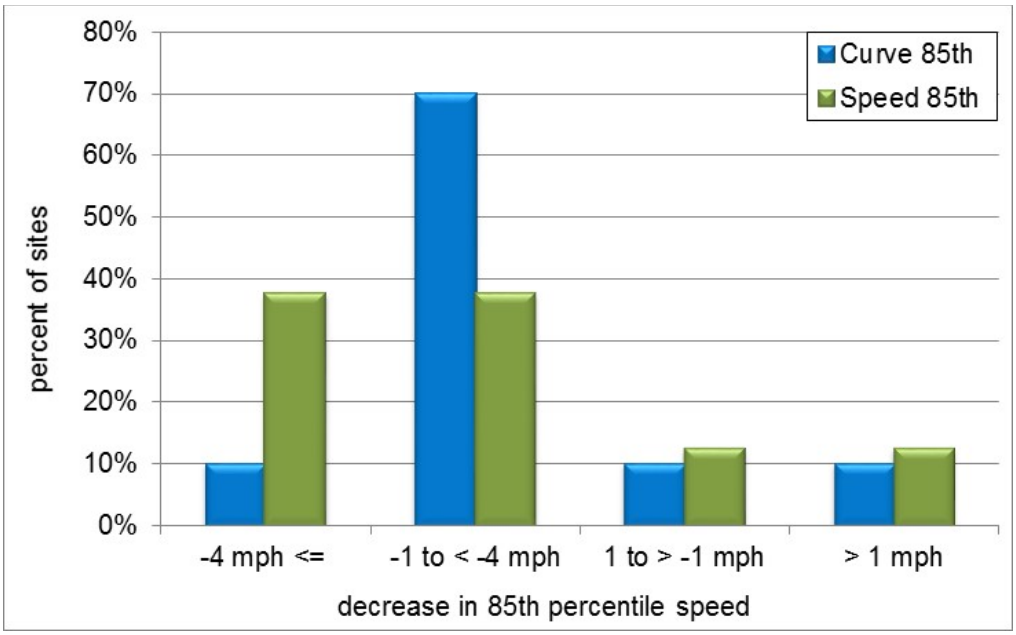


Figure 71. Chart. Changes in 85th percentile speed at the CC by sign type 24 months after sign installation.

COMPARISON OF MEAN AND 85TH PERCENTILE SPEED CHANGES OVER TIME

Data were collected over a period of 2 years to assess whether regular drivers become habituated to the signs, which might lessen their effectiveness. Table 45 showed the average change in mean and 85th percentile speed at the PC. The average change in mean speed at 1 month was -1.82 mph and the average changes at 12 and 24 months (-2.57 and -1.97 mph, respectively) were greater than at the 1-month after period. The average change in 85th percentile speed at the PC was similar for the 1- and 24-month after periods (-2.19 and -2.17 mph, respectively) and the decrease was greater at 12 months (-2.86 mph) than at 1 month. These data anecdotally suggest that the signs remained effective over time.

To test that assumption, a Wilcoxon-signed rank test was used to evaluate differences among the 1-, 12-, and 24-month after periods. The Wilcoxon-signed rank test is a non-parametric test and was used given the data were not normally distributed. The test compares the absolute value of the differences among observations, which are ranked from smallest to largest.

The individual changes in mean and 85th percentile speeds for sites at the PC were compared using the Wilcoxon-signed rank test. Results of the analysis indicated no statistical difference between changes in mean speeds at the PC for any of the time periods. The following shows the test statistics:

- 1 and 12 months ($p = 0.29$).
- 1 and 24 months ($p = 0.43$).
- 12 and 24 months ($p = 0.43$).

Similarly, no statistically significant differences in the change in 85th percentile speeds at the PC were noted with the following test statistics:

- 1 and 12 months (p = 0.45).
- 1 and 24 months (p = 0.60).
- 12 and 24 months (p = 0.36).

As shown in table 46, the average changes in mean speeds at 1, 12, and 24 months at the CC were -2.08, -1.65, and -1.76 mph, respectively. The average changes in 85th percentile speeds at the CC were -2.52, -1.55, and -1.89 mph for the 1-, 12-, and 24-month after periods, respectively. In both instances, the average decreases in speeds at the CC at 1 month were slightly greater than for the 12- or 24-month after period.

To test whether the differences were statistically significant, the individual changes in mean and 85th percentile speeds for sites at the CC were compared using the Wilcoxon-signed rank test. As shown by the test statistics below, there were no statistically significant differences between changes in mean speed across sites over the three after periods:

- 1 and 12 months (p = 0.87).
- 1 and 24 months (p = 0.99).
- 12 and 24 months (p = 0.88).

Results were similar for changes in 85th percentile speeds at the CC. As indicated, there were no statistically significant differences in changes in 85th percentile speeds across sites:

- 1 and 12 months (p = 0.53).
- 1 and 24 months (p = 0.50).
- 12 and 24 months (p = 0.98).

As indicated, changes in mean and 85th percentile speeds appeared to be consistent across the three after periods. This suggests the signs may have a long-term impact on speed.

STUDY LIMITATIONS/EXPERIMENTAL CONSIDERATIONS FOR SPEED DATA COLLECTION

The data collection methodology selected to compare speeds before and after installation of the DSFS system was based on the team's and project monitor's assessment of what was considered common practice and what was both practical and economically feasible given project resources. However, the team acknowledges that there are certain limitations with field studies in general and in the data collection method selected.

Comparison of speeds before and after installation of a countermeasure can be challenging, given speeds can vary for a number of reasons independent of the treatment. Speeds can vary as a result of temporal or seasonal fluctuations, weather, driver expectation of enforcement, etc. The ideal method to control for temporal and seasonal fluctuations would have been to collect data continuously for an entire year before installation of the signs and then for the 2 years after. However, installation of semi-permanent data collection devices was not practical or economical.

The major emphasis of this research project was to develop crash modification factors (CMF) for DSFS systems. Treatment and control sites were selected for the crash analysis. Ideally, speed data would also have been collected at the control sites so that speed fluctuations independent of the treatment could be assessed. However, given the magnitude of data collection and reduction required for the speed study, resources were not available to collect speed data at the control sites. As a result, control sites were used only for the crash analysis. It was decided, therefore, to use a location upstream from each treatment site as a comparison location for that site for the speed study as described in chapter 5. The intent of the comparison location was simply to identify any unusual trends in speed that might have been occurring independent of the treatment. The comparison locations were not intended to be true "control" locations whereby some statistical analysis could be conducted to compare speed trends unrelated to the treatment.

The impacts of temporal and seasonal fluctuations were minimized as much as possible. Based on the assumption that travel patterns are reasonably consistent for a given time period over several years, data were collected during the same month each year to minimize the impact of seasonal fluctuations. In addition, data were collected only during weekdays and weekends, and holidays were avoided. Unusual events and adverse weather were also avoided, and it was assumed that enforcement was consistent from the before to the after periods.

Data were also collected and reduced using a minimum 48 h so that temporal fluctuations over the course of the day were accounted for. An interval of 24 h was used for about 15 percent of sites owing to various issues with data collection. Use of increments of 24 h ensures that no time periods are over-represented (i.e., each hour of the day was represented the same number of times). However, the team acknowledges these assumptions may not have been valid and that there are a number of other factors that may have affected the speed data.

To account for unknown factors in some measure, data were also collected at a location that was approximately 0.5 miles upstream of the curve to serve as a monitoring (comparison) location. This distance was selected because it was far enough upstream that the sign would not be visible to drivers. It was assumed that vehicles at this location would not have been influenced by the sign and data would represent normal driving. As a result, this location was used to monitor whether speeds had fluctuated independent of the DSFS system. The impact of increases or decreases in speeds at these monitoring locations is discussed for each individual site in appendix A.

Consideration was given to using statistical methods to account for any upstream changes. If the data were perfectly normally distributed, the data at the PC and CC could be adjusted to account for the changes upstream. However, the speed data were slightly non-normal, particularly in the tails of the distribution. And, of course, the study team's major interest in the speed data is the upper tail of the distribution because high speeds are of concern. The non-normal nature of the tails of the distribution did not affect the use of the *t*-test to compare means. It would have been possible to adjust the means at the PC and CC. However comparisons of the 85th percentile speed and the percentage of vehicles traveling 5, 10, 15, or 20 mph over the posted or advisory speed would have been influenced by differences in the tails of the distributions. As a result, it was not possible to adjust the distributions to account for changes. Given that an acceptable statistical method to account for any upstream changes was not available, these data are included as a qualitative assessment in the discussion of each of the test sites in appendix A.

Although the upstream data collection point (the monitoring, or comparison location) was typically far enough from the curve that it should not have affected driver behavior, in some cases, drivers may have been able to see the sign activated for drivers ahead of them. This may have had some impact at the monitoring location. The monitoring point could have been set further upstream. However, it was critical to avoid intersections and other access points where drivers could turn onto or off the system, so that the same drivers would pass over both the upstream monitoring and curve data collection locations.

Some other data collection methods may have better accounted for temporal and seasonal fluctuations. One method that accounts for speed trends when comparing before and after speeds is to track vehicles between points and then compare changes in individual vehicle speeds between those points (Donnell et al. 2006). This method can also be used to remove vehicles that turn onto or off a roadway just prior to a countermeasure. Vehicles between points can be tracked by collecting data using road tubes with synchronized counter times. Vehicles are then matched up between counter locations using headway and vehicle type.

In this study, data were collected at three locations at 22 curves for four time periods (before, 1 month after, 12 months after, and 24 months after), resulting in 264 datasets for seven States. Tracking vehicles using the counters and road tubes was considered but, given the scale of the data collection effort and available project resources, it was decided that the use of synchronized counters and road tubes was not feasible.

The use of video data recording was also considered. However, the costs to collect and process data were prohibitive. In addition, at many of the sites, it would have been impossible to place a camera unobtrusively in a location that would allow vehicles to be tracked over a significant distance during both day and night conditions.

Another methodological issue that needs to be discussed is the exact placement of the speed recorders. The recorders could have been placed anywhere before or within the curve. Ideally, it would have been desirable to identify the magnitude and the location of each driver's speed change. However, this cannot be done easily, given that each driver slows at a different point and each roadway varied in setting, and the location at which drivers begin to slow may be different for nighttime versus daytime. In addition, regardless of where drivers begin to slow, curve entry speed determines whether they can negotiate the curve successfully or not. As a result, it was decided that speeds at the PC and the CC accurately reflect operational conditions at the site and are therefore appropriate for a before/after experimental design.

CHAPTER 7. CRASH ANALYSIS

A crash analysis was conducted in addition to the speed analyses. Crash data were collected for up to 4 years before and up to 3 years after sign installation. To select treatment and control sites, crash data for 3 years before installation of the signs and for all sites except Iowa were requested from the corresponding State or county agency as described in chapter 2.

The team had access to the Iowa crash database and was able to extract all the necessary crash variables for Iowa. Once the signs had been installed for at least 2 years in other States, the team contacted the corresponding State or county agency again and requested crash data for the intervening period from the original data request before sign installation. In some cases, more than 2 years had elapsed, and the agency provided more than 2 years of data.

VARIABLES

Several models were developed that included different types of crashes. In all cases, quarterly crash frequency was the response variable used. Data were aggregated to quarters rather than years since given a limited amount of after periods were available, and use of quarters allowed the quarter in which installation occurred to be excluded from the analysis without having to exclude the entire installation year. In addition, the signs were not functioning at several sites for various periods, so the quarter in which the signs were nonfunctional could also be excluded from the analysis. Year and quarter when a crash occurred were derived from the date of crash.

Use of quarters also allowed season to be included as a covariate. A relationship between crashes and season is expected, given more crashes may occur during winter or regular wet weather conditions. More crashes may also occur in the summer months when more driving occurs. Quarters were designated using the following convention, which aggregates months during which weather conditions were the most likely to be similar:

- Winter (December, January, February).
- Spring (March, April, May).
- Summer (June, July, August).
- Fall (September, October, November).

In addition, use of season as a covariate allowed the team to account for differences that may have occurred due to an unequal distribution of quarters in the before and after period.

The following four different models were developed:

- Total crashes at section for both directions of travel.
- Total crashes at section by direction.
- SV crashes for both directions of travel.
- SV crashes by direction.

Crashes for vehicles traveling in the direction of the DSFS sign were evaluated separately because the sign was most likely to reduce crashes for vehicles traveling in that direction. A

model was also developed for crashes in both directions (total crashes) because slowing vehicles in one direction may have some impact on vehicles in the opposite direction.

When aggregated by direction, crashes for single vehicles traveling in the indicated direction and multivehicle crashes where one or more vehicles were traveling in the indicated direction were included. At treatment sites, the direction included was the direction of the sign (i.e., WB). The signs were installed to face the direction where most crashes had occurred based on preliminary crash data. In all cases, this was in the direction of the outside of the curve. Given the primary direction for treatment sites was the outside of the curve, crashes in the direction of the outside curve were aggregated by quarter for control sites as well.

An attempt was made to develop a model for fatal crashes. However, the number of fatal crashes per site was low, and there were not sufficient data to develop a reliable model.

AADT was used as a measure of exposure. Given the study period was fairly short term, in most cases, AADT was the same or similar for the before and after periods. When possible, the team requested data for only the curve of interest (treatment or control). However, different States geolocate crashes differently, so in some cases, the agency provided crashes for a section that may have included adjacent curves and some tangent sections. To account for differences in curve and section length, section length was also modeled as a covariate.

Table 47 describes the covariates included in the models. Originally, the team intended to include a number of factors in the crash analysis, such as whether the crash had been designated as speed related, time of day, crash type, and so forth. However, variations existed across States both in the fields included on crash forms and in the precision with which a particular field was collected. Consequently, differing levels of detail were provided by the various States. For instance, not all States had a reliable indicator of whether a crash was speed related. Roadway width and shoulder type were similar across sites (11- to 12-ft lanes, earth/gravel shoulders), so these variables were not included in the analysis.

Table 47. Description of covariates.

Name	Description	Range	Categorical Value	
SiteID	Unique identifier for each site, used to account for repeated observations	NA	NA	
Volume	Annual average daily traffic	400 to 8,400 vpd	NA	
Season	Season of the year	Categorical	Winter	
			Spring	
			Summer	
			Fall	
SignType	Type of sign	Categorical	0	control site
			1	speed sign
			2	curve advisory sign
Tangent	Posted speed limit	50 to 65	NA	
Advisory	Curve advisory speed limit	None and 15 to 50	NA	
SpeedDiff	differential of posted and advisory speed	0 to 40 mph	NA	
CurveType	Type of curve	Categorical	0	isolated curve
			1	S-curve[1]
			2	Several closely spaced[1]
Length	Length of treatment or control section; accounts for different section lengths	0.40 to 2.0 miles	NA	
Period	Installation period	Categorical	0	Control
			1	Before installation of sign
			2	Install quarter or quarter when signs were not functioning
			3	After sign installation
Radius	Radius of curve	138 to 5,953 ft	NA	
Year-2004	Year after 2004, included to show trend over time	Categorical	NA	

NA = Not applicable
vpd = Vehicles per day
[1]About 500 ft or less spacing between curves

DESCRIPTIVE STATISTICS

A simple analysis of the crash data was first conducted to assess general trends. Data were aggregated by State because sites within each State had similar before and after periods. Data were also aggregated overall. Crash rate per quarter was calculated using the equation in figure 72.

$$CR_{ij} = \frac{Crash_{ij}}{Qtr_{ij}}$$

Figure 72. Equation. Calculation of crash rate per quarter.

Where:

CR_{ij} = crash rate per quarter for period j for State *i*.
$Crash_i$ = number of crashes for period *j*.
Qtr_j = number of quarters for period *j*.

Change in crash rate per quarter was calculated by subtracting crash rate for the before period from the after period, so a negative number indicates a decrease in crash rate. Crash rate was calculated for total crashes and SV crashes. Results are similar given most crashes were SV crashes. Crash rate was compared by State and was compared across the entire study.

Table 48 shows results for both directions. The number of sites included in the analysis is also shown. A few sites had problems with data and were not included in the final analysis. As indicated, total crashes in the before period ranged from 0.10 to 1.02 crashes per quarter for control sites and from 0.13 to 1.14 for treatment sites. In the after period, total crashes per quarter ranged from 0.07 to 0.74 and 0.11 to 0.86 for treatment sites.

Two States had an increase in total crashes per quarter for control sites (Florida and Texas) from the before to after period while the remaining States had decreases ranging from 0.08 to 0.28. Two States (Florida and Texas) had an increase in total crashes per quarter (0.13 and 0.01) for treatment sites, with the remaining States having decreases that ranged from 0.16 to 0.64. In all States except Florida and Texas, treatment sites had much larger decreases in crash rates than the control sites.

Table 48 also provides crash rates for SV crashes for both directions. SV crashes for both directions ranged from 0.08 to 0.74 for control sites and 0.05 to 1.07 crashes per quarter for the before period. The SV crash rate ranged from 0.06 to 0.59 for control sites and 0.14 to 0.50 for treatment sites in the after period.

Florida experienced increases in SV crashes at control sites from the before to after period (with an increase of 0.17 crashes per quarter), with the remaining States having decreases from 0.02 to 0.15. All test States except Texas had decreases in SV crashes per quarter from the before to after period, ranging from 0.03 to 0.63 crashes per quarter. In many cases, the decrease in crash rate for treatment sites was two to three times that for the control sites.

Crash rate for total crashes for all control sites is 0.48 for the before period and 0.40 for the after period, with a change of -0.08 (17-percent decrease). Crash rate for total crashes for treatment sites is 0.55 before and 0.33 after, with a change of -0.22 crashes per quarter (40-percent decrease). The SV crash rate across sites is 0.38 for the before and 0.31 after for control sites, and 0.45 before and 0.24 after for treatment sites, resulting in change of -0.07 (19-percent decrease) for control sites and a -0.21 change for treatment sites (47-percent decrease). The decrease in crashes at treatment sites was 2.75 to 3.0 times higher than at control sites.

Table 48. Simple before and after comparison of crashes for both directions.

		Number of Sites	Before		After		Change	
			Total Crashes (crashes/qtr)	SV Crashes (crashes/qtr)	Total Crashes (crashes/qtr)	SV Crashes (crashes/qtr)	Total crashes/qtr (percent change)	SV crashes/qtr (percent change)
Florida	Control	2	15 (0.50)	10 (0.33)	9 (0.56)	8 (0.50)	0.06 (13%)	0.17 (52%)
	Treatment	2	22 (0.73)	16 (0.53)	12 (0.86)	7 (0.50)	0.13 (18%)	-0.03 (-6%)
Arizona	Control	3	23 (0.55)	22 (0.52)	11 (0.41)	10 (0.37)	-0.14 (-25%)	-0.15 (-29%)
	Treatment	2	17 (0.61)	14 (0.50)	2 (0.11)	1 (0.06)	-0.50 (-82%)	-0.44 (-89%)
Washington	Control	3	43 (1.02)	31 (0.74)	29 (0.74)	23 (0.59)	-0.28 (-27%)	-0.15 (-20%)
	Treatment	2	32 (1.14)	30 (1.07)	9 (0.50)	8 (0.44)	-0.64 (-56%)	-0.63 (-59%)
Iowa	Control	6	44 (0.49)	36 (0.40)	26 (0.36)	19 (0.26)	-0.13 (-26%)	-0.14 (-34%)
	Treatment	4	34 (0.53)	26 (0.41)	12 (0.28)	6 (0.14)	-0.25 (-47%)	-0.27 (-66%)
Ohio	Control	3	6 (0.15)	5 (0.13)	2 (0.07)	2 (0.07)	-0.08 (-55%)	-0.06 (-45%)
	Treatment	3	24 (0.62)	22 (0.56)	10 (0.33)	9 (0.30)	-0.29 (-47%)	-0.26 (-46%)
Oregon	Control	5	36 (0.48)	29 (0.39)	17 (0.43)	11 (0.28)	-0.06 (-11%)	-0.11 (-29%)
	Treatment	4	26 (0.42)	21 (0.34)	6 (0.26)	5 (0.22)	-0.16 (-37%)	-0.12 (-35%)
Texas	Control	3	4 (0.10)	3 (0.08)	2 (0.11)	1 (0.06)	0.01 (8%)	-0.02 (-28%)
	Treatment	3	5 (0.13)	2 (0.05)	2 (0.14)	2 (0.14)	0.01 (11%)	0.09 (179%)
All sites	Control	25	171 (0.48)	136 (0.38)	96 (0.40)	74 (0.31)	-0.08 (-17%)	-0.07 (-19%)
	Treatment	20	160 (0.55)	131 (0.45)	53 (0.33)	38 (0.24)	-0.22 (-40%)	-0.21 (-47%)

SV = Single-vehicle
qtr = Quarter

Table 49 shows results for crashes that were in the direction of the sign for treatment sites and in the direction of the outside curve for control sites. As shown, the crash rate for total crashes per quarter was 0.08 to 0.74 for the before period and 0.0 to 0.56 for the after period for control sites. The crash rate for total crashes per quarter was 0.11 to 0.64 in the before period and 0.0 to 0.50 in the after period for treatment sites.

Iowa had an increase in crash rate of 0.23 for control sites, and Texas had an increase of 0.03. Decreases from 0.03 to 0.21 crashes per quarter at control sites were found for the other States. Florida, Iowa, and Oregon had minor increases in crashes (0.01 to 0.07) for the after period for treatment sites. The remaining States had decreases in SV crashes for treatments from 0.11 to 0.42 crashes per quarter. In most cases, the decreases were two to six times higher for treatment sites than control sites.

Before-installation results for SV crashes ranged from 0.05 to 0.45 crashes per quarter for control sites and 0.06 to 0.61 for treatment sites. After-installation SV crash rates ranged from 0.0 to 0.41 for control sites and 0.0 to 0.29 for treatment sites.

Results for control sites showed that one State (Iowa) had an increase of 0.11, and Texas had no change in SV crash rate from the before to after period, with the remaining States experiencing decreases from 0.04 to 0.20.

Results for treatment sites indicated that Florida had an increase in the SV crash rate of 0.06, and all other States had decreases from 0.01 to 0.44 from the before to after period. When decreases were noted, treatment sites had significantly greater decreases than control sites. Overall, treatment sites experienced decreases that where three to four times greater than those at control sites.

Results by direction were averaged across States, with crash rates of 0.28 for total crashes per quarter for control sites and 0.35 for treatment sites in the before period and 0.30 and 0.23 for the after period. This represents an increase of 0.02 crashes per quarter at control sites and a decrease of 0.12 at treatment sites (a 9-percent increase versus a 35-percent decrease). SV crash results for all sites show a crash rate of 0.22 for control sites and 0.29 for treatment sites in the before period, and 0.22 for control sites and 0.15 for treatment sites in the after period. This represents a decrease of 0.01 and 0.14, respectively (a decrease of 4 percent compared with 49 percent). The overall decrease in SV crash rate was 6 to 14 times higher for treatment sites than for control sites.

Descriptive statistics are provided to indicate overall trends. Caution should be used in applying the results, given that data were not normalized by season and more quarters of a particular season may have been present in the before period than in the after period. However, results show that, in general, a much greater decrease in crashes per quarter occurred at treatment sites compared with control sites.

Table 49. Simple before and after comparison of crashes for one direction.

		Number of Sites	Before		After		Change	
			Total Crashes (crashes/qtr)	SV Crashes (crashes/qtr)	Total Crashes (crashes/qtr)	SV Crashes (crashes/qtr)	Total crashes/qtr (percent change)	SV Crashes/qtr (percent change)
Florida	Control	2	8 (0.27)	6 (0.20)	1 (0.06)	0 (0.00)	-0.21 (-77%)	-0.20 (-100%)
	Treatment	2	13 (0.43)	7 (0.23)	7 (0.50)	4 (0.29)	0.07 (16%)	0.06 (26%)
Arizona	Control	3	18 (0.43)	17 (0.40)	10 (0.37)	9 (0.33)	-0.06 (-14%)	-0.07 (-18%)
	Treatment	2	10 (0.36)	8 (0.29)	0 (0.00)	0 (0.00)	-0.36 (-100%)	-0.29 (-100%)
Washington	Control	3	31 (0.74)	19 (0.45)	22 (0.56)	16 (0.41)	-0.18 (-24%)	-0.04 (-9%)
	Treatment	2	18 (0.64)	17 (0.61)	4 (0.22)	3 (0.17)	-0.42 (-66%)	-0.44 (-72%)
Iowa	Control	6	17 (0.19)	13 (0.14)	18 (0.42)	11 (0.26)	0.23 (122%)	0.11 (77%)
	Treatment	4	17 (0.27)	13 (0.20)	12 (0.28)	6 (0.14)	0.01 (5%)	-0.06 (-31%)
Ohio	Control	3	4 (0.10)	3 (0.08)	0 (0.00)	0 (0.00)	-0.10 (-100%)	-0.08 (-100%)
	Treatment	3	19 (0.49)	17 (0.44)	7 (0.23)	6 (0.20)	-0.26 (-53%)	-0.24 (-55%)
Oregon	Control	5	25 (0.33)	20 (0.27)	12 (0.30)	9 (0.23)	-0.03 (-10%)	-0.04 (-16%)
	Treatment	4	12 (0.26)	10 (0.22)	6 (0.31)	4 (0.21)	0.05 (20%)	-0.01 (-3%)
Texas	Control	3	3 (0.08)	2 (0.05)	2 (0.11)	1 (0.06)	0.03 (44%)	0.00 (8%)
	Treatment	3	2 (0.11)	1 (0.06)	0 (0.00)	0 (0.0)	-0.11 (-100%)	-0.06 (-100%)
All Sites	Control	25	100 (0.28)	80 (0.22)	65 (0.30)	46 (0.22)	0.02 (9%)	-0.01 (-4%)
	Treatment	20	89 (0.35)	73 (0.29)	36 (0.23)	23 (0.15)	-0.12 (-35%)	-0.14 (-49%)

SV = Single-vehicle
qtr = Quarter

DEVELOPMENT OF CRASH MODIFICATION FACTORS USING A FULL BAYES MODEL

Description of Model

To study the effectiveness of various safety treatments, a before-and-after analysis was conducted using a Full Bayes model to develop CMFs. Expected crash rates are represented by safety performance functions (SPF) that relate the expected crash rate to traffic and road characteristics.

The Bayesian method accounts for regression-to-the-mean effects that result from the natural tendency to select treatment sites with high observed crash frequencies. Control sites were similar to treatment sites in terms of traffic volume, geometry, and location. A discussion of how treatment and control sites were selected is provided in chapter 2.

In the literature, SPF estimation in the context of before-and-after analysis has been conducted via the Empirical Bayes (EB) approach in conjunction with negative binomial model structure (Hauer et al. 2002; Hovey and Chowdhury 2005; Persaud and Lyon 2007; Elvik 2008). The estimated SPF is used to predict crash rates for treatment sites that would have occurred without the treatment (Hauer 1997). The predicted crash rates are then compared with the observed crash counts during the after period to develop CMFs.

Recently, the Full Bayesian (FB) method has gained a lot of interest because of the following advantages compared with the EB approach:

- Takes into account all uncertainties in the analysis.
- Provides more detailed causal inferences (Carriquiry et al. 2004).
- Requires fewer data.
- Has more flexibility in selecting crash count distributions (Lan et al. 2009).

Model Development

The dataset included 624 observations for control sites and 492 observations for treatment sites. Year was considered as covariate in the regression term to account for changes over time. Correlations between observations from the same section were accounted for as the within-subject errors in the model.

As noted in the Variables section earlier in this chapter, four separate models were developed: total and SV crashes in both directions and in the direction of the treatment/outside of curve. Quarterly crashes was the response variable. Crash counts across years and sites can be expressed by the general model (Congdon 2001) shown in figure 73.

$$\textit{Crash counts} = \textit{trend} + \textit{regression term} = + \textit{random effects}$$

Figure 73. Equation. Expression for crash counts across years and sites.

Where “trend” accounts for the effect of time, the “regression term” is of the same form as SPFs used in EB studies (Hauer et al. 2002, Persaud et al. 2002), and “random effect” accounts for

latent variables across the sites. Correlations between observations from the same section were accounted for as the within-subject errors in the model.

Model Form and Selection Criteria

To find the appropriate model for the FB analysis, several models were tested. A zero inflated model (ZIP and ZINB) was evaluated against the plain count model (Poisson and Negative Binomial) followed by the Vuong test. Both zero inflated Poisson and Poisson-Gamma models were selected. Then, after applying the FB method, a deviance information criterion (DIC) was used to compare the different Bayesian hierarchical models (Spiegelhalter et al. 2003).

The models were developed using the equations shown in figure 74 and figure 75. Let $Y_{i,t}$ be the observed number of crashes at site *i* in year *t*, $\lambda_{i,t}$ be the expected number of crashes at site *i* in year *t*, ε_i be the multiplicative random effect at site *i*, $X_{i,t}$ be the corresponding covariates such as traffic and road conditions. The expressions for all models compared are listed as follows:

$$\text{Model A (ZIP): } Y_{it} \sim \text{ZIP}(\pi_{i,t}, \lambda_{i,t})$$

Figure 74. Equation. Model A (ZIP).

Where:

$$\ln \lambda_{i,t} = \alpha 1 + \mathbf{X1'}_{it}\boldsymbol{\beta_1} + \gamma_1 (t - 2004).$$
$$logit(\pi_{i,t}) = \alpha_2 + \mathbf{X2}_{i,t}\boldsymbol{\beta_2} + \gamma_2 (t - 2004).$$

and

$$\text{Model B (ZINB): } Y_{i,t} \sim \text{ZIP}(\pi_{i,t}, \varepsilon_i \lambda_{i,t})$$

Figure 75. Equation. Model B (ZIP).

Where:

$$\ln \lambda_{i,t} = \alpha_1 + \mathbf{X1'}\boldsymbol{\beta_1} + \gamma_1 (t - 2004).$$
$$logit(\pi_{i,t}) = \alpha_2 + \mathbf{X2'}\boldsymbol{\beta_2} + \gamma_2 (t - 2004).$$
$$\varepsilon_i \sim \text{Gamma}(\phi, 1/\phi).$$

Prior Choices for FB Methodology

Prior distributions for parameters ($\alpha_1, \alpha_2, \beta_1, \beta_2, \gamma_1, \gamma_2$) are assumed non-informative $N(0, 10^3)$ to reflect the lack of precise knowledge of the value of the coefficients. The prior distribution for parameter ϕ is assumed *Gamma* (1,1). The posterior distributions were calibrated using Monte Carlo Markov Chain (Gamerman 2006, Gilks et al. 1996) methods using all data from the control sites and the before period data for the treated sites.

Development of CMFs

The CMFs were calculated using the equation shown in figure 76.

$$CMF = \frac{\sum_{i=1}^{n}\sum_{t=T+1}^{T+m} Y_{i,t}}{\sum_{i=1}^{n}\sum_{t=T+1}^{T+m} \lambda_{i,t}}$$

Figure 76. Equation. CMF calculation.

Where *n* is the number of treated sites, *m* is number of years after treatment, *T* is the last year before treatment, and $\lambda_{i,t}$ is expected crashes without treatment for intersection *i* in year *t* in the after period. The corresponding standard error (STDE) for the CMF was calculated using the equation in figure 77.

$$STDE(CMF) = CMF \times \sqrt{\frac{Var(\sum_{i=1}^{n}\sum_{t=T+1}^{T+m} Y_{i,t})}{(\sum_{i=1}^{n}\sum_{t=T+1}^{T+m} Y_{i,t})^2} + \frac{Var(\sum_{i=1}^{n}\sum_{t=T+1}^{T+m} \lambda_{i,t})}{(\sum_{i=1}^{n}\sum_{t=T+1}^{T+m} \lambda_{i,t})^2}}$$

Figure 77. Equation. Calculation of standard error for the CMF.

Final Models

The safety effect of installing the DSFS system was developed using the described methodology. As noted in the Variables section earlier in this chapter, four different models were developed: total and SV crashes in both directions, and total and SV crashes in the direction of sign or outside of curve. The best model was chosen with 95-percent significant covariates using DIC. Table 50 shows the parameter estimates for the best fit model for all crashes in both directions.

Table 50. Parameter estimations for ZIP model for total crashes in both directions.

Parameter	Posterior Mean	P-value
Intercept	-7.4295	< .0001
Log(volume)	0.6456	< .0001
Length	0.6784	< .0001
SpeedDiff	0.0432	< .0001
S-curve versus. single curve	-0.3602	0.0174
Multiple versus single curve	0.1819	0.0002
Spring versus winter	-0.1159	0.3239
Summer versus winter	-0.3105	0.0202
Fall versus winter	-0.3247	0.0128
2005 versus 2011	1.3004	< .0001
2006 versus 2011	1.0324	< .0001
2007 versus 2011	1.0054	< .0001
2008 versus 2011	0.8083	0.0005
2009 versus 2011	0.4502	0.0693
2010 versus 2011	0.8056	0.0005
Parameters for probability model		
Intercept	-3.9830	0.0002
SpeedDiff	0.1219	0.0003

Table 51 shows the parameter estimates for the best fit model for total crashes in the direction of the DSFS system for treatment sites and control sites.

Table 51. Parameter estimations for ZIP model for total crashes in one direction.

Parameter	Posterior Mean	P-value
Intercept	-8.0551	< .0001
Log(volume)	0.6992	< .0001
Length	0.7602	< .0001
SpeedDiff	0.0278	0.002
S-curve versus single curve	0.1061	0.5443
Multiple versus single curve	0.4392	0.0463
Spring versus winter	-0.3236	0.0460
Summer versus winter	-0.3088	0.06604
Fall versus winter	-0.5034	0.004
2005 versus 2011	1.2227	< .0001
2006 versus 2011	0.9846	0.0005
2007 versus 2011	0.9411	0.0009
2008 versus 2011	0.5879	0.0476
2009 versus 2011	0.2842	0.3684
2010 versus 2011	0.6984	0.0158
Parameters for probability model		
Intercept	-1.1540	0.006

Table 52 shows the parameter estimates for the best fit model for SV crashes in both directions.

Table 52. Parameter estimations for ZIP model for SV crashes in both directions

Parameter	Posterior Mean	P-value
Intercept	-7.5668	< .0001
Log(volume)	0.5629	< .0001
Length	0.7287	< .0001
SpeedDiff	0.0382	< .0001
S-curve versus single curve	-0.3182	0.0578
Multiple versus single curve	0.2889	0.0003
Spring versus winter	-0.0413	0.6621
Summer versus winter	-0.3927	0.0117
Fall versus winter	-0.2790	0.0542
2005 versus 2011	1.7834	< .0001
2006 versus 2011	1.5176	< .0001
2007 versus 2011	1.3917	< .0001
2008 versus 2011	1.2045	< .0001
2009 versus 2011	0.8893	0.0048
2010 versus 2011	1.2391	< .0001
Parameters for probability model		
Intercept	-4.3494	0.0053
SpeedDiff	0.1238	0.0025

Table 53 shows the parameter estimates for the best fit model for SV crashes in the direction of the DSFS system for treatment sites or control sites.

Table 53. Parameter estimations for ZIP model for SV crashes in one direction.

Parameter	Posterior Mean	P-value
Intercept	-7.7523	< .0001
Log(volume)	0.5269	< .0001
Length	0.7984	< .0001
SpeedDiff	0.0329	< .0001
S-curve versus single curve	0.2163	0.2721
Multiple versus single curve	0.6136	0.0398
Spring versus winter	-0.3131	0.0936
Summer versus winter	-0.3916	0.0502
Fall versus winter	-0.5374	0.0071
2005 versus 2011	1.6955	< .0001
2006 versus 2011	1.4447	< .0001
2007 versus 2011	1.2980	0.0005
2008 versus 2011	0.8900	0.0226
2009 versus 2011	0.6567	0.1093
2010 versus 2011	1.0992	0.0040
Parameters for probability model		
Intercept	-1.3295	0.0336

Crash Modification Factors

Table 54 lists the CMFs and associated parameters for the four models that were developed.

Table 54. Results for calculation of crash modification factors.

Crash Type	Direction Type	Observed Crashes	Estimated Crashes	CMF (STDE)	95-Percent CI
Total	Both	52.1	54.6	0.95 (0.01)	0.93, 0.97
Total	Toward sign or outside of curve	32.5	34.8	0.93 (0.02)	0.89, 0.97
Single-vehicle	Both	38.6	40.7	0.95 (0.01)	0.93, 0.97
Single-vehicle	Toward sign or outside of curve	22.3	23.4	0.95 (0.02)	0.91, 0.99

CMF =Crash mitigation factor
STDE = Standard error
CI = Confidence interval

Based on the estimated coefficients, predicted crashes per year after installing the DSFS system were calculated and are shown in table 54. The predicted number of crashes was calculated by estimating crashes for each quarter for each treatment site and summing the predicted crashes for the after period. CMFs were calculated by dividing the observed crashes by the predicted values.

For total crashes in both directions, the CMF is calculated as 52.1/54.6 = 0.95. In other words, total crashes for both directions are expected to decrease by 5 percent, and all crashes in the direction of the DSFS system are expected to decrease by 7 percent. SV crashes in both directions are expected to decrease by 5 percent, and SV crashes in the direction of the sign are expected to decrease by 5 percent.

To determine whether the reduction due to the treatment was significant or not, 95-percent CIs for the CMFs were calculated and are shown in table 54. For example, the 95-percent CI for all crashes in both directions is [0.95 ± 1.96 x 0.01] = [0.93, 0.97], not containing 1, so the crash reduction for all crash types is statistically significant.

Results of the statistical analyses indicate that the DSFS system results in a crash reduction from 7 to 5 percent.

APPENDIX A: SPEED RESULTS FOR INDIVIDUAL SITES

RESULTS FOR ARIZONA—SR 377

A curve advisory sign was installed at Arizona treatment site SR 377 in September 2008 for the SB direction of travel. The site is about 15 miles southwest of Holbrook, AZ.

Table 55 shows the results for the speed control point, which is 0.5 miles upstream of the sign. The site has a dynamic curve display that was placed for the SB direction of traffic. Speeds decreased at the control site from the before to the 1-month and 12-month after periods. This suggests that speeds overall may have decreased independent of the sign.

Table 55. Results for Arizona: SR 377 at 0.5 miles upstream (SB).

	Before	1 Mo	Change	12 Mo	Change	24 Mo	Change
ADT	937	898	-39	826	-111	822	-115
Sample size	2,061	1,976	NA	1,817	NA	1,624	NA
Mean speed (mph)	68.4	65.6	-2.8	65.8	-2.6	66.3	-2.1
SD of mean	6.7	6.0	NA	6.7	NA	6.3	NA
85th percentile speed (mph)	74	71	-3	72	-2	72	-2
Fraction of vehicles exceeding posted or advisory speed limit							
By 5 mph	40.0	20.5	-48.8%	25.1	-37.3%	26.9	-32.8%
By 10 mph	14.5	5.6	-61.4%	6.0	-58.6%	8.2	-43.4%
By 15 mph	5.2	1.9	-63.5%	1.7	-67.3%	2.2	-57.7%
By 20 mph	1.8	0.6	-66.7%	0.4	-77.8%	0.4	-77.8%

ADT = Average daily traffic
NA = Not applicable
SD = Standard deviation

Table 56 shows the results at the PC. There was a significant decrease in all speed metrics for the 1-, 12-, and 24-month after periods. The speed reduction was greater than that which occurred for the upstream control.

Mean speeds decreased in all cases by up to 5.6 mph, and 85th percentile speeds decreased by up to 8 mph.

There were also moderate decreases in the percent of vehicles exceeding the posted or advisory speed. Decreases of up to 33 percent occurred for vehicles exceeding by 5 mph or more, up to 17.8 percent for 10 mph or more over, up to 6.2 percent for 15 mph over, and up to 2.7 percent for 20 mph or more over. These represented a percent change of up to 96.4 percent.

Table 56. Results for Arizona: SR 377 at the PC (SB).

	Before	1 Mo	Change	12 Mo	Change	24 Mo	Change
Sample size	2,292	1,978	NA	1,793	NA	1,633	NA
Mean speed (mph)	69.4	63.8	-5.6	65.8	-3.6	64.7	-4.7
SD of mean	7.0	5.0	NA	5.7	NA	5.7	NA
85th percentile speed (mph)	76	68	-8	71	-5	70	-6
Fraction of vehicles exceeding posted or advisory speed limit							
By 5 mph	0.41	0.08	-79.9%	0.23	-44.8%	0.16	-60.3%
By 10 mph	0.20	0.02	-91.3%	0.04	-78.5%	0.03	-86.2%
By 15 mph	0.07	0.01	-92.5%	0.01	-83.6%	0.01	-91.0%
By 20 mph	0.03	0.00	-96.4%	0.00	-89.3%	0.00	-92.9%

NA = Not applicable
SD = Standard deviation

Table 57 presents results for the CC. Speeds decreased in most cases, but the decrease was smaller than that experienced at the upstream control location. Decreases were also smaller than at the PC. Decreases were larger for the 24-month after period than for the 1- or 12-month after period. Mean speed decreases resulted between 0.2 and -3.5 mph, with decreases in 85th percentile speed between 0 and 4 mph.

Table 57. Results for Arizona: SR 377 at the CC (SB).

	Before	1 Mo	Change	12 Mo	Change	24 Mo	Change
Sample size	2,050	2,026	NA	1,806	NA	1,633	NA
Mean speed (mph)	66.5	64.8	-1.7	66.7	0.2	63.0	-3.5
SD of mean	6.2	5.2	NA	5.4	NA	5.6	NA
85th percentile speed (mph)	72	69	-3	72	0	68	-4
Fraction of vehicles exceeding posted or advisory speed limit							
By 5 mph	0.28	0.131	-52.5%	0.29	4.3%	0.08	-69.9%
By 10 mph	0.08	0.03	-70.2%	0.06	-26.2%	0.01	-84.5%
By 15 mph	0.02	0.01	-79.2%	0.01	-58.3%	0.01	-79.2%
By 20 mph	0.01	0.00	-60.0%	0.01	0.0%	0.00	-60.0%*

*Not statistically significant at 95-percent level of significance
NA = Not applicable
SD = Standard deviation

RESULTS FOR ARIZONA—SR 95

A speed feedback sign was installed at Arizona treatment site SR 95 in September 2008 for the SB direction of travel. The site is about 20 miles southeast of Lake Havasu City, AZ. Between the 12- and 24-month after periods, the State installed other traffic calming devices at the curve independent of the team, as shown in figure 78. Results are presented for the 24-month after period, but are noted as being unusual.

Figure 78. Photo. Additional traffic calming installed between 12 and 24 months at SR 95.

Table 58 shows the final results for the speed control point, which is 0.5 miles upstream of the sign.

Table 58. Results for Arizona: SR 95 at 0.5 miles upstream (SB).

	Before	1 Mo	Change	12 Mo	Change	24 Mo	Change
ADT	2,682	2,475	-207	2,189	-493	2,274	-408
Sample size	5,065	4,867	**NA**	2,158	**NA**	4,477	NA
Mean speed (mph)	65.2	62.7	-2.5	63.0	-2.2	63.9	-1.3
SD of mean	6.0	6.2	NA	5.8	NA	6.0	NA
85th percentile speed (mph)	71	69	-2	68	-3	69	-2
Fraction of vehicles exceeding posted or advisory speed limit							
By 5 mph	0.85	0.71	-16.2%	0.74	-12.2%	0.79	-6.3%
By 10 mph	0.57	0.39	-32.6%	0.38	-33.5%	0.48	-15.9%
By 15 mph	0.22	0.12	-47.2%	0.11	-51.8%	0.15	-31.2%
By 20 mph	0.05	0.03	-40.8%	0.03	-49.0%	0.03	-34.7%

ADT = Average daily traffic
NA = Not applicable
SD = Standard deviation

The site has a dynamic speed display that was placed for the SB direction of traffic. Speeds decreased from the before period to 1-month and 12-month after periods at the control site. This suggests that speeds overall may have decreased independent of the signs.

Table 59 shows the results at the PC.

Table 59. Results for Arizona: SR 95 at the PC (SB).

	Before	1 Mo	Change	12 Mo	Change	24 Mo[1]	Change
Sample size	5,076	4,814	NA	2,170	NA	4,460	NA
Mean speed (mph)	57.2	52.8	-4.4	53.3	-3.9	55.8	-1.4
SD of mean	5.4	5.3	NA	5.9	NA	6.1	NA
85th percentile speed (mph)	66	58	-8	59	-7	63	-3
Fraction of vehicles exceeding posted or advisory speed limit							
By 5 mph	0.92	0.75	-18.6%	0.77	-16.9%	0.86	-7.0%
By 10 mph	0.69	0.32	-54.6%	0.36	-48.8%	0.58	-15.9%
By 15 mph	0.32	0.09	-70.8%	0.13	-58.9%	0.25	-21.0%
By 20 mph	0.09	0.03	-70.1%	0.04	-57.5%	0.08	-12.6%

[1]Additional traffic calming installed by Arizona DOT
NA = Not applicable
SD = Standard deviation

There was a significant decrease in all speed metrics for both the 1-month and 12-month after periods. The speed reduction was greater than that which occurred for the upstream control.

Mean speeds decreased by 4.4 and 3.9 mph, and 85th percentile speeds decreased by 8 and 7 mph. Moderate decreases occurred for the percent traveling 5, 10, 15, and 20 mph or more over the 45 mph advisory speed. The percent change in the fraction of vehicles traveling 15 or 20 mph or more over the advisory speed decreased by up to 70.8 percent.

At 24 months, speed reductions had also occurred, but they were lower than for 1-month and 12-month after periods, even though additional traffic calming had been installed.

Table 60 shows the results for the CC.

Table 60. Results for Arizona: SR 95 at the CC (SB).

	Before	1 Mo	Change	12 Mo	Change	24 Mo*	Change
Sample size	5,042	4,765		4,338		4173	-501
Mean speed (mph)	54.7	49.4	-5.3	51.8	-2.9	50.6	-4.1
SD of mean	5.8	5.0		5.5		5.8	
85th percentile speed (mph)	61	54	-7	57	-4	56	-5
Fraction of vehicles exceeding posted or advisory speed limit							
by 5 mph	0.82	0.48	-41.5%	0.68	-17.8%	0.58	-29.6%
by 10 mph	0.51	0.14	-73.3%	0.30	-41.8%	0.24	-53.8%
by 15 mph	0.20	0.03	-85.6%	0.08	-61.0%	0.06	-69.2%
by 20 mph	0.05	0.01	-88.9%	0.02	-66.7%	0.02	-66.7%

*Additional traffic calming installed by Arizona DOT
NA = Not applicable
SD = Standard deviation

Speeds decreased for all speed metrics for both data collection periods, and the change was greater than the change at the control location. Decreases in mean speed were 5.3 and 2.9 mph, with a decrease in 85th percentile speed of 7 and 4 mph.

Moderate decreases were noted in the fraction of vehicles traveling 5, 10, 15, and 20 mph, with a percent change of almost 90 percent in the fraction of vehicles traveling 15 or 20 mph over the advisory speed. At 24 months, speed reductions were similar to the 1- and 12-month after periods, even though additional traffic calming had been installed.

RESULTS FOR FLORIDA—SR 267 BY TALLAHASSEE

A curve warning sign was installed for the SB direction of traffic at Florida treatment site SR 267 in December 2008. The site is about 25 miles west of Tallahassee, FL. Table 61 shows the results for the speed control point, which is 0.5 miles upstream of the sign (dynamic curve display).

Table 61. Results for Florida: SR 267 upstream of curve (SB).

	Before	3 Mo	Change	12 Mo	Change	24 Mo	Change
ADT	1,958	1,899	-59	1,682	-276	1,713	-245
Sample size	3,783	3,665	NA	3,250	NA	3,370	NA
Mean speed (mph)	62.9	67.4	4.5	56.3	-6.6	61.0	-1.9
SD of mean	6.1	6.8	NA	4.7	NA	5.30	NA
85th percentile speed (mph)	68	74	6	61	-7	66	-2
Fraction of vehicles exceeding posted or advisory speed limit							
By 5 mph	0.75	0.91	21.7%	0.22	-70.8%	0.60	-19.0%
By 10 mph	0.35	0.67	91.4%	0.05	-87.1%	0.23	-33.2%
By 15 mph	0.11	0.34	196.5%	0.01	-90.3%	0.05	-54.0%
By 20 mph	0.04	0.13	277.1%	0.00	-91.4%	0.01	-62.9%

ADT = Average daily traffic
NA = Not applicable
SD = Standard deviation

The team collected data 3 months rather than 1 month after the signs were installed because they experienced problems with the signs at the 1 month after period. Speeds increased from the before period to 3-month after period, and decreased for the 12-month and 24-month after periods. The speeds in the 12-month after period for the control site appear to be unusually low, although there were no known reasons this may have occurred.

Table 62 shows results for the PC. Minor decreases occurred in the various speed metrics for the 3-month and 24-month after period, while a very large decrease in mean (6.5 mph) and 85th percentile (8 mph) occurred for the 12-month after period. However, as noted, very large decreases also occurred for the control site for the 12-month after period. Mean speeds decreased by 6.5 mph while the 85th percentile speed decreased by 8 mph.

Minor decreases in the fraction of vehicles traveling 5, 10, 15, or 20 mph over the posted speed limit of 55 mph occurred. However, the magnitude of the differences was significant, with percent changes up to 100 percent noted.

Table 62. Results for Florida: SR 267 at the PC (SB).

	Before	3 Mo	Change	12 Mo	Change	24 Mo	Change
Sample size	3,782	3697	NA	3,285	NA	1,998	NA
Mean speed (mph)	54.3	53.4	-0.9	47.8	-6.5	53.2	-1.1
SD of mean	5.7	5.7	NA	4.8	NA	5.7	NA
85th percentile speed (mph)	60	59	-1	52	-8	59	-1
Fraction of vehicles exceeding posted or advisory speed limit							
By 5 mph	0.15	0.12	-20.9%	0.01	-95.4%	0.10	-32.0%
By 10 mph	0.03	0.02	-25.0%	0.00	-96.4%	0.01	-60.7%
By 15 mph	0.01	0.00	-57.1%	0.0	-100.0%	0.00	-71.4%
By 20 mph	0.00	0.00	0.0%	0.0	-100.0%	0.00	-100.0%*

*Not statistically significant at 95-percent level of significance
NA = Not applicable
SD = Standard deviation

Table 63 shows results for the CC. Modest decreases occurred for all of the after periods. Decreases for the 12-month after period are smaller than the decreases that occurred at the control site. Moderate decreases also occurred for the fraction of vehicles traveling 5, 10, 15, and 20 mph over the posted speed limit.

Table 63. Results for Florida: SR 267 at the CC (SB).

	Before	3 Mo	Change	12 Mo	Change	24 Mo	Change
Sample size	3,770	3,711	NA	3,098	NA	2,015	NA
Mean speed (mph)	53.2	52.5	-0.7	51.3	-1.9	52.4	-0.8
SD of mean	6	5.9	NA	5.8	NA	5.6	NA
85th percentile speed (mph)	59	58	-1	57	-2	58	-1
Fraction of vehicles exceeding posted or advisory speed limit							
By 5 mph	0.12	0.10	-17.2%	0.07	-41.8%	0.09	-23.8%
By 10 mph	0.02	0.02	-28.6%	0.01	-42.9%	0.01	-66.7%
By 15 mph	0.00	0.00	-50.0%	0.00	-50.0%	0.00	-100.0%
By 20 mph	0.00	0.00	N/A	0.00	N/A	0.00	N/A

NA = Not applicable
SD = Standard deviation

RESULTS FOR FLORIDA—US 20 BY TALLAHASSEE

A curve advisory speed sign was installed WB on US 20 by Tallahassee. The sign was installed in December 2008. The site is about 12 miles west of Tallahassee, FL. Table 64 shows the results for the speed control point, which is 0.5 miles upstream of the sign.

Table 64. Results for Florida: US 20 by Tallahassee upstream of curve (WB).

	Before	3 Mo	Change	12 Mo	Change	24 Mo	Change
ADT	2,100	3,685	1,585	3,327	1,227	3,248	1,148
Sample size	6,193	7,232	NA	6,542	NA	6,713	NA
Mean speed (mph)	58.1	56.4	-1.7	58.9	0.8	56.9	-1.2
SD of mean	5.2	5.0	NA	5.5	NA	5.2	NA
85th percentile speed (mph)	63	61	-2	64	1	61	-2
Fraction of vehicles exceeding posted or advisory speed limit							
By 5 mph	0.37	0.22	-39.2%	0.46	25.9%	0.28	-24.8%
By 10 mph	0.08	0.03	-57.1%	0.11	48.1%	0.05	-40.3%
By 15 mph	0.02	0.01	-53.3%	0.02	46.7%	0.01	-46.7%
By 20 mph	0.01	0.00	-80.0%	0.00	-20.0%	0.00	-40.0%*

*Not statistically significant at 95-percent level of significance
ADT = Average daily traffic
NA = Not applicable
SD = Standard deviation

Data were collected 3 months after the signs were installed rather than 1 month because the signs experienced problems at the 1-month after period. Speeds at the control point decreased from the before period to the 3-month after period, and increased for the 12-month after period by a small amount. Moderate decreases occurred at the 24-month after period, which were similar to the 3-month after period.

Table 65 provides results for US 20 at the PC. Modest decreases occurred for the 3-month, 12-month, and 24-month after periods for all speed metrics. Modest speed changes occurred for the mean and 85th percentile speeds, which were similar to the decreases noted for the control period. Moderate changes occurred for the fraction of vehicles that exceeded the 55 mph speed limit.

Table 66 shows results for the CC. Moderate decreases occurred for all after periods, with a decrease of about 3 mph for both the mean and 85th percentile speeds at 3 months; a decrease of almost 23 percent occurred from the 3-month after period for vehicles traveling 5 mph over the 55 mph posted speed limit. Moderate decreases also occurred for the 12-month after period, with a 1 mph decrease in mean and 85th percentile speeds. Decreases of 2 mph occurred for the mean and 85th percentile speeds at the 24-month after period.

Moderate decreases in the fraction of vehicles traveling 5, 10, 15, or 20 mph or more over the posted speed limit occurred, which resulted in percent changes of up to 80 percent.

Table 65. Results for Florida: US 20 by Tallahassee at the PC (WB).

	Before	3 Mo	Change	12 Mo	Change	24 Mo	Change
Sample size	5,964	7,049	NA	6,403	NA	6487	NA
Mean speed (mph)	57.3	55.9	-1.4	55.4	-1.9	56.2	-1.1
SD of mean	4.3	4.5	NA	4.5	NA	5.2	NA
85th percentile speed (mph)	61	60	-1	59	-2	60	-1
Fraction of vehicles exceeding posted or advisory speed limit							
By 5 mph	0.26	0.18	-31.1%	0.14	-45.5%	0.20	-22.6%
By 10 mph	0.05	0.03	-34.8%	0.02	-50.0%	0.06	37.0%
By 15 mph	0.01	0.01	-44.4%	0.01	-44.4%	0.02	122.2%
By 20 mph	0.00	0.00	0.0%*	0.00	-50.0%	0.01	150.0%

*Not statistically significant at 95-percent level of significance
NA = Not applicable
SD = Standard deviation

Table 66. Results for Florida: US 20 by Tallahassee at the CC (WB).

	Before	3 Mo	Change	12 Mo	Change	24 Mo	Change
Sample size	5,964	7,014	NA	6,342	NA	6,487	NA
Mean speed (mph)	58.2	55.3	-2.9	57.1	-1.1	56.1	-2.1
SD of mean	4.3	4.3	NA	4.5	NA	4.4	NA
85th percentile speed (mph)	62	59	-3	61	-1	60	-2
Fraction of vehicles exceeding posted or advisory speed limit							
By 5 mph	0.36	0.12	-65.4%	0.25	-29.6%	0.18	-48.6%
By 10 mph	0.07	0.02	-78.3%	0.04	-40.6%	0.02	-66.7%
By 15 mph	0.01	0.00	-70.0%	0.01	-40.0%	0.00	-60.0%
By 20 mph	0.00	0.00	-50.0%	0.00	-50.0%	0.00	0.0%*

*Not statistically significant at 95-percent level of significance
NA = Not applicable
SD = Standard deviation

RESULTS FOR FLORIDA—US 20 BY GAINESVILLE

The Florida US 20 site near Gainesville has a dynamic speed display for the EB direction of traffic. The site is 26 miles east of Gainesville, FL. The advisory speed is 45 mph with a tangent speed of 55 mph. Table 67 presents results for the upstream speed control site.

Table 67. Results for Florida: US 20 Gainesville upstream of curve (EB).

	Before	1 Mo	Change	12 Mo	Change	24 Mo	Change
ADT	2,816	3,031	215	2,985	169	3,077	261
Sample	5,504	5,953	NA	5,829	NA	6,041	NA
Mean speed (mph)	55.6	59.5	3.9	55.1	-0.5	55.4	-0.2*
SD of mean	6.0	6.6	NA	5.9	NA	6.3	NA
85th percentile speed (mph)	61	65	4	60	-1	61	0
Fraction of vehicles exceeding posted or advisory speed limit							
By 5 mph	0.23	0.52	126.6%	0.19	-17.9%	0.22	-3.9%*
By 10 mph	0.05	0.20	319.1%	0.03	-27.7%	0.04	-17.0%*
By 15 mph	0.01	0.05	455.6%	0.01	-22.2%*	0.01	0.0%*
By 20 mph	0.00	0.01	300.0%	0.00	0.0%*	0.00	-33.3%*

*Not statistically significant at 95-percent level of significance
ADT = Average daily traffic
NA = Not applicable
SD = Standard deviation

As shown, speed metrics increased significantly for the 1-month after period, while minor decreases were noted for the 12-month after period. Little change was noted for the 24-month after period at the control site. The decrease for vehicles exceeding the posted speed limit of 55 by 15 and 20 mph were not statistically significant at the 90-percent level of significance.

Table 68 shows changes in speed metrics for the PC. Speeds increased for the 1-month after period, with an increase of 3.3 mph and 4.0 mph for the mean and 85th percentile speed, respectively. However, this is similar to the increase that was noted for the control location.

Moderate decreases were noted for the 12-month after period, with a decrease of almost 3 mph for the mean and 4 mph for the 85th percentile speed. Significant decreases were observed for the percent change in vehicles exceeding the advisory speed by 5, 10, 15, and 20 mph. These results suggest that the sign had a large impact on high-end speeds at the 12-month data collection period.

Moderate decreases also occurred for the 24-month after period. It is not known why speeds increased at 3 months but decreased at 12 and 24 months.

Table 69 provides results for the CC. Significant decreases occurred for both the 1- and 12-month after period. A decrease of about 4 mph occurred for the mean and 85th percentile speeds for both time periods. Large decreases in the percent of vehicles exceeding the advisory speed were noted, with a large decrease in the percent of vehicle exceeding the advisory speed by 15 and 20 mph. Only moderate decreases were noted for the 24-month after period. Decreases were greater at the CC as compared with the PC.

Table 68. Results for Florida: US 20 Gainesville at the PC (EB).

	Before	3 Mo	Change	12 Mo	Change	24 Mo	Change
Sample	5,490	5,904	NA	5,861	NA	6,046	NA
Mean (mph)	57.8	61	3.3	55.0	-2.8	56.7	-1.1
SD of mean	6.0	6.5	NA	5.2	NA	5.2	NA
85th percentile speed (mph)	63	67	4	59	-4	61	-2
Fraction of vehicles exceeding posted or advisory speed limit							
By 5 mph	0.93	0.96	2.8%	0.90	-3.6%	93.5	0.1%*
By 10 mph	0.76	0.89	16.0%	0.58	-24.7%	70.9	-7.2%
By 15 mph	0.38	0.66	71.3%	0.14	-64.2%	25.6	-33.2%
By 20 mph	0.10	0.26	172.9%	0.02	-77.1%	5.3	-44.8%

*Not statistically significant at 95-percent level of significance
NA = Not applicable
SD = Standard deviation

Table 69. Results for Florida: US 20 Gainesville at the CC (EB).

	Before	3 Mo	Change	12 Mo	Change	24 Mo	Change
Sample size	5,496	5,897	NA	5,878	NA	6,062	NA
Mean speed (mph)	58.2	54.5	-3.7	54.5	-3.7	57.0	-1.2
SD of mean	5.8	5.1	NA	5.5	NA	5.8	NA
85th percentile speed (mph)	63	59	-4	59	-4	62	-1
Fraction of vehicles exceeding posted or advisory speed limit							
By 5 mph	0.95	0.88	-7.1%	0.89	-6.5%	0.94	-1.1%
By 10 mph	0.79	0.62	-21.2%	0.54	-32.0%	0.74	-6.3%
By 15 mph	0.41	0.12	-69.9%	0.12	-70.2%	0.29	-28.1%
By 20 mph	0.10	0.02	-80.4%	0.02	-80.4%	0.06	-40.2%

NA = Not applicable
SD = Standard deviation

RESULTS FOR IOWA—US 30

A curve display sign was installed at the US 30 site for the EB direction of traffic in November 2008. No advisory speeds are present with a tangent speed of 55 mph. The site was 4 miles west of Tama, IA. Data were not collected at the 1-month after period because of adverse winter weather conditions, but are reported for 3 months after instead. Table 70 provides results for the upstream speed control location. All speed metrics decreased for all after time periods, which may suggest that speeds decreased overall independent of the sign.

Table 70. Results for Iowa: US 30 upstream (EB).

	Before	3 Mo	Change	12 Mo	Change	24 Mo	Change
ADT	5,506	4,408	-1,098	4,578	-928	5,221	-285
Sample size	9,176	8,589	NA	8,878	NA	5,064	NA
Mean speed (mph)	58.0	54.8	-3.2	54.2	-3.8	56.5	-1.5
SD of mean	6.1	4.9	NA	5.6	NA	5.2	NA
85th percentile speed (mph)	63	59	-4	59	-4	61	-2
Fraction of vehicles exceeding posted or advisory speed limit							
By 5 mph	0.40	0.12	-69.0%	0.11	-71.5%	0.26	-35.5%
By 10 mph	0.08	0.01	-86.3%	0.01	-85.0%	0.04	-53.8%
By 15 mph	0.02	0.00	-87.5%	0.00	-87.5%	0.01	-68.8%
By 20 mph	0.01	0.00	-100.0%	0.00	-100.0%	0.00	-85.7%

ADT = Average daily traffic
NA = Not applicable
SD = Standard deviation

Table 71 shows results for at the PC for US 30. As indicated, speeds also decreased for all after time periods for all speed metrics. However, the decreases were generally within the range of those noted for the control site.

Table 71. Results for Iowa: US 30 at the PC (EB).

	Before	3 Mo	Change	12 Mo	Change	24 Mo	Change
Sample size	9,258	8,646	NA	8,805	NA	5,051	NA
Mean speed (mph)	58.9	58.0	-0.9	56.4	-2.5	58.1	-0.8
SD of mean	4.5	4.1	NA	4.5	NA	4.1	NA
85th percentile speed (mph)	63	62	-1	60	-3	62	-1
Fraction of vehicles exceeding posted or advisory speed limit							
by 5 mph	0.46	0.37	-19.5%	0.21	-53.2%	0.36	-21.4%
by 10 mph	0.08	0.04	-44.2%	0.02	-76.6%	0.04	-50.6%
by 15 mph	0.01	0.01	-37.5%	0.00	-62.5%	0.01	-25.0%
by 20 mph	0.00	0.00	100.0%	0.00	0.0%*	0.00	0.0%*

*Not statistically significant at 95-percent level of significance
NA = Not applicable
SD = Standard deviation

Table 72 provides speed metrics at the CC for the Iowa US 30 site. Decreases were noted for the 3- and 24-month after periods. However, speeds increased for the 12-month after period.

Table 72. Results for Iowa: US 30 at the CC (EB).

	Before	3 Mo	Change	12 Mo	Change	24 Mo	Change
Sample size	9,223	5,630	NA	1,181	NA	5,078	NA
Mean speed (mph)	59.4	57.9	-1.5	59.8	0.4	57.4	-2.0
SD of mean	4.6	4.6	NA	6.0	NA	4.3	NA
85th percentile speed (mph)	63	62	-1	66	3	61	-2
Fraction of vehicles exceeding posted or advisory speed limit							
By 5 mph	0.50	0.37	-25.6%	0.61	22.0%	0.28	-44.0%
By 10 mph	0.10	0.04	-58.2%	0.13	29.6%	0.03	-67.3%
By 15 mph	0.01	0.00	-63.6%	0.01	9.1%	0.01	-54.5%
By 20 mph	0.00	0.00	-50.0%	0.00	-50.0%	0.00	-50.0%

NA = Not applicable
SD = Standard deviation

Changes were similar to those experienced at the upstream control site. Speeds decreased at the control site for those time periods so the control site does not indicate a trend of speed increase, which might explain the phenomenon. Speeds at the 24-month after period are similar to those for the 3-month after period, with about a 1 mph decrease in mean and 85th percentile speeds up to a 10-percent decrease in vehicles traveling over the posted speed limit.

RESULTS FOR IOWA—US 67

Table 73 provides results for the upstream speed control site at US 67 in Iowa, which has a dynamic speed display for the SB direction of traffic, installed in November 2008. The posted speed limit is 55 mph, and no advisory speed is present. The site is 15 miles northeast of Bettendorf, IA.

A very large increase was noted for all speed metrics for the 1-month after period at the control site. However, no pattern was observed regarding increases or decreases for the other after periods. Both minor decreases and increases were noted.

Table 73. Results for Iowa: US 67 upstream (SB).

	Before	1 Mo	Change	12 Mo	Change	24 Mo	Change
ADT	1,891	1,985	94	1,882	-9	1,886	-5
Sample size	3,728	3,820	NA	3,639	NA	3,690	NA
Mean speed (mph)	52.6	67.5	14.9	52.1	-0.5	52.8	0.2*
SD of mean	7.3	9.2	NA	7.9	NA	8.1	NA
85th percentile speed (mph)	58	75	17	58	0	59	1
Fraction of vehicles exceeding posted or advisory speed limit							
By 5 mph	0.10	0.74	†	0.10	-10%	0.13	31%
By 10 mph	0.01	0.71	†	0.01	11%*	0.01	11%
By 15 mph	0.00	0.43	†	0.00	-50%*	0.00	-50%*
By 20 mph	0.00	0.18	†	0.00	-100%	0.00	-100%*

*Not statistically significant at 95-percent level of significance
†Owing to abnormally high speeds for the 1-month after period, percent change was very large (> 700 percent)
ADT = Average daily traffic
NA = Not applicable
SD = Standard deviation

Table 74 shows results for the data collection point at the PC. Modest decreases occurred for most of the speed metrics with the largest decreases occurring at the 24-month after period.

Table 74. Results for Iowa: US 67 at the PC (SB).

	Before	1 Mo	Change	12 Mo	Change	24 Mo	Change
Sample size	4,334	3,818	NA	3,703	NA	3,779	NA
Mean speed (mph)	57.6	56.8	-0.8	56.6	-1.0	55.2	-2.4
SD of mean	5.3	5.0	NA	4.8	NA	4.8	NA
85th percentile speed (mph)	62	61	-1	61	-1	59	-3
Fraction of vehicles exceeding posted or advisory speed limit							
By 5 mph	32.1	25.8	-19.6%	22.4	-30.2%	13.5	-57.9%
By 10 mph	7.2	4.1	-43.1%	3.9	-45.8%	2.0	-72.2%
By 15 mph	1.4	0.8	-42.9%	0.8	-42.9%	0.4	-71.4%
By 20 mph	0.3	0.1	-66.7%	0.2	-33.3%	0.1	-66.7%*

*Not statistically significant at 95-percent level of significance
NA = Not applicable
SD = Standard deviation

Decreases in mean speed ranged from 0.8 to 2.4 mph, and decreases in 85th percentile speed were 1 to 3 mph. Significant decreases occurred in the fraction of vehicles exceeding the tangent speed limit of 55 mph by 5, 10, and 15 mph or more. The percent change was most significant for vehicles traveling 20 mph or more over limit, with percent changes up to 67 percent. Decreases were usually greater than those at the control site for the corresponding time period.

Table 75 shows results for the CC. Unlike the PC, large decreases were noted for all time periods in the after period. Reductions up to 11 mph for mean speed and 12 mph for the 85th percentile speeds were noted. Large decreases in the number of vehicles exceeding the posted speed limit of 55 mph occurred. A 100-percent change in the fraction of vehicles over the posted speed limit was noted for all of the 1-month intervals, three of the 12-month intervals, and three of the 24-month intervals. Decreases were much greater at the CC than at the PC.

Table 75. Results for Iowa: US 67 at the CC (SB).

	Before	1 Mo	Change	12 Mo	Change	24 Mo	Change
Sample size	3,822	3,791	NA	3,691	NA	3,764	NA
Mean speed	63.1	52.2	-10.9	55.2	-7.9	56.1	-7.0
SD of mean	5.5	4.3	NA	4.6	NA	4.6	NA
85th percentile speed	68	56	-12	59	-9	60	-8
By 5 mph	0.78	0.03	-96.5%	0.148	-82.2%	0.20	-74.1%
By 10 mph	0.38	0.00	-99.0%	0.02	-94.8%	0.02	-93.7%
By 15 mph	0.10	0.00	-97.9%	0.00	-96.9%	0.00	-97.9%
By 20 mph	0.02	0.00	-95.2%	0.00	-95.2%	0.00	-100.0%

NA = Not applicable
SD = Standard deviation

RESULTS FOR IOWA—US 69

A dynamic curve display was installed at US 69 for the NB direction of traffic. The posted speed limit is 55 mph, and the curve has an advisory speed of 50 mph. The site is 29 miles south of Des Moines, IA. The sign was installed in April 2009.

Table 76 shows results for the upstream (speed control) location. Minor decreases were noted for all after periods. Most of the changes in the fraction of vehicles traveling over the advisory speed were not statistically significant.

Table 76. Results for Iowa: US 69 upstream (NB).

	Before	1 Mo	Change	12 Mo	Change	24 Mo	Change
ADT	750	808	58	808	58	715	-35
Sample size	1,482	1,600	NA	1,604	NA	1415	NA
Mean speed (mph)	57.1	56.7	-0.4	56.7	-0.4	56.1	-1
SD of mean	5.9	5.8	NA	6.1	NA	6.5	NA
85th percentile speed (mph)	62	61	-1	62	0	61	-1
Fraction of vehicles exceeding posted or advisory speed limit							
By 5 mph	0.32	0.28	-11%	0.30	-6%*	0.26	-17.4%
By 10 mph	0.06	0.05	-17%	0.07	13%*	0.06	-6.3%*
By 15 mph	0.01	0.01	8%	0.01	-8%*	0.01	-8.3%*
By 20 mph	0.00	0.00	0%*	0.00	-33%*	0.01	66.7%*

*Not statistically significant at 95-percent level of significance
ADT = Average daily traffic
NA = Not applicable
SD = Standard deviation

Table 77 shows speed metrics for the PC. Minor decreases were noted for the 1- and 12-month after periods, but were within the range of decrease noted for the control location. Moderate decreases occurred for the 24-month after period with a decrease of 2.7 mph in mean speed and 2 mph for 85th percentile speed.

Table 77. Results for Iowa: US 69 the PC (NB).

	Before	1 Mo	Change	12 Mo	Change	24 Mo	Change
Sample size	1,574	1,832	NA	1,674	NA	1,513	NA
Mean speed (mph)	56.8	56.6	-0.2	55.5	-1.3	54.1	-2.7
SD of mean	5.4	4.5	NA	6.1	NA	5.2	NA
85th percentile speed (mph)	61	61	0	61	0	59	-2
Fraction of vehicles exceeding posted or advisory speed limit							
By 5 mph	0.73	0.71	-3.1%	0.63	-13.7%	0.47	-35.2%
By 10 mph	0.29	0.25	-14.3%	0.23	-19.9%	0.12	-58.5%
By 15 mph	0.05	0.04	-24.5%	0.04	-28.6%	0.02	-61.2%
By 20 mph	0.01	0.01	-25.0%	0.01	-37.5%	0.00	-87.5%

NA = Not applicable
SD = Standard deviation

Vehicles traveling 5 mph over the advisory speed of 50 mph by 35 percent and the fraction traveling 10 mph over decreased 58.5 percent. Vehicles traveling 15 mph over the advisory

speed limit decreased by only 3.0 percent, but this represented a 61-percent decrease; the fraction traveling 20 mph or more over the speed limit decreased 87.5 percent.

Decreases were greater for the 24-month after period than for the previous two after periods, with a 2.7 and 2 mph decrease in mean and 85th percentile speeds. Significant decreases in the percent of vehicles traveling over the 50 mph advisory speed were also noted.

Similar decreases were noted for the CC as for the PC as shown in table 78. Modest decreases occurred for all speed metrics for the 1-month after period, but moderate decreases were noted for the 12- and 24-month after periods.

Table 78. Results for Iowa: US 69 at the CC (NB).

	Before	1 Mo	Change	12 Mo	Change	24 Mo	Change
Sample size	1,573	1,666	NA	1,659	NA	1,509	NA
Mean speed (mph)	56.1	56.1	0.0	53.6	-2.5	54.8	-1.3
SD of mean	4.8	5.1	NA	5.3	NA	5.8	NA
85th percentile speed (mph)	60	61	1	58	-2	60	0
Fraction of vehicles exceeding posted or advisory speed limit							
By 5 mph	0.68	0.66	-2.5%	0.47	-30.5%	0.55	-19.3%
By 10 mph	0.22	0.22	0.4%	0.10	-59.6%	0.17	-22.9%
By 15 mph	0.02	0.00	-95.8%	0.01	-70.8%	0.02	-12.5%*
By 20 mph	0.00	0.00	-100.0%	0.00	-100.0%	0.00	0.0%*

*Not statistically significant at 95-percent level of significance
NA = Not applicable
SD = Standard deviation

RESULTS FOR IOWA—IOWA 136

A speed display was installed at Iowa 136 for the NB direction of traffic in April 2009. The site has a posted speed limit of 50 mph and an advisory speed of 45 mph. The site is 7 miles northwest of Clinton, IA.

Table 79 shows results for the upstream speed control site. Significant increases occurred for the 1-month after period, with minor decreases in the 12-month and 24-month after period.

Table 79. Results for Iowa: Iowa 136 upstream (NB).

	Before	1 Mo	Change	12 Mo	Change	24 Mo	Change
ADT	621	715	94	746	125	642	21
Sample size	1,228	1,365	NA	1,480	NA	1,278	50
Mean speed	53.0	60.2	7.2	52.7	-0.3	51.6	-1.4
SD of mean	7.62	10.8	NA	6.6	-1.0	8	NA
85th percentile speed	59	71	12	58	-1.0	58	-1
Fraction of vehicles exceeding posted or advisory speed limit							
By 5 mph	0.43	0.68	58%	0.40	-6.1%	0.37	-14.7%
By 10 mph	0.14	0.52	280%	0.11	-23.4%	0.10	-26.3%
By 15 mph	0.04	0.34	*	0.02	-59.5%	0.01	-67.6%
By 20 mph	0.01	0.19	*	0.00	-66.7%	0.00	-66.7%

*Change in excess of 300 percent
ADT = Average daily traffic
NA = Not applicable
SD = Standard deviation

As noted in table 80, moderate decreases in speed resulted for all time periods for all speed metrics at the PC for Iowa 136. Decreases up to 3 mph in mean and up to 4 mph for 85th percentile speed occurred. The reduction in the fraction of vehicles exceeding the advisory speed of 45 mph was up to 17 percent for 5 mph over, up to 58 percent for 10 mph, up to 72 percent for 15 mph, and up to 89 percent for 20 mph.

Table 80. Results for Iowa: Iowa 136 at the PC (NB).

	Before	1 Mo	Change	12 Mo	Change	24 Mo	Change
Sample size	1,174	1,327	NA	1,417	NA	1,228	NA
Mean speed (mph)	53.6	50.9	-2.7	52.3	-0.8	51.5	-2.1
SD of mean	6.0	5.0	NA	6.1	NA	5.8	NA
85th percentile speed (mph)	59	55	-4	58	-1	57	-2
Fraction of vehicles exceeding posted or advisory speed limit							
By 5 mph	0.79	0.65	-16.8%	0.76	-2.8%	0.68	-13.1%
By 10 mph	0.44	0.18	-57.9%	0.34	-22.2%	0.27	-38.7%
By 15 mph	0.14	0.04	-71.9%	0.10	-31.5%	0.07	-52.5%
By 20 mph	0.04	0.01	-73.0%	0.02	-52.3%	0.00	-89.2%

NA = Not applicable
SD = Standard deviation

Table 81 shows speed metrics for the CC at Iowa 136. Moderate decreases in average speed and 85th speed resulted at the CC for the 1-, 12-, and 24-month after periods. Moderate changes in the percent of vehicles traveling 5, 10, 15, or 20 mph or more over the advisory speed occurred for all the after periods.

Table 81. Results for Iowa: Iowa 136 at the CC (NB).

	Before	1 Mo	Change	12 Mo	Change	24 Mo	Change
Sample size	1,178	1,324	NA	1,345	NA	628	NA
Mean speed (mph)	52.2	51.6	-0.6	50.2	-2.0	50.7	-1.5
SD of mean	5.8	5.2	NA	5.8	NA	6.6	NA
85th percentile speed (mph)	58	56	-2	55	-3	57	-1
Fraction of vehicles exceeding posted or advisory speed limit							
By 5 mph	0.71	0.70	-1.5%	0.59	-17.0%	0.65	-9.2%
By 10 mph	0.34	0.24	-28.6%	0.19	-44.8%	0.25	-25.4%
By 15 mph	0.09	0.05	-40.2%	0.03	-64.4%	0.05	-44.8%
By 20 mph	0.02	0.01	-43.8%	0.00	-75.0%	0.01	-68.8%

NA = Not applicable
SD = Standard deviation

RESULTS FOR OHIO—ALKIRE ROAD

A dynamic speed sign was installed for Alkire Road in Ohio. The curve has an advisory speed of 30 mph with a speed limit of 55 mph. The sign was installed for the EB direction of traffic. The site is located about 16 miles southwest of Columbus, OH. Table 82 shows results for the upstream speed control location.

Table 82. Results for Ohio: Alkire Road upstream of curve (EB).

	Before	1 Mo	Change	12 Mo	Change	24 Mo	Change
ADT	1,450	1,519	69	1,490	40	1,486	36
Sample size	2,863	3,005	NA	1,476	NA	2,913	NA
Mean speed (mph)	52.7	58.8	6.1	51.3	-1.4	50.1	-2.6
SD of mean	6.9	8	NA	7.7	NA	7.9	NA
85th percentile speed (mph)	59	66	7	58	-1	57	-2
Fraction of vehicles exceeding posted or advisory speed limit							
By 5 mph	0.14	0.45	2.1%	0.11	-21.8%	0.08	-44.4%
By 10 mph	0.04	0.20	4.0%	0.02	-40.0%	0.02	-50.0%
By 15 mph	0.01	0.08	7.2%	0.01	-50.0%	0.01	-30.0%*
By 20 mph	0.00	0.03	14.0%	0.00	50.0%*	0.00	0.0%*

*Not statistically significant at 95-percent level of significance
ADT = Average daily traffic
NA = Not applicable
SD = Standard deviation

Minor decreases were noted for the PC as shown in table 83. Minor reductions resulted in the fraction of vehicles traveling 5 mph or more over the advisory speed of 30 mph occurred (up to 7.9 percent). Moderate reductions were noted in the percent of vehicles exceeding the advisory speed of 30 mph by 10 mph or more for all of the after periods, with decreases up to 25.1 percent. Moderate decreases were also noted in the percent of vehicles traveling 15 mph or more over the advisory speed, with decreases up 41.1 percent noted. Large reductions resulted in the fraction of vehicles traveling 20 mph or more over the advisory speed, with a 27.1 percent reduction at 1 month, a 54.2 percent reduction at 12 months, and a 44.9 percent reduction at 24 months.

Table 83. Results for Ohio: Alkire Road at the PC (EB).

	Before	1 Mo	Change	12 Mo	Change	24 Mo	Change
Sample size	2,913	1,482	NA	1,488	NA	2,927	NA
Mean speed (mph)	43.5	43	-0.5	40.7	-2.8	41.1	-2.4
SD of mean	5.7	5.1	NA	5.6	NA	6.2	NA
85th percentile speed (mph)	49	48	-1	46	-3	47	-2
Fraction of vehicles exceeding posted or advisory speed limit							
By 5 mph	0.95	0.95	0.2%	0.87	-7.9%	0.89	-6.6%
By 10 mph	0.81	0.79	-2.4%	0.60	-25.1%	0.65	-19.6%
By 15 mph	0.43	0.38	-11.9%	0.25	-41.1%	0.26	-38.3%
By 20 mph	0.12	0.09	-27.1%	0.05	-54.2%	0.07	-44.9%

NA = Not applicable
SD = Standard deviation

Table 84 provides results for the CC data collection location. Minor speed increases were noted for most of the speed metric for the 1-month after period. Speeds had increased significantly at the upstream control point, which may suggest that the sign may have been more effective than shown in the results for the PC and CC.

Table 84. Results for Ohio: Alkire Road at the CC (EB).

	Before	1 Mo	Change	12 Mo	Change	24 Mo	Change
Sample size	2,927	3,006		1,480		2,906	
Mean speed (mph)	41.5	41.9	0.4	38.6	-2.9	37.6	-3.9
SD of mean	6.1	5.6		5.6		6.0	
85th percentile speed (mph)	47	47	0	44	-3	43	-4
Fraction of vehicles exceeding posted or advisory speed limit							
By 5 mph	0.90	0.93	3.0%	0.78	-13.4%	0.73	-19.0%
By 10 mph	0.65	0.70	6.6%	0.42	-35.4%	0.37	-43.1%
By 15 mph	0.28	0.31	14.2%	0.14	-49.1%	0.10	-63.6%
By 20 mph	0.08	0.07	-21.4%	0.02	-71.4%	0.02	-73.8%

NA = Not applicable
SD = Standard deviation

Speeds decreased moderately at the 12- and 24-month after periods, with decreases of 2.9 and 3.9 mph, and decreases of 3 and 4 mph in 85th percentile speeds. Large decreases occurred in the fraction of vehicles exceeding the advisory speed of 30 mph at the 12- and 24-month after periods. Minor increases in the fraction of vehicles traveling 5, 10, or 15 mph or more over the advisory speed for the 1-month after period (up to 14 percent) while a 21-percent decrease occurred for vehicles traveling 20 mph or more over the advisory speed. At the 12- and 24-month after periods, reductions occurred for all thresholds. The fraction of vehicles traveling 5 mph or more over decreased by up to 19 percent, the fraction traveling 10 mph or more decreased by up to 64 percent, and the percent traveling 20 mph or more over decreased by 74 percent.

RESULTS FOR OHIO—NORTON ROAD

Norton Road in Ohio was selected for a dynamic curve sign. The site has a posted speed limit of 55 mph and an advisory speed of 35 mph, and is located about 15 miles southwest of Columbus, OH. The sign was placed for the SB direction of traffic.

Table 85 shows results for the upstream speed control location. Minor speed decreases occurred at the upstream control sight. However, only the decrease in percent of vehicles traveling 5 mph or more over the posted speed limit was statistically significant. This suggests that no change in speeds occurred overall due to factors other than the dynamic curve sign.

Table 85. Results for Ohio: Norton Road upstream of curve (SB).

	Before	1 Mo	Change	12 Mo	Change	24 Mo	Change
ADT	3,671	3,382	-289	3,496	-175	3,255	-416
Sample size	7,192	3,312	NA	6,849	0.6	6,266	NA
Mean speed (mph)	50.0	49.8	-0.2*	50.6	0.6	49.7	-0.3
SD of mean	6.4	6.3	NA	6.2	NA	6.3	NA
85th percentile speed (mph)	56	56	0	57	1	56	0
Fraction of vehicles exceeding posted or advisory speed limit							
By 5 mph	0.05	0.04	-25%	0.06	22%	0.04	-45%
By 10 mph	0.01	0.01	-25%*	0.01	-8%	0.01	-20%
By 15 mph	0.00	0.00	-25%*	0.00	-50%*	0.00	-5%*
By 20 mph	0.00	0.00	0%*	0.00	0%*	0.00	-5%

*Not statistically significant
ADT = Average daily traffic
NA = Not applicable
SD = Standard deviation

Minor decreases were noted for the PC as shown in table 86. No real change in mean or 85th percentile speed occurred at 1 month. However, a moderate reduction in the percent of vehicles traveling 10, 15, or 20 mph over the advisory speed of 35 mph was noted (7.5, 9.0, and 2.2 percent).

Moderate decreases in mean speed (2.4 mph) and 85th percentile speed (2 mph) resulted for the 12-month after period. Moderate decreases also resulted in the percent 5, 10, 15, and 20 mph over the advisory speed for the 12-month after period. Minor increases resulted for the 24-month after period, but most were not statistically significant.

Table 87 shows results for the CC data collection location. Moderate decreases were noted for all speed metrics with reductions of about 3 mph in mean and 85th percentile speeds at 1 month after installation of the signs. Significant decreases in the fraction of vehicles traveling over the advisory speed also occurred, with a 14-percent decrease for 5 mph over, 41 percent decrease for 10 mph over, 64 percent decrease for 15 mph over, and 74 percent decrease for 20 mph over. Only minor changes occurred at the 12-month after period, and increases occurred for the 24-month after period.

Table 86. Results for Ohio: Norton Road at the PC (SB).

	Before	1 Mo	Change	12 Mo	Change	24 Mo	Change
Sample size	7,005	6,453	NA	3,819	240	6,247	NA
Mean speed (mph)	50.1	49.2	-0.9	47.7	-2.4	50.7	0.6
SD of mean	5.6	5.8	NA	5.3	NA	5.4	NA
85th percentile speed (mph)	55	55	0	53	-2	56	1
Fraction of vehicles exceeding posted or advisory speed limit							
By 5 mph	0.99	0.96	-1.5%	0.94	-3.6%	0.98	0.0%*
By 10 mph	0.89	0.81	-8.5%	0.74	-16.7%	0.89	0.2%*
By 15 mph	0.58	0.49	-15.6%	0.37	-36.0%	0.62	6.6%
By 20 mph	0.19	0.16	-11.8%	0.08	-54.8%	0.23	22.0%

*Not statistically significant at 95-percent level of significance
NA = Not applicable
SD = Standard deviation

Table 87. Results for Ohio: Norton Road at the CC (SB).

	Before	1 Mo	Change	12 Mo	Change	24 Mo	Change
Sample size	7,037	6,500	NA	7,441	NA	3,122	NA
Mean speed (mph)	45.5	42.4	-3.1	45.3	-0.2	47.5	2.0
SD of mean	6.4	6.1	NA	6.1	NA	6.0	NA
85th percentile speed (mph)	51	48	-3	51	0	53	2
Fraction of vehicles exceeding posted or advisory speed limit							
By 5 mph	0.88	0.76	-14.4%	0.88	-0.9%	0.93	5.2%
By 10 mph	0.65	0.38	-41.3%	0.60	-8.4%	0.77	18.5%
By 15 mph	0.23	0.08	-63.9%	0.22	-3.9%	0.37	60.5%
By 20 mph	0.04	0.01	-73.7%	0.04	-7.9%	0.08	110.5%

NA = Not applicable
SD = Standard deviation

RESULTS FOR OHIO—PONTIUS ROAD

A dynamic curve sign was installed on Pontius Road in Ohio. The posted speed limit is 55 mph, and an advisory speed of 30 mph is present. The site is located about 15 miles southeast of Columbus, OH. Table 88 shows results for the upstream location (speed control).

Table 88. Results for Ohio: Pontius Road upstream of curve (SB).

	Before	1 Mo	Change	12 Mo	Change	24 Mo	Change
Sample size	1,306	1,213	-93	1,233	-73	1,100	-206
Mean speed (mph)	2,579	2,404	NA	2,453	NA	978	NA
SD of mean	52.5	52.7	0.2*	49.1	-3.4	50.3	-2.2
85th percentile speed (mph)	6.1	5.5	NA	4.7	NA	5.2	NA
Sample size	58	58	0	53	-5	55	-3
Fraction of vehicles exceeding posted or advisory speed limit							
By 5 mph	0.09	0.09	2.2%*	0.01	-88.9%	0.04	-58.9%
By 10 mph	0.02	0.01	-17.6%*	0.00	-88.2%	0.00	-82.4%
By 15 mph	0.00	0.00	-50.0%*	0.00	-75.0%	0.00	-75.0%
By 20 mph	0.00	0.00	0.0%*	0.00	0.0%*	0.0	0.0%*

*Not statistically significant at 95-percent level of significance
NA = Not applicable
SD = Standard deviation

Speed decreased or increased by very minor amounts for all speed metrics, but none of the changes were statistically significant at the 95-percent level of significance. Speeds decreased moderately for the 12- and 24-month after periods.

Changes in speed are noted in table 89 for the PC. Only minor changes occurred for change in mean speed (0.9 mph) and change in percent of vehicles exceeding the advisory speed of 30 mph by 5 mph or more (1 percent) at 1 month. Moderate increases in the percent of vehicles traveling 10, 15, or 20 mph or more over the advisory speed occurred.

Only minor changes occurred for the 12-month after period, with most of the changes not being statistically significant. At the 24-month after period, speeds were lower than for any of the previous time periods. Speed decreases were moderate, with a mean speed and 85th percentile decrease of 2 mph. Moderate decreases in the percent of vehicles exceeding the advisory speed by 5, 10, 15, or 20 mph occurred.

Fairly large increases in speed were noted in the CC data as shown in table 90 at 1 month. Mean speed increased by 2.8 mph, and the 85th percentile increased by 6 mph. There was also a large increase in the number of vehicles exceeding the advisory speed of 30 mph by 20 mph or more (211 percent). It is not likely that the presence of the sign caused the increase, but the reason for the increase is unknown.

Table 89. Results for Ohio: Pontius Road at the PC (SB).

	Before	1 Mo	Change	12 Mo	Change	24 Mo	Change
Sample size	2,538	2,499		2,436		2269	
Mean speed (mph)	44.9	45.8	0.9	45.0	0.1	43.0	-1.9
SD of mean	5.1	4.8		4.9		5.8	
85th percentile speed (mph)	50	50	0	50	0	48	-2
Fraction of vehicles exceeding posted or advisory speed limit							
By 5 mph	0.97	0.98	0.9%	0.98	1.1%	0.94	-3.1%
By 10 mph	0.88	0.92	4.0%	0.88	-0.2%*	0.75	-15.0%
By 15 mph	0.57	0.64	11.4%	0.55	-4.0%*	0.41	-28.7%
By 20 mph	0.15	0.20	34.2%	0.16	3.3%*	0.11	-25.0%

*Not statistically significant at 95-percent level of significance
NA = Not applicable
SD = Standard deviation

Table 90. Results for Ohio: Pontius Road at the CC (SB).

	Before	1 Mo	Change	12 Mo	Change	24 Mo	Change
Sample size	1,324	1,856		2,448		2,271	
Mean speed (mph)	44.4	47.2	2.8	42.4	-2.0	42.6	-1.8
SD of mean	4.7	7.7		5.0		5.3	
85th percentile speed (mph)	49	55	6	47	-2	47	-2
Fraction of vehicles exceeding posted or advisory speed limit							
By 5 mph	0.97	0.97	-0.5%*	0.95	-2.2%	0.96	-1.8%
By 10 mph	0.87	0.86	-1.0%*	0.73	-16.2%	0.75	-13.6%
By 15 mph	0.51	0.62	22.0%	0.34	-33.8%	0.34	-32.8%
By 20 mph	0.12	0.38	210.7%	0.06	-48.4%	0.07	-40.2%

*Not statistically significant at 95-percent level of significance
NA = Not applicable
SD = Standard deviation

Speeds at the PC and upstream location were nearly unchanged from the before period to the 1-month after period, suggesting that speeds overall did not increase. A check of the traffic counting equipment and data did not reveal any equipment malfunction. Moderate speed decreases occurred at the 12- and 24-month after periods, with decreases of about 2 mph for the mean and 85th percentile speeds for both periods. Moderate decreases occurred in the fraction of vehicles exceeding the advisory speed.

RESULTS FOR OREGON—OR 42

The treatment site on OR 42 in Oregon has a posted speed limit of 55 mph and an advisory speed of 35 mph. The sign type is a dynamic speed sign. The site is located 34 miles southwest of Roseburg, OR. The curve advisory speed is 35 mph, and the tangent speed is 55 mph. The sign was installed in October 2009. Data were collected through the 12-month after period. The sign experienced a large number of maintenance issues; after numerous fixes were attempted, it was determined that continued maintenance was beyond project resources, and the sign was removed in September 2011.

Table 91 shows results for the upstream location (speed control). At 1 month after, minor decreases in speed resulted for all speed metrics. Although only minor actual decreases resulted, the percent change in the fraction of vehicles exceeding the advisory speed was fairly significant. At 12 months, essentially no speed changes had occurred.

Table 91. Results for Oregon: OR 42 upstream of curve (WB).

	Before	1 Mo	Change	12 Mo	Change
ADT	1,119	1,112	-7	1,146	27
Sample size	2,081	2,082	NA	2,292	NA
Mean speed (mph)	60.7	59.5	-1.2	60.1	-0.6
SD of mean	5.7	5.2	NA	6.5	NA
85th percentile speed (mph)	66	64	-2	66	0
Fraction of vehicles exceeding posted or advisory speed limit					
By 5 mph	0.59	0.48	-19.4%	0.54	-9.3%
By 10 mph	0.22	0.14	-36.5%	0.21	-3.7%
By 15 mph	0.06	0.03	-58.1%	0.05	-12.9%
By 20 mph	0.02	0.01	-61.5%	0.02	23.1%

ADT = Average daily traffic
NA = Not applicable
SD = Standard deviation

Table 92 provides results for the PC. A significant decrease of 4 mph in mean and 85th percentile speed occurred at the 1-month after period, with a 6 mph decrease in both metrics for the 12-month after period. Moderate decreases occurred for vehicles traveling 5 mph or more over the advisory speed (6 percent for the 1-month after period, and 13 percent for the 12-month after period).

Significant decreases resulted for the percent of vehicles traveling 10, 15, 20 mph or more over the advisory speed limit of 35 mph, with decreases of 19.9 percent and 32.2 percent for 10 mph or more over, 40.2 percent and 61.6 percent for 15 mph or more over, and 64.5 percent and 81.1 percent for 20 mph or more over.

Table 92. Results for Oregon: OR 42 at the PC (WB).

	Before	1 Mo	Change	12 Mo	Change
ADT	1,022	1,112	90	1,237	215
Sample size	1,809	2,090	NA	2,270	NA
Mean speed (mph)	51.8	47.7	-4.1	45.7	-6.1
SD of mean	6.3	6.2	NA	6.1	NA
85th percentile speed (mph)	58	54	-4	52	-6
Fraction of vehicles exceeding posted or advisory speed limit					
By 5 mph	0.97	0.91	-6.1%	0.85	-12.5%
By 10 mph	0.89	0.71	-19.9%	0.60	-32.2%
By 15 mph	0.67	0.40	-40.2%	0.26	-61.6%
By 20 mph	0.34	0.12	-64.5%	0.06	-81.1%

ADT = Average daily traffic
NA = Not applicable
SD = Standard deviation

Table 93 shows results for the CC on OR 42. A decrease of about 3 mph was noted for the mean and 85th percentile speeds at 1 month, and 2.3 and 3 mph at 12 months. Reductions in the percent of vehicles traveling over the advisory speed limit were also recorded that were greater in most cases than at the PC.

Table 93. Results for Oregon: OR 42 at the CC (WB).

	Before	1 Mo	Change	12 Mo	Change
ADT	1,113	1,366	253	1,385	272
Sample size	2,066	2,178	NA	2,361	NA
Mean speed	43.1	40.4	-2.7	40.8	-2.3
SD of mean	5.0	4.7	NA	5.4	NA
85th percentile speed	49	46	-3	46	-3
Fraction of vehicles exceeding posted or advisory speed limit					
by 5 mph	0.76	0.58	-23.6%	0.61	-20.7%
by 10 mph	0.40	0.22	-44.3%	0.23	-42.5%
by 15 mph	0.10	0.04	-54.7%	0.05	-52.6%
by 20 mph	0.01	0.01	-46.2%	0.01	-15.4%*

*Not statistically significant at 95-percent level of significance
ADT = Average daily traffic
NA = Not applicable
SD = Standard deviation

RESULTS FOR OREGON—OR 238

A dynamic speed sign was selected for the treatment site on OR 238 in Oregon. The posted speed limit is 55 mph with an advisory speed of 30 mph. The sign was placed for the EB direction of traffic. The sign was installed in October 2009, and the site is 12 miles southeast of Grants Pass, OR. Table 94 shows results for the upstream speed control location.

Table 94. Results for Oregon: OR 238 upstream of curve (EB).

	Before	1 Mo	Change	12 Mo	Change	24 Mo	Change
ADT	1,719	1,585	-134	1,767	48	1,759	40
Sample size	3,404	3,136	NA	1,731	NA	3457	NA
Mean speed (mph)	53.3	53.4	0.1*	52.5	-0.8	53.5	0.2*
SD of mean	5.0	5.6	NA	5.6	NA	5.5	NA
85th percentile speed (mph)	58	59	1	58	0	58	0
Fraction of vehicles exceeding posted or advisory speed limit							
By 5 mph	0.09	0.12	30.0%	0.09	-5.6%*	0.11	20.0%
By 10 mph	0.02	0.02	5.3%*	0.02	10.5%*	0.02	-15.8%*
By 15 mph	0.00	0.00	-50.0%*	0.01	25.0%*	0.00	-25.0%*
By 20 mph	0.00	0.00	0.0%*	0.00	0.0%*	0.00	0.0%*

*Not statistically significant at 95-percent level of significance
ADT = Average daily traffic
NA = Not applicable
SD = Standard deviation

Small increases in speeds were noted at the upstream control site, although most of the differences were not statistically significant. This indicates that no major changes in speed occurred at the control data collection location.

Moderate decreases in mean and 85th percentile (about 3 mph) were found at the PC for OR 238, as shown in table 95, for both the 1-month and 12-month after periods. More significant changes in the percent of vehicles exceeding the advisory curve speed of 30 mph occurred, as shown.

There was a decrease of up to 17 percent in the fraction of vehicles exceeding the advisory speed by 5 mph, a decrease up to 42 percent in vehicles exceeding the advisory speed by 10 mph, a decrease up to 61 percent for vehicles exceeding the advisory speed by 15 mph, and a decrease up to 72 percent in vehicles exceeding the advisory speed by 20 mph.

Table 95. Results for Oregon: OR 238 at the PC (EB).

	Before	1 Mo	Change	12 Mo	Change	24 Mo	Change
Sample size	3,338	3,119	NA	3,440	NA	3,371	NA
Mean speed (mph)	41.7	38.3	-3.4	38.9	-2.8	39.6	-2.1
SD of mean	4.4	5.0	NA	4.6	NA	4.9	NA
85th percentile speed (mph)	46	43	-3	43	-3	44	-2
Fraction of vehicles exceeding posted or advisory speed limit							
By 5 mph	0.95	0.79	-16.7%	0.84	-11.8%	0.86	-9.1%
By 10 mph	0.71	0.41	-42.1%	0.46	-35.4%	0.52	-27.1%
By 15 mph	0.25	0.10	-61.0%	0.10	-59.4%	0.15	-40.6%
By 20 mph	0.03	0.01	-62.1%	0.01	-72.4%	0.02	-34.5%

NA = Not applicable
SD = Standard deviation

Although reductions were smaller, similar results were found for the CC as for the PC as shown in table 96.

Table 96. Results for Oregon: OR 238 at the CC (EB)

	Before	1 Mo	Change	12 Mo	Change	24 Mo	Change
ADT	1,696	1,535	-161	1,965	269	1,751	55
Sample size	3,331	3,027	NA	3,302	NA	1704	NA
Mean speed (mph)	36.8	34.3	-2.5	36.4	-0.4	35.7	-1.1
SD of mean	4.0	3.9	NA	4.1	NA	3.9	NA
85th percentile speed (mph)	41	38	-3	40	-1	39	-2
Fraction of vehicles exceeding posted or advisory speed limit							
By 5 mph	0.73	0.48	-34.0%	0.69	-6.2%	0.62	-14.5%
By 10 mph	0.23	0.09	-62.6%	0.21	-10.0%	0.15	-36.5%
By 15 mph	0.03	0.01	-77.8%	0.02	-18.5%*	0.02	-40.7%
By 20 mph	0.00	0.00	-50.0%	0.00	0.0%*	0.00	-50.0%*

*Not statistically significant at 95-percent level of significance
NA = Not applicable
SD = Standard deviation

The mean and 85th percentile speeds decreased by up to 3 mph, and large decreases in the percent of vehicles exceeding the advisory speed by 5 (34 percent), 10 mph (63 percent), 15 mph (78 percent), and 20 mph (50 percent) occurred for the 1-month after period. Decreases at the 12-month after period were minor, and changes in the percent over the number of vehicles exceeding the advisory speed by 15 and 20 mph were not statistically significant. Changes at 24 months were higher than for the 12-month after period, with a decrease in mean speed of

1.1 mph and 2 mph for 85th percentile speeds. Small decreases resulted for the changes in vehicles traveling over the advisory speed.

RESULTS FOR OREGON—US 101

US 101 in Oregon was selected for a dynamic curve sign. The posted speed limit is 55 mph with an advisory speed of 45 mph. The sign was placed for the SB direction of traffic. Speed and volume data were collected through the 1-month after period. The sign had numerous problems, including power issues, problems with LEDs, etc. The sign was fixed several times, and fixing the sign required a long-distance trip each time. The sign quit functioning again after the 12-month after period. As a result, after 12 months, it was decided to abandon further fixes to the sign, so 24-month after data were not collected.

Table 97 shows results for the upstream speed control data collection location. Moderate increases in speeds were noted at the upstream control site for most of the speed metrics except for the percent of vehicles traveling 15 or 20 mph or more over the posted speed limit.

Table 97. Results for Oregon: US 101 upstream of curve (SB).

	Before	1 Mo	Change	12 Mo	Change
ADT	1,410	1,468	58	1,934	524
Sample size	2,746	2,788	NA	3,758	NA
Mean speed (mph)	52.6	55.1	2.5	60.2	7.6
SD of mean	5.6	6.7	NA	6.6	NA
85th percentile speed (mph)	58	61	3	67	9
Fraction of vehicles exceeding posted or advisory speed limit					
By 5 mph	0.09	0.21	120%	0.57	504%
By 10 mph	0.01	0.04	157%	0.25	1,714%
By 15 mph	0.00	0.00	50%*	0.07	3,250%
By 20 mph	0.00	0.00	0%*	0.02	0%

*Not statistically significant at 95-percent level of significance
ADT = Average daily traffic
NA = Not applicable
SD = Standard deviation

Significant increases resulted for the 12-month after period, with an increase in mean speed of 7.6 mph and an increase in 85th percentile speed of 9 mph. Significant increases also resulted for the fraction of vehicles traveling over the speed limit.

Table 98 presents results for the PC. Minor decreases in mean (0.8 mph) and 85th percentile speed (1 mph) were reported at 1 month. Modest decreases in the percent of vehicles traveling over the advisory speed of 45 mph were noted. Similar decreases for mean (1.8 mph) and 1 mph in 85th percentile speed occurred.

Moderate decreases occurred after 12 months that were even greater than after 1 month for the percent over the advisory speed, with up to a 10-percent decrease in the fraction of vehicles traveling 5 mph or more over the advisory speed. Decreases up to 26.2 percent occurred for vehicles traveling 10 mph or more over the advisory speed while a 35 percent reduction occurred for vehicles traveling 15 mph or more over. Decreases up to 53.5 percent in the fraction of

vehicles traveling 20 mph or more over were noted. Because speeds increased at the control site, the effectiveness of the signs may be even greater than noted.

Table 98. Results for Oregon: US 101 at the PC (SB).

	Before	1 Mo	Change	12 Mo	Change
Sample size	2,769	2,823	NA	3,796	NA
Mean speed (mph)	55.6	54.8	-0.8	53.8	-1.8
SD of mean	6.7	5.2	NA	6.5	NA
85th percentile speed (mph)	61	60	-1	60	-1
Fraction of vehicles exceeding posted or advisory speed limit					
By 5 mph	0.88	0.86	-2.3%	0.79	-10.7%
By 10 mph	0.65	0.55	-15.0%	0.48	-26.2%
By 15 mph	0.26	0.17	-34.6%	0.17	-35.8%
By 20 mph	0.04	0.02	-53.5%	0.03	-30.2%

NA = Not applicable
SD = Standard deviation

A significant decrease in mean and 85th percentile speeds (almost 6 mph) occurred at the CC, as shown in table 99, for both the 1- and 12-month after periods. Very large decreases in vehicles traveling at high speeds resulted with a reduction of 43.0 percent of vehicles traveling 5 mph or more and up to 78.7 percent reduction in vehicles traveling 10 mph or more over the advisory speed of 45 mph. Reductions up to 95.3 percent were observed in the fraction of vehicles traveling 15 mph or more over the advisory speed and up to 96.7 percent reduction for vehicles traveling 20 mph or more over.

Table 99. Results for Oregon: US 101 at the CC (SB).

	Before	1 Mo	Change	12 Mo	Change
ADT	1,418	1,369	-49	1,963	545
Sample size	2,770	1,343	NA	3,821	NA
Mean speed (mph)	54.8	49.2	-5.6	49.2	-5.6
SD of mean	5.5	4.6	NA	5.7	NA
85th percentile speed (mph)	60	54	-6	55	-5
Fraction of vehicles exceeding posted or advisory speed limit					
By 5 mph	0.85	0.48	-43.0%	0.50	-41.4%
By 10 mph	0.54	0.11	-78.7%	0.17	-67.7%
By 15 mph	0.19	0.01	-95.3%	0.03	-86.0%
By 20 mph	0.03	0.00	-96.7%	0.00	-93.3%

ADT = Average daily traffic
NA = Not applicable
SD = Standard deviation

RESULTS FOR OREGON—OR 126

OR 126 in Oregon has a posted speed limit of 55 mph with no advisory speed. A dynamic curve sign was placed for the EB direction of traffic. The site is 24 miles west of Eugene, OR. The sign was installed in January 2010.

Table 100 shows results for the upstream speed control data collection location. As shown, moderate decreases in speeds occurred at the upstream control site for all of the speed metrics after 1 month and significant decreases occurred at the 12-month after period, with decreases of 4.7 mph in average speed and 6 mph for the 85th percentile speed.

Table 100. Results for Oregon: OR 126 upstream of curve (EB).

	Before	1 Mo	Change	12 Mo	Change	24 Mo	Change
ADT	1,878	1,822	-56	2,191	313	2,126	248
Sample size	3,677	3,549		4,279		4,119	
Mean speed (mph)	56.9	55.2	-1.7	55.8	-1.1	52.2	-4.7
SD of mean	6.0	5.7		6.0		5.6	
85th percentile speed (mph)	63	61	-2	61	-2	57	-6
Fraction of vehicles exceeding posted or advisory speed limit							
By 5 mph	0.31	0.21	-31.5%	0.24	-23.5%	0.09	-72.7%
By 10 mph	0.10	0.05	-52.1%	0.06	-33.3%	0.01	-85.4%
By 15 mph	0.02	0.01	-59.1%	0.01	-36.4%	0.00	-90.9%
By 20 mph	0.01	0.00	-60.0%	0.00	-20.0%*	0.0	-100.0%

*Not statistically significant at 95-percent level of significance
ADT = Average daily traffic
NA = Not applicable
SD = Standard deviation

Table 101 shows results for the PC. Minor decreases occurred for all speed metrics for all of the after periods, although the decreases were smaller than for the control point. This may suggest that the sign had limited effectiveness for the PC.

Decreases were the greatest for the 24-month after period, with a decrease of almost 2 mph in mean speed and 1 mph in 85th percentile speed. A 6.5 percent decrease resulted for the number of vehicles traveling 5 mph over the advisory speed, with an 18.0-percent decrease in the fraction of vehicles traveling 10 mph or more over, 23.4-percent decrease for 15 mph over, and 14.4-percent decrease for vehicles traveling 20 or mph over.

Table 101. Results for Oregon: OR 126 at the PC (EB).

	Before	1 Mo	Change	12 Mo	Change	24 Mo	Change
Sample size	3,648	3,545	NA	4,233	NA	4,123	NA
Mean speed (mph)	53.7	53.1	-0.6	53.5	-0.2*	52.0	-1.7
SD of mean	5.3	5.9	NA	6.5	NA	6.0	NA
85th percentile speed (mph)	59	59	0	60	1	58	-1
Fraction of vehicles exceeding posted or advisory speed limit							
By 5 mph	0.96	0.94	-1.5%	0.92	-3.3%	0.89	-6.5%
By 10 mph	0.81	0.73	-9.9%	0.73	-10.2%	0.67	-18.0%
By 15 mph	0.44	0.39	-11.6%	0.44	-0.5%*	0.34	-23.4%
By 20 mph	0.12	0.13	9.3%*	0.17	44.9%	0.10	-14.4%

*Not statistically significant at 95-percent level of significance
NA = Not applicable
SD = Standard deviation

Table 102 shows results for the CC for OR 126. Minor decreases also occurred for all speed metrics for the 1-month and 24-month after periods. Decreases are greater in most cases than for the control site. A fairly substantial decrease in the percent of vehicles traveling over the posted speed limit by 15 and 20 mph was noted.

Table 102. Results for Oregon: OR 126 at the CC (EB).

	Before	1 Mo	Change	12 Mo	Change	24 Mo	Change
Sample size	3,729	3,563	NA	4,260	NA	4,108	NA
Mean speed (mph)	50.9	49.6	-1.3	46.5	-4.4	48.8	-2.1
SD of mean	5.7	5.2	NA	5.4	NA	5.7	NA
85th percentile speed (mph)	56	55	-1	52	-4	55	-1
Fraction of vehicles exceeding posted or advisory speed limit							
By 5 mph	0.88	0.85	-3.5%	0.65	-26.5%	0.78	-12.0%
By 10 mph	0.60	0.48	-19.4%	0.27	-54.9%	0.43	-28.5%
By 15 mph	0.24	0.16	-32.5%	0.07	-72.4%	0.16	-35.4%
By 20 mph	0.06	0.03	-46.8%	0.01	-87.1%	0.04	-40.3%

NA = Not applicable
SD = Standard deviation

Moderate decreases in mean (4.4 mph) and 85th percentile speeds (4 mph) resulted for the 24-month after period. Moderate decreases also resulted for the fraction traveling over the advisory speed, with up to 26.5 percent decrease for the 5 mph over, up to 54.9 percent decrease for 10 mph or more over, up to 72.5 percent decrease for the 15 mph over, and up to 87.1 percent for 20 mph over.

RESULTS FOR TEXAS—FM 481

A speed display sign was installed at Texas site FM 481 in April 2010. The site has a curve advisory speed of 50 mph and a speed limit of 65 mph for passenger vehicles. The speed limit for trucks is 60 mph during the daytime and 55 mph at nighttime. The site is 20 miles southwest of Uvalde, TX.

Results are summarized below. Table 103 shows speed and volume changes for the upstream control section. Moderate speed increases resulted for all the after periods for all speed metrics.

Table 103. Results for Texas: FM 481 upstream of curve (EB).

	Before	1 Mo	Change	12 Mo	Change	24 Mo	Change
ADT	523	545	22	442	-81	473	-50
Sample size	975	957	NA	865	NA	466	NA
Mean speed (mph)	65.9	68.2	2.3	68.5	2.6	67.5	1.6
SD of mean	6.7	7.1	NA	6.9	NA	6.6	NA
85th percentile speed (mph)	72	74	2	77	5	67	2
Fraction of vehicles exceeding posted or advisory speed limit							
By 5 mph	0.24	0.40	63.1%	0.42	73.8%	0.35	43.4%
By 10 mph	0.08	0.14	75.6%	0.14	74.4%	0.12	51.2%
By 15 mph	0.02	0.06	137.5%	0.05	125.0%	0.04	70.8%
By 20 mph	0.01	0.03	333.3%	0.02	283.3%	0.02	150.0%

ADT = Average daily traffic
NA = Not applicable
SD = Standard deviation

Table 104 shows results for FM 481 at the PC. Significant decreases occurred in mean and 85th percentile speeds for the 1-, 12-, and 24-month after periods (between 4 and 6 mph). Decreases up to 16.5 percent in the fraction of vehicles traveling 5 mph or more over the advisory speed resulted, and decreases up to 35.2 percent in vehicles traveling 10 mph or more over.

Table 104. Results for Texas: FM 481 at the PC (EB).

	Before	1 Mo	Change	12 Mo	Change	24 Mo	Change
Sample size	993	982	NA	876	NA	463	NA
Mean speed (mph)	66.7	61.5	-5.2	61.1	-5.6	61.0	-5.7
SD of mean	7	7.7	NA	7.7	NA	7.2	NA
85th percentile speed (mph)	73	69	-4	69	-4	68	-5
Fraction of vehicles exceeding posted or advisory speed limit							
By 5 mph	0.96	0.82	-14.1%	0. 08	-16.5%	0.81	-14.9%
By 10 mph	0.86	0.62	-28.5%	0.60	-29.8%	0.56	-35.2%
By 15 mph	0.66	0.38	-42.3%	0.35	-47.3%	0.33	-49.9%
By 20 mph	0.36	0.03	-91.3%	0.11	-70.1%	0.11	-67.9%

NA = Not applicable
SD = Standard deviation

A significant decrease in vehicles traveling 15 mph or more resulted with decreases between 42.3 and 49.9 2 percent. A large reduction in vehicles traveling 20 mph or more over the advisory speed resulted, with decreases of up to 91.3 percent.

Table 105 shows changes in speed metrics for the CC. Mean speed increased by approximately 1 mph and 85th percentile speed increased by 3 mph for the 1-month after period. Many of the changes in percent of vehicles over the advisory speed were not statistically significant.

Table 105. Results for Texas: FM 481 at the CC (EB)

	Before	1 Mo	Change	12 Mo	Change	24 Mo	Change
Sample size	998	984		854		446	
Mean speed (mph)	61.0	62.3	1.3	60.1	-0.9	60.0	-1.0
SD of mean	6.9	7.8		7.1		7.0	
85th percentile speed (mph)	67	70	3	67	0	67	0
Fraction of vehicles exceeding posted or advisory speed limit							
By 5 mph	0.87	0.86	-1.8%*	0.80	-7.7%	0.81	-7.3%
By 10 mph	0.65	0.64	-0.2%*	0.55	-14.4%	0.50	-21.9%
By 15 mph	0.29	0.33	13.1%	0.25	-12.7%	0.26	-12.0%
By 20 mph	0.06	0.17	160.9%	0.07	4.7%*	0.07	15.6%

*Not statistically significant at 95-percent level of significance
NA = Not applicable
SD = Standard deviation

At 12 and 24 months, mean speed decreased by about 1 mph with no change in the 85th percentile speed. A decrease of up to 7.7 percent resulted for vehicles traveling 5 mph or more over the advisory speed. A decrease of up to 21.9 percent resulted for vehicles traveling 10 mph or more over the advisory speed and a decrease up to 13.1 percent occurred for vehicles traveling 15 mph or more over the advisory speed. Increases were noted for vehicles traveling 20 mph or more over the advisory speed.

RESULTS FOR TEXAS—FM 755

A dynamic speed sign was installed on FM 755 in Texas for the WB direction of traffic. The site is 39 miles northeast of Rio Grande City, TX. The site has a posted speed limit of 65 mph with a posted truck speed of 60 for daytime and 55 mph for nighttime. The sign was vandalized and knocked over right after installation so data were not collected for the 1-month after period. Data were collected at 12 months. Results for the 12-month after period are summarized below.

The sign was knocked over again before the 24-month after period and was not functioning at the 24-month after data collection period. Table 106 shows speed and volume the 12-month after period for all speed metrics.

Table 106. Results for Texas: FM 755 upstream of curve (WB).

	Before	12 Mo	Change
ADT	346	399	NA
Sample size	663	781	NA
Mean speed (mph)	66.9	68.8	1.9
SD of mean	8.8	8.1	NA
85th percentile speed (mph)	75	76	1
Fraction of vehicles exceeding posted or advisory speed limit			
By 5 mph	0.34	0.42	26.2%
By 10 mph	0.17	0.20	17.5%*
By 15 mph	0.07	0.08	15.5%*
By 20 mph	0.02	0.04	66.7%*

*Not statistically significant at 95-percent level of significance
ADT = Average daily traffic
NA = Not applicable
SD = Standard deviation

Moderate speed changes resulted for the PC as shown in table 107. Mean speed decreased by 2.9 mph and 85th percentile speed decreased by 4 mph. The fraction of vehicles traveling 5 mph or more over the posted speed limit decreased by 10.0 percent, and the fraction traveling 10 mph or more over decreased by 28.3 percent. A 35.6 percent decrease resulted for the fraction traveling 15 mph over. The fraction of vehicles traveling 20 mph or more over the advisory speed decreased by 68.5 percent.

Table 107. Results for Texas: FM 755 at the PC (WB).

	Before	12 Mo	Change
Sample size	658	319	NA
Mean speed (mph)	62.7	59.8	-2.9
SD of mean	8.5	7.4	NA
85th percentile speed (mph)	71	67	-4
Fraction of vehicles exceeding posted or advisory speed limit			
By 5 mph	0.85	0.76	-10.0%
By 10 mph	0.69	0.50	-28.3%
By 15 mph	0.43	0.28	-35.6%
By 20 mph	0.18	0.06	-68.5%

*Not statistically significant at 95-percent level of significance
NA = Not applicable
SD = Standard deviation

Only moderate changes occurred at the CC for FM 755, as shown in table 108. A minor decrease of 1.4 mph in the average speed and an increase of 1 mph in the 85th percentile speed resulted. No statistically significant changes in vehicles traveling over the advisory speed occurred at the CC.

Table 108. Results for Texas: FM 755 at the CC (WB).

	Before	12 Mo	Change
Sample size	656	332	
Mean speed (mph)	54.5	55.9	-1.4
SD of mean	9.6	7.5	
85th percentile speed (mph)	63	62	1
Fraction of vehicles exceeding posted or advisory speed limit			
By 5 mph	0.58	0.61	4.0%*
By 10 mph	0.30	0.30	-0.3%*
By 15 mph	0.10	0.11	10.5%*
By 20 mph	0.01	0.02	100.0%*

*Not statistically significant at 95-percent level of significance
NA = Not applicable
SD = Standard deviation

RESULTS FOR TEXAS—SH 359

A curve advisory sign was installed on SH 359 in Texas in April 2010. The tangent speed is 70 mph with a truck speed that is 65 mph at night. The site is 45 miles west of Laredo, TX. The sign faces the WB direction of traffic.

Table 109 shows speed and volume changes for the upstream control section. Minor speed decreases resulted for the 1-, 12-, and 24-month after periods for all speed metrics.

Table 109. Results for Texas: SH 359 upstream of curve (WB).

	Before	1 Mo	Change	12 Mo	Change	24 Mo	Change
ADT	1,483	1,596	113	1,408	-75	1,570	87
Sample size	2,889	3,049	NA	2,692	NA	1485	NA
Mean speed (mph)	67.6	65.3	-2.3	67.3	-0.3*	66.8	-0.8
SD of mean	6.1	5.5	NA	5.9	NA	5.7	NA
85th percentile speed (mph)	73	70	-3	72	-1	67	-2
Fraction of vehicles exceeding posted or advisory speed limit							
By 5 mph	0.10	0.04	-64.6%	0.08	-21.2%	0.06	-37.4%
By 10 mph	0.04	0.01	-64.9%	0.02	-37.8%	0.02	-48.6%
By 15 mph	0.01	0.01	-58.3%	0.01	-33.3%*	0.01	-25.0%
By 20 mph	0.00	0.00	-33.3%*	0.00	-66.7%	0.00	0.0%

* Not statistically significant at 95-percent level of significance
ADT = Average daily traffic
NA = Not applicable
SD = Standard deviation

Table 110 shows results at the PC. Moderate speed decreases resulted for the 1- and 12-month after periods for SH 359 at the PC of the curve. A decrease of 3.4 and 1.7 mph occurred for the 1- and 12-month after periods, respectively, with decreases of 5 and 3 mph for 85th percentile speed.

Table 110. Results for Texas: SH 359 at the PC (WB).

	Before	1 Mo	Change	12 Mo	Change	24 Mo	Change
Sample size	2,894	3,048	NA	2,712	NA	1490	NA
Mean speed (mph)	69.6	66.2	-3.4	67.9	-1.7	67.7	-1.9
SD of mean	6.6	5.5	NA	5.7	NA	5.7	NA
85th percentile speed (mph)	75	70	-5	72	-3	72	-3
Fraction of vehicles exceeding posted or advisory speed limit							
By 5 mph	0.17	0.04	-75.0%	0.08	-51.2%	0.07	-57.1%
By 10 mph	0.06	0.01	-80.0%	0.02	-58.2%	0.03	-54.5%
By 15 mph	0.02	0.00	-78.9%	0.01	-73.7%	0.01	-47.4%
By 20 mph	0.01	0.00	-50.0%	0.00	-100.0%	0.01	-16.7%

NA = Not applicable
SD = Standard deviation

Because the speed limit was high (70 mph) with no advisory speed, only a moderate number of vehicles exceeded the posted speed limit in the before period for any of the speed intervals. Significant decreases in the fraction of vehicles exceeding the posted speed limit resulted (up to 75 percent for 5 mph or more, up to 80 percent for 10 mph or more, up to 79 percent for 15 mph or more and up to 100 percent for 20 mph or more).

Table 111 provides speed changes at the CC for SH 359. Moderate decreases in mean speed (2.3 mph) and 85th percentile speeds (3 mph) resulted for the 1-month after period. Minor changes resulted for the fraction traveling over the posted speed limit, although the magnitude of change was significant.

Table 111. Results for Texas: SH 359 at the CC (WB).

	Before	1 Mo	Change	12 Mo	Change	24 Mo	Change
Sample size	2,854	3,043	NA	3,206	NA	67.2	NA
Mean speed (mph)	69.6	67.3	-2.3	66.8	-2.8	6.2	-2.4
SD of mean	6.5	5.7	NA	6.9	NA	72	NA
85th percentile speed (mph)	75	72	-3	72	-3	67.2	-3
Fraction of vehicles exceeding posted or advisory speed limit							
By 5 mph	0.17	0.06	-66.1%	0.08	-55.0%	0.06	-64.3%
By 10 mph	0.05	0.02	-59.6%	0.01	-72.3%	0.02	-68.1%
By 15 mph	0.02	0.01	-68.8%	0.00	-87.5%	0.01	-50.0%
By 20 mph	0.01	0.00	-57.1%	0.00	-85.7%	0.00	-57.1%

NA = Not applicable
SD = Standard deviation

At 12 months, speeds had increased, with a 3-mph increase in both mean and 85th percentile speeds and minor increases in the fraction of vehicles exceeding the posted speed limit.

RESULTS FOR TEXAS—US 90

A curve advisory sign was placed on US 90 in Texas for the EB direction of traffic. The posted speed limit is 70 mph, and no advisory speed is present. The site is located 35 miles west of Uvalde, TX. The sign was installed in April 2010. The sign quit functioning in January 2011. It

was decided that the cost was too prohibitive to make an additional trip to fix the sign. As a result, data were not collected for the 24-month after period.

Results for the 12-month after period are summarized below. Table 112 shows speed and volume changes for the upstream control section. Minor increases in mean and 85th percentile speeds resulted for both the 1-month and 12-month after periods and large increases in the percent of vehicles traveling 5, 10, or 15 mph or more over the posted speed limit.

Table 112. Results for Texas: US 90 upstream of curve (EB).

	Before	1 Mo	Change	12 Mo	Change
ADT	1,525	1,502	NA	1,549	NA
Sample size	2,834	2,908	NA	2,773	NA
Mean speed (mph)	68.3	69.1	0.8	69.1	0.8
SD of mean	5.3	5.4	NA	5.7	NA
85th percentile speed (mph)	73	73	0	74	1
Fraction of vehicles exceeding posted or advisory speed limit					
By 5 mph	0.08	0.10	26.6%	0.11	34.2%
By 10 mph	0.01	0.01	40.0%*	0.02	50.0%
By 15 mph	> 0.00	> 0.00	200.0%	> 0.00	300.0%
By 20 mph	0.00	0.00	0.0%	> 0.00	0.0%

*Not statistically significant at 95-percent level of significance
ADT = Average daily traffic
NA = Not applicable
SD = Standard deviation

Table 113 shows results for the PC for US 90. Minor speed increases occurred for the 1-month after period, although most of changes were in vehicles traveling over the posted speed limit. Minor and relatively insignificant changes occurred at 12 months at the PC. However, moderate increases had occurred at the upstream control location, so speeds may have increased overall, making the impact of the signs less obvious.

As shown in Table 114, moderate decreases resulted for the 1-month and 12-month after periods at the CC for US 90 (about 1 to 2 mph for both mean and 85th percentile speeds). Although decreases in percent of vehicles traveling over the posted speed limit resulted, most of the decreases were not statistically significant. However, speeds had increased at the control site, which may indicate speeds had increased overall. In addition, given the speed limit was so high, it may be difficult to detect changes.

Table 113. Results for Texas: US 90 at the PC (EB).

	Before	1 Mo	Change	12 Mo	Change
Sample size	2,825	2,903	NA	2,766	NA
Mean speed (mph)	65.1	66.7	1.6	65.7	0.6
SD of mean	5.9	5.6	NA	6.2	NA
85th percentile speed (mph)	70	72	2	71	1
Fraction of vehicles exceeding posted or advisory speed limit					
By 5 mph	0.02	0.04	110.5%	0.03	47.4%
By 10 mph	> 0.00	0.01	75.0%*	0.01	25.0%*
By 15 mph	> 0.00	> 0.00	0.0%*	> 0.00	200.0%
By 20 mph	> 0.00	> 0.00	-100.0%	> 0.00	0.0%*

*Not statistically significant at 95-percent level of significance
NA = Not applicable
SD = Standard deviation

Table 114. Results for Texas: US 90 at the CC (EB).

	Before	1 Mo	Change	12 Mo	Change
Sample size	2,785	1,443	NA	2,789	NA
Mean speed (mph)	66.1	65.1	-1.0	64.5	-1.6
SD of mean	6.4	6.1	NA	6.8	NA
85th percentile speed (mph)	71	70	-1	70	-1
Fraction of vehicles exceeding posted or advisory speed limit					
By 5 mph	0.03	0.02	-29.4%	0.02	-52.9%
By 10 mph	0.01	> 0.00	-33.3%*	0.01	-16.7%*
By 15 mph	> 0.00	0.0	-100.0%	> 0.00	0.0%*
By 20 mph	0.00	0.0	0.0%*	0.0	0.0%*

*Not statistically significant at 95-percent level of significance
NA = Not applicable
SD = Standard deviation

RESULTS FOR WASHINGTON—US 101

US 101 in Washington has a posted speed limit of 50 mph with an advisory speed of 30 mph. A dynamic curve display was placed for the EB direction of traffic. The site is about 5 miles southwest of Aberdeen, WA.

Table 115 shows results for the upstream speed control data collection location. Moderate increases in speed occurred for the mean for all of the after periods by about 4 to 5 mph. The 85th percentile speed decreased by 2 mph for the 1-month after period, and 1 mph for the 12- and 24-month after periods. Minor decreases resulted for the percent of vehicles over the speed limit by 10, 15, or 20 mph or more.

Table 115. Results for Washington: US 101 upstream of curve (EB).

	Before	1 Mo	Change	12 Mo	Change	24 Mo	Change
ADT	1,963	1,841	-122	1,564	-399	1,489	-474
Sample size	3,563	3,509	NA	3,064	NA	2,861	NA
Mean speed (mph)	46.7	50.4	3.7	51.6	4.9	50.9	4.2
SD of mean	10.9	7.4	NA	7.0	NA	7.5	NA
85th percentile speed (mph)	59	57	-2	58	-1	58	-1
Fraction of vehicles exceeding posted or advisory speed limit							
By 5 mph	0.27	27.8	1.5%	0.33	19.0%	.30	9.5%
By 10 mph	0.14	7.2	-48.9%	0.10	-29.1%	0.07	-49.6%
By 15 mph	0.06	0.02	-73.7%	0.02	-61.4%	0.02	-73.7%
By 20 mph	0.02	< 0.00	-85.0%	0.01	-75.0%	< 0.00	-90.0%

ADT = Average daily traffic
NA = Not applicable
SD = Standard deviation

Table 116 provides results for the PC. Major reductions in speed resulted for the 1-, 12-, and 24-month after periods, with speed reductions of up to 5 mph for mean and 85th percentile speeds. Large decreases were also present in the percent of vehicles exceeding the advisory speed by 5, 10, 15, or 20 mph.

As noted, the change in percent of vehicles traveling 15 and 20 mph or more over the advisory speed was more than 30 percent. This suggests the signs were very effective in reducing high-end speeds. Decreases were much greater than those noted at the control site.

There were moderate reductions (about 4 percent) in the fraction of vehicles traveling over the advisory speed by 5 mph or more and those traveling 10 mph or more (decreases between 11 and 16 percent). There were also significant decreases in the fraction of vehicles exceeding the advisory speed by 15 mph, with decreases between 27 and 44 percent. In addition, a significant decrease in vehicles traveling 20 mph or more occurred with decreases ranging from 51 to 72 percent.

Table 116. Results for Washington: US 101 at the PC (EB).

	Before	1 Mo	Change	12 Mo	Change	24 Mo	Change
Sample size	3,400	3,510	NA	2,839	NA	2,802	NA
Mean speed (mph)	48.4	43.3	-5.1	43.5	-4.9	44.8	-3.6
SD of mean	6.4	5.8	NA	5.6	NA	6.3	NA
85th percentile speed (mph)	54	49	-5	49	-5	51	-3
Fraction of vehicles exceeding posted or advisory speed limit							
By 5 mph	0.98	0.94	-4.3%	0.94	-4.7%	0.94	-4.1%
By 10 mph	0.95	0.79	-16.2%	0.80	-15.9%	0.84	-11.3%
By 15 mph	0.78	0.46	-41.4%	0.44	-43.6%	0.57	-26.9%
By 20 mph	0.43	0.14	-68.2%	0.12	-71.5%	0.21	-51.3%

NA = Not applicable
SD = Standard deviation

Reductions also occurred at the CC for all speed metrics, although the changes were not as major as at the PC, as shown in table 117. The major decrease was in 85th percentile speeds at the

1-month after period (7 mph). Decreases of 22 percent and 15 percent resulted for the percent of vehicles exceeding the advisory speed by 5 mph for the 1- and 12-month after periods, respectively.

Table 117. Results for Washington: US 101 at the CC (EB).

	Before	1 Mo	Change	12 Mo	Change	24 Mo	Change
Sample size	3,521	3,499	NA	3,061	NA	2,861	NA
Mean speed (mph)	38.6	35.7	-2.9	36.6	-2.0	37.0	-1.6
SD of mean	4.6	5.1	NA	4.6	NA	4.8	NA
85th percentile speed (mph)	43	36	-7	41	-2	42	-1
Fraction of vehicles exceeding posted or advisory speed limit							
By 5 mph	0.85	0.63	-26.2%	0.71	-17.4%	0.74	-13.8%
By 10 mph	0.39	0.22	-44.7%	0.26	-33.9%	0.29	-26.0%
By 15 mph	0.08	0.03	-59.0%	0.04	-47.4%	0.05	-34.6%
By 20 mph	0.01	<0.00	-69.2%	0.01	-61.5%	0.00	-100.0%

NA = Not applicable
SD = Standard deviation

The change for the percent of vehicles traveling 10 mph or more over the advisory speed changed by 17 and 13 percent for the 1- and 12-month after periods, respectively. Moderate decreases of 2 mph occurred for mean and 85th percentile speeds for the 12-month after period, and about 1 mph for the 24-month after period. Moderate decreases occurred in the fraction of vehicles traveling 5 or 10 mph over, with decreases of 14 to 26 percent, and decreases of 26 to 45 percent for vehicles traveling 10 mph or more advisory speed.

Decreases between 35 and 59 percent resulted for the percent traveling over the 15 mph. Decreases for vehicles traveling 20 mph or more over were between 62 and 100 percent.

RESULTS FOR WASHINGTON—SR 7

SR 7 in Washington has a posted speed limit of 50 mph with an advisory speed of 35 mph. A dynamic speed display was placed for the EB direction of traffic. The site is 33 miles south of Tacoma, WA. The sign was installed in August 2008. The sign was vandalized in July 2009 and replaced. The sign was vandalized again in December 2009. Because the team had already made a number of unexpected visits to do sign maintenance, it was determined that it was not feasible to make another site visit, so the sign was not replaced, and data were not collected at the 24-month after period.

Table 118 shows results for the upstream speed control data collection location. A moderate decrease in mean speed occurred for the 1-month after period (1.8 mph), and a moderate increase (2.3 mph) occurred for 12-month after period. The 85th percentile speed and percent of vehicles over the speed limit decreased for the 1-month after period except for the percent of vehicles traveling 20 mph or more over the posted speed limit. All but the percent of vehicles traveling 20 mph or more over the posted speed limit increased slightly for the 12-month after period.

Table 118. Results for Washington: SR 7 upstream of curve (EB).

	Before	1 Mo	Change	12 Mo	Change
ADT	837	1,318	481	1,318	481
Sample size	1,634	2,598	NA	1,138	NA
Mean speed (mph)	49.4	47.6	-1.8	51.7	2.3
SD of mean	7.0	6.5	NA	5.8	NA
85th percentile speed (mph)	56	54	-2	57	1
Fraction of vehicles exceeding posted or advisory speed limit					
By 5 mph	0.21	0.12	-40.7%	0.29	38.8%
By 10 mph	0.06	0.04	-31.3%	0.07	14.1%*
By 15 mph	0.02	0.01	-23.5%	0.02	29.4%*
By 20 mph	0.01	0.01	16.7%	<0.00	-33.3%*

ADT = Average daily traffic
NA = Not applicable
SD = Standard deviation

Table 119 presents results for the PC for SR 7. Moderate decreases occurred for the change in mean and 85th percentile speeds. A very significant decrease in the percent of vehicles traveling over the advisory speed of 35 mph by 5, 10, 15, and 20 mph occurred for the 1-month after period, with a change of 32.0 percent for 5 mph or more and a change of 60.5 percent for 10 mph or more. The decreases were smaller for the 12-month after period than for the 1-month after period.

Table 119. Results for Washington: SR 7 at the PC (EB).

	Before	1 Mo	Change	12 Mo	Change
Sample size	1,588	2,569	NA	1,147	NA
Mean speed (mph)	43.1	39.9	-3.2	41.4	-1.7
SD of mean	6.5	5.5	NA	5.8	NA
85th percentile speed (mph)	50	45	-5	47	-3
Fraction of vehicles exceeding posted or advisory speed limit					
By 5 mph	0.73	0.49	-32.0%	0.59	-18.5%
By 10 mph	0.45	0.18	-60.5%	0.27	-40.4%
By 15 mph	0.15	0.05	-65.6%	0.09	-41.7%
By 20 mph	0.03	0.01	-56.0%	0.01	-44.0%

NA = Not applicable
SD = Standard deviation

Table 120 presents results for the CC data collection location. Moderate decreases in 85th percentile speed and percent over the advisory speed by 5, 10, and 15 mph were noted for the 1-month after period. All speeds, however, increased for the 12-month after period, with a 4-mph increase in mean speed and 2-mph increase for 85th percentile speeds. Speed increases were similar for those noted at the control site.

Table 120. Results for Washington: SR 7 at the CC (EB).

	Before	1 Mo	Change	12 Mo	Change
ADT	814	1,323	509	1,463	649
Sample size	1,561	2,569	NA	1,440	NA
Mean speed (mph)	38.3	38.8	0.5	42.0	3.7
SD of mean	9.6	5.3	NA	6.8	NA
85th percentile speed (mph)	47	44	-3	49	2
Fraction of vehicles exceeding posted or advisory speed limit					
By 5 mph	0.55	0.40	-28.3%	0.59	6.7%
By 10 mph	0.26	0.14	-45.6%	0.28	8.9%
By 15 mph	0.06	0.04	-38.6%	0.14	136.8%
By 20 mph	0.01	0.01	0.0%*	0.05	575.0%

NA = Not applicable
SD = Standard deviation

APPENDIX B. COMPARISON OF DAYTIME AND NIGHTIME SPEEDS

Changes in speed were compared for daytime versus nighttime for a select group of sites to assess whether the signs were more likely to be effective for one temporal period or the other. Data were evaluated for the before period and 12-month after period for seven sites. The 12-month after period was used because the signs would have been placed at that point for some time and any novelty effect would have worn off.

Data for each period were disaggregated by daytime and nighttime periods. Daytime was defined as 15 min after sunrise until 15 min before sunset as determined by reported sunrise and sunset time for the dates when data were collected. Nighttime was considered as 15 min after sunset until 15 min before sunrise. Data for the 30-min period around sunrise and sunset were discarded. Data were compared at the PC as well as at the CC.

Speed metrics were first compared for daytime versus nighttime for both the before and 12-month after period. This comparison was done to determine whether speeds were similar for daytime versus nighttime. Change was calculated by subtracting daytime speeds from nighttime speeds.

Speed metrics were also compared for daytime periods and then compared with nighttime periods. Daytime speed data for the before period was subtracted for daytime data at the 12-month after period. Similarly, nighttime speed data for the before period was subtracted for nighttime data at the 12-month after period. Changes in speed metrics were then compared between the two periods.

The tables in this appendix show the actual change in the fraction of vehicles traveling 5, 10, 15, or 20 mph or more over the posted or advisory speed rather than showing percent change as was done in the main section of the report.

Table 121 shows speeds for vehicles during the daytime compared with speeds for the nighttime for Washington site US 101. Nighttime speeds are lower than daytime speeds for both the before and 12-month after periods at the PC, but most differences are not statistically significant. Similarly, nighttime speeds were marginally lower during the nighttime at the CC both before and 12 months after installation of the signs.

Table 122 shows changes in speed metrics for the daytime period compared with the nighttime period. At the PC, decreases were slightly less for the nighttime period than for the daytime period, although the differences were minor. Daytime decrease at the CC was also greater than for nighttime, but the differences were also small.

Table 121. Comparison of speed changes daytime versus nighttime for Washington US 101.

	At Point of Curvature						At Center of Curve					
	Before			12 mo			Before			12 mo		
	Day	Night	Change	Day	Night	Change	Day	Night	Change	Day	Night	Change
Mean speed	48.8	47.1	-1.7	43.5	42.9	-0.6*	38.6	38.3	-0.3*	36.6	36.6	0*
85th percentile speed	54	54	0	49	49	0	43	43	0	41	41	0
Percent vehicles exceeding posted or advisory speed limit												
By 5 mph	98.4%	97.9%	-0.6%*	93.7%	92.2%	-1.5%*	85.8%	83.4%	-2.4%*	70.4%	69.9%	-0.5%*
By 10 mph	94.8%	94.2%	-0.6%*	79.7%	75.8%	-3.9%*	39.6%	37.4%	-2.2%*	25.2%	27.9%	2.6%*
By 15 mph	79.7%	71.2%	-8.5%	44.4%	40.8%	-3.6%*	7.9%	8.6%	0.7%*	4.1%	3.9%	-0.2%*
By 20 mph	45.4%	32.3%	-13.1%	12.2%	11.9%	-0.2%*	1.4%	1.1%	-0.3%*	0.5%	0.6%	0.1%*

*Not statistically significant at the 95-percent level of significance

Table 122. Comparison of speed changes for daytime versus nighttime for Washington US 101.

	At Point of Curvature						At Center of Curve					
	Daytime			Nighttime			Daytime			Nighttime		
	Before	12 mo	Change	Before	12 mo	Change	Before	12 mo	Change	Before	12 mo	Change
Mean speed	48.8	43.5	-5.3	47.1	42.9	-4.2	38.6	36.6	-2.0	38.3	36.6	-1.7
85th percentile speed	54	49	-5	54	49	-5	43	41	-2	43	41	-2
Percent vehicles exceeding posted or advisory speed limit												
By 5 mph	98.4%	93.7%	-4.7%	97.9%	92.2%	-5.7%	85.8%	70.4%	-15.4%	83.4%	69.9%	-13.5%
By 10 mph	94.8%	79.7%	-15.0%	94.2%	75.8%	-18.4%	39.6%	25.2%	-14.4%	37.4%	27.9%	-9.5%
By 15 mph	79.7%	44.4%	-35.3%	71.2%	40.8%	-30.3%	7.9%	4.1%	-3.8%	8.6%	3.9%	-4.7%
By 20 mph	45.4%	12.2%	-33.2%	32.3%	11.9%	-20.4%	1.4%	0.5%	-0.9%	1.1%	0.6%	-0.6%

Table 123 shows speeds for vehicles during the daytime compared with speeds for the nighttime for Washington site SR 7. At the PC, mean nighttime speeds in the before period were 2 mph higher than during the daytime, with an increase of 1 mph for 85th percentile speeds. The percentage of vehicles traveling 5, 10, 15, or 20 mph or more over the advisory speed of 35 mph was also higher for nighttime speeds than daytime speeds. A total of 14.4 percent more vehicles were traveling 5 mph or more over the limit during the nighttime than during the daytime, with 7.2 percent more for those traveling 10 mph or more, and 6.4 and 4.6 percent more traveling 15 or 20 mph or more over the advisory speed limit.

At 12 months, nighttime speeds were still higher, but the difference was smaller, with a 1-mph increase for average and 85th percentile speeds. Results for the CC indicate that nighttime speeds were higher than daytime speeds for the before period, with similar increases as the PC. At 12 months, nighttime speeds were moderately higher than daytime speeds, with average speeds 2.7 mph higher and 85th percentile speeds 6 mph higher. At nighttime, about 16 to 17 percent more vehicles were traveling 5, 10, and 15 mph over the speed limit than during daytime. Almost 9 percent more nighttime vehicles were traveling 20 mph or more over the advisory speed.

Table 124 shows differences for changes in daytime speeds compared with changes in nighttime speeds for Washington site SR 7. At the PC, changes in average nighttime speeds after installation of the sign were twice that for daytime speeds, while changes in 85th percentile speeds were the same.

Decreases in vehicles traveling over the advisory speed at nighttime were about 6 percent higher for vehicles traveling 5 or 10 mph over, and were almost twice that for vehicles traveling 15 or 20 mph over than for daytime.

At the CC, speeds increased for both daytime and nighttime vehicles, with a slightly higher increase in average speed for daytime compared with nighttime (3.9 versus 2.8 mph). Much larger decreases in the percentage of vehicles exceeding the advisory speed occurred during the nighttime than daytime.

Table 123. Comparison of speed changes daytime versus nighttime for Washington SR 7.

	At Point of Curvature						At Center of Curve					
	Before			12 mo			Before			12 mo		
	Day	Night	Change	Day	Night	Change	Day	Night	Change	Day	Night	Change
Mean speed	42.9	45.0	2.1	41.4	42	0.6	37.9	41.7	3.8	41.8	44.5	2.7
85th percentile speed	49	50	1	47	48	1	46	46	0	48	54	6
Percent vehicles exceeding posted or advisory speed limit												
By 5 mph	70.7%	85.1%	14.4%	58.4%	67.0%	8.7%	53.5%	66.4%	12.9%	57.1%	74.8%	17.6%
By 10 mph	44.0%	51.2%	7.2%	26.9%	27.5%	0.5%	25.5%	30.3%	4.8%	26.7%	42.7%	16.0%
By 15 mph	14.4%	19.8%	5.4%	8.9%	9.9%	1.0%	5.4%	7.6%	2.1%	12.4%	29.1%	16.8%
By 20 mph	2.0%	6.6%	4.6%	1.3%	3.3%	2.0%	0.6%	2.5%	1.9%	4.8%	13.6%	8.8%

Table 124. Comparison of speed changes for daytime versus nighttime for Washington SR 7.

	At Point of Curvature						At Center of Curve					
	Daytime			Nighttime			Daytime			Nighttime		
	Before	12 mo	Change	Before	12 mo	Change	Before	12 mo	Change	Before	12 mo	Change
Mean speed	42.9	41.4	-1.5	45.0	42.0	-3.0	37.9	41.8	3.9	41.7	44.5	2.8
85th percentile speed	49	47	-2	50	48	-2	46	48	2	46	54	8
Percent vehicles exceeding posted or advisory speed limit												
By 5 mph	70.7%	58.4%	-12.3%	85.1%	67.0%	-18.1%	53.5%	57.1%	3.6%	66.4%	74.8%	8.4%
By 10 mph	44.0%	26.9%	-17.1%	51.2%	27.5%	-23.8%	25.5%	26.7%	1.2%	30.3%	42.7%	12.5%
By 15 mph	14.4%	8.9%	-5.6%	19.8%	9.9%	-9.9%	5.4%	12.4%	6.9%	7.6%	29.1%	21.6%
By 20 mph	2.0%	1.3%	-0.8%	6.6%	3.3%	-3.3%	0.6%	4.8%	4.2%	2.5%	13.6%	11.1%

Table 125 shows the comparison of nighttime speeds to daytime speeds for Arizona site SR 95. At the PC, nighttime speeds were higher than daytime speeds for both the before and 12-month after periods. Mean speeds for nighttime were 1.7 and 3.2 mph higher, and 85th percentile speeds were 3 mph higher for both periods.

The fraction of vehicles traveling 5, 10, or 15 mph over the advisory speeds was higher by 5 to 14 percent for nighttime compared with daytime, with little difference noted for vehicles traveling 20 mph over the limit.

Table 126 provides change in speeds for the daytime period compared with changes for the nighttime period for Arizona SR 95. Changes in daytime speeds were higher than nighttime speeds at the PC. Average speeds were 4.3 mph compared with 3.0 mph, with a decrease of 4 mph in 85th percentile speeds compared with 3 mph.

Decreases in the fraction of vehicles traveling 5 or 10 mph over the advisory speed limit were about 10 percent lower for daytime than for nighttime, and about 2 to 3 percent lower for 15 and 20 mph over the limit. Results at the CC were similar to those at the PC. Slightly greater decreases were observed for the daytime period than for the nighttime period, but the difference was about 1 mph for mean and 85th percentile speeds.

Table 125. Comparison of speed changes daytime versus nighttime for Arizona SR 95.

	At Point of Curvature						At Center of Curve					
	Before			12 mo			Before			12 mo		
	Day	Night	Change	Day	Night	Change	Day	Night	Change	Day	Night	Change
Mean speed	56.9	58.6	1.7	52.6	55.6	3.2	54.4	56.3	1.9	51.3	53.8	2.5
85th percentile speed	62	65	3	58	62	3	60	63	3	57	59	2
Percent vehicles exceeding posted or advisory speed limit												
By 5 mph	91.7%	96.1%	4.3%	73.4%	86.9%	9.3%	81.4%	86.4%	5.0%	64.9%	77.5%	12.6%
By 10 mph	68.2%	75.6%	7.4%	31.4%	49.0%	21.1%	49.4%	59.7%	10.3%	26.4%	42.7%	16.3%
By 15 mph	30.2%	41.1%	10.9%	10.1%	23.3%	17.1%	17.6%	30.6%	13.0%	5.9%	14.8%	8.9%
By 20 mph	7.7%	15.7%	8.0%	2.5%	7.7%	9.2%	3.7%	10.9%	7.3%	0.8%	4.3%	3.5%

Table 126. Comparison of speed changes for daytime changes versus nighttime changes for Arizona SR 95.

	At Point of Curvature						At Center of Curve					
	Daytime			Nighttime			Daytime			Nighttime		
	Before	12 mo	Change	Before	12 mo	Change	Before	12 mo	Change	Before	12 mo	Change
Mean speed	56.9	52.6	-4.3	58.6	55.6	-3.0	54.4	51.3	-3.1	56.3	53.8	-2.5
85th percentile speed	62	58	-4	65	62	-3	60	57	-3	63	59	-4
Percent vehicles exceeding posted or advisory speed limit												
By 5 mph	91.7%	73.4%	-18.3%	96.1%	86.9%	-9.1%	81.4%	64.9%	-16.5%	86.4%	77.5%	-8.9%
By 10 mph	68.2%	31.4%	-36.9%	75.6%	49.0%	-26.7%	49.4%	26.4%	-23.0%	59.7%	42.7%	-17.1%
By 15 mph	30.2%	10.1%	-20.1%	41.1%	23.3%	-17.8%	17.6%	5.9%	-11.6%	30.6%	14.8%	-15.8%
By 20 mph	7.7%	2.5%	-5.1%	15.7%	7.7%	-8.0%	3.7%	0.8%	-2.8%	10.9%	4.3%	-6.6%

Table 127 shows changes for Arizona site SR 377. No major differences occurred between nighttime and daytime speeds for any of the time periods at the PC. Similar results occurred for the CC.

Table 128 provides change in speeds for the daytime period compared with changes for the nighttime period for Arizona SR 377. As shown, decreases in speed between the before and 12-month after period were moderately larger than for the daytime period at the PC. The daytime decrease in mean speed was 3.4 and change in 85th percentile speed was 4 mph, compared with the nighttime decrease of 4.2 mph and 8 mph, respectively.

Decreases in the fraction traveling over the posted speed limit were also greater for the nighttime versus daytime periods. At the CC, essentially no change occurred from the before to 12-month after period during the daytime, while moderate decreases occurred for the nighttime period.

Table 127. Comparison of speed changes daytime versus nighttime for Arizona SR 377.

	At Point of Curvature						At Center of Curve					
	Before			12 mo			Before			12 mo		
	Day	Night	Change	Day	Night	Change	Day	Night	Change	Day	Night	Change
Mean speed	69.5	69.2	-0.3	66.1	65.0	-1.1	66.4	66.4	0.0	66.8	65.9	-0.9
85th percentile speed	75	78	3	71	70	-1	72	73	1	72	71	-1
Percent vehicles exceeding posted or advisory speed limit												
By 5 mph	47.2%	50.0%	2.8%	23.6%	19.3%	-4.3%	26.4%	32.7%	6.3%	29.3%	27.8%	-1.6%
By 10 mph	18.3%	28.6%	10.3%	4.3%	4.5%	0.3%	8.0%	10.1%	2.1%	6.1%	6.5%	0.4%
By 15 mph	6.4%	10.7%	4.3%	1.1%	1.2%	0.1%	2.3%	3.6%	1.3%	1.1%	0.8%	-0.3%
By 20 mph	2.7%	3.6%	0.8%	0.3%	0.0%	-0.3%	0.6%	0.0%	-0.6%	0.6%	0.4%	-0.2%

Table 128.Comparison of speed changes for daytime changes versus nighttime changes for Arizona SR 377.

	At Point of Curvature						At Center of Curve					
	Daytime			Nighttime			Daytime			Nighttime		
	Before	12 mo	Change	Before	12 mo	Change	Before	12 mo	Change	Before	12 mo	Change
Mean speed	69.5	66.1	-3.4	69.2	65.0	-4.2	66.4	66.8	0.4	66.4	65.9	-0.5
85th percentile speed	75	71	-4	78	70	-8	72	72	0	73	71	-2
Percent vehicles exceeding posted or advisory speed limit												
By 5 mph	47.2%	23.6%	-23.6%	50.0%	19.3%	-30.7%	26.4%	29.3%	2.9%	32.7%	27.8%	-5.0%
By 10 mph	18.3%	4.3%	-14.0%	28.6%	4.5%	-24.0%	8.0%	6.1%	-1.9%	10.1%	6.5%	-3.6%
By 15 mph	6.4%	1.1%	-5.3%	10.7%	1.2%	-9.5%	2.3%	1.1%	-1.1%	3.6%	0.8%	-2.8%
By 20 mph	2.7%	0.3%	-2.4%	3.6%	0.0%	-3.6%	0.6%	0.6%	0.0%	0.0%	0.4%	0.4%

Table 129 compares speeds at night to speeds during the day for Florida site SR 20 (Gainesville). At the PC, nighttime speeds were lower than daytime speeds during the before period and were slightly higher after. The differences, however, were small, with changes in mean and 85th percentile speeds of 1 mph or less. Changes in the fraction of vehicles traveling 5, 10, 15, or 20 mph over the advisory speed were 5 percent or less.

Table 130 provides the comparison of speed changes for the daytime with the nighttime for the 12-month after period for Florida site SR 20 (Gainesville). At the PC, mean speed decreases were slightly larger for daytime than for nighttime (3.1 compared with 2.2 for mean speeds and 4 mph compared with 3 mph for 85th percentile).

The decreases in the fraction of vehicles traveling 5 or mph over the advisory speed were almost twice as much for the nighttime period. Decreases for the fraction of vehicles traveling 10 mph over were 20.8 percent for the daytime period compared with 14.7 percent for the nighttime period. The decrease in the fraction of vehicles traveling 15 mph or more over was 27.3 percent for the daytime compared with 19.2 percent for the nighttime. The daytime period decrease for 20 mph or more over the advisory speed was 1.5 percent greater than for the nighttime period.

Table 129. Comparison of speed changes daytime versus nighttime for Florida SR 20—Gainesville.

	At Point of Curvature						At Center of Curve					
	Before			12 mo			Before			12 mo		
	Day	Night	Change	Day	Night	Change	Day	Night	Change	Day	Night	Change
Mean speed	58.0	57.4	-0.6	54.9	55.2	0.3	58.3	58.0	-0.3	54.3	55.0	0.7
85th percentile speed	63	63	0.0	59	60	1	63	64	1.0	59	60	1
Percent vehicles exceeding posted or advisory speed limit												
By 5 mph	94.2%	90.9%	-3.3%	90.5%	89.2%	-1.3%	95.5%	93.2%	-2.3%	88.4%	88.9%	0.5%
By 10 mph	78.0%	73.4%	-4.6%	57.2%	58.7%	1.5%	80.6%	75.9%	-4.7%	52.5%	56.5%	4.0%
By 15 mph	39.5%	36.2%	-3.3%	12.2%	17.1%	4.9%	41.1%	41.8%	0.6%	10.5%	16.5%	5.9%
By 20 mph	9.8%	10.0%	0.3%	1.8%	3.6%	1.8%	10.0%	11.3%	1.3%	1.5%	3.5%	1.9%

Table 130. Comparison of speed changes for daytime changes versus nighttime changes for Florida SR 20—Gainesville.

	At Point of Curvature						At Center of Curve					
	Daytime			Nighttime			Daytime			Nighttime		
	Before	12 mo	Change	Before	12 mo	Change	Before	12 mo	Change	Before	12 mo	Change
Mean speed	58.0	54.9	-3.1	57.4	55.2	-2.2	58.3	54.3	-4.0	58.0	55.0	-3.0
85th percentile speed	63	59	-4	63	60	-3	63	59	-4	64	60	-4
Percent vehicles exceeding posted or advisory speed limit												
By 5 mph	94.2%	90.5%	-3.8%	90.9%	89.2%	-1.8%	95.5%	88.4%	-7.0%	93.2%	88.9%	-4.3%
By 10 mph	78.0%	57.2%	-20.8%	73.4%	58.7%	-14.7%	80.6%	52.5%	-28.0%	75.9%	56.5%	-19.3%
By 15 mph	39.5%	12.2%	-27.3%	36.2%	17.1%	-19.2%	41.1%	10.5%	-30.6%	41.8%	16.5%	-25.3%
By 20 mph	9.8%	1.8%	-8.0%	10.0%	3.6%	-6.5%	10.0%	1.5%	-8.5%	11.3%	3.5%	-7.8%

Table 131 shows the differences between daytime and nighttime speeds for Florida site SR 267. At the PC, very little difference was noted for the daytime versus nighttime periods before and 12 months after installation of the sign. Results were similar for the CC. Differences in average and 85th percentile speeds were 1 mph or less for both the before and 12-month after period.

Table 132 provides change in speed for the daytime period compared with changes for the nighttime period for Florida SR 267. At the PC, decreases in mean and 85th percentile speeds for the 12-month after period were within 1 mph for the daytime compared with the nighttime period.

Decreases in the fraction of vehicles traveling 5, 10, 15, or 20 mph over the posted speed were within 2 percent for daytime compared with nighttime. Similar results were found for the CC. Differences in decreases for mean and 85th percentile speeds were within 1 mph. Differences in the fraction of vehicles traveling over the posted speed were also within 2 percent.

Table 131. Comparison of speed changes daytime versus nighttime for Florida SR 267.

	At Point of Curvature						At Center of Curve					
	Before			12 mo			Before			12 mo		
	Day	Night	Change	Day	Night	Change	Day	Night	Change	Day	Night	Change
Mean speed	54.5	54.3	-0.2	47.7	47.8	-0.2	53.3	53.4	0.1	51.0	51.9	0.9
85th percentile speed	60	60	0.0	53	52	0.0	59	60	1.0	57	58	1
Percent vehicles exceeding posted or advisory speed limit												
By 5 mph	15.5%	17.3%	1.8%	0.8%	0.6%	1.8%	11.8%	15.4%	3.6%	6.8%	8.4%	1.5%
By 10 mph	2.6%	4.4%	1.8%	0.2%	0.1%	1.8%	1.7%	3.7%	1.9%	1.0%	1.3%	0.3%
By 15 mph	0.8%	1.0%	0.2%	0.0%	0.0%	0.2%	0.4%	0.6%	0.3%	0.1%	0.2%	0.1%
By 20 mph	0.1%	0.2%	0.1%	0.0%	0.0%	0.1%	0.0%	0.1%	0.1%	0.0%	0.0%	0.0%

Table 132. Comparison of speed changes for daytime changes versus nighttime changes for Florida SR 267.

	At Point of Curvature						At Center of Curve					
	Daytime			Nighttime			Daytime			Nighttime		
	Before	12 mo	Change	Before	12 mo	Change	Before	12 mo	Change	Before	12 mo	Change
Mean speed	54.5	47.7	-6.8	54.3	47.8	-6.5	53.3	51.0	-2.3	53.4	51.9	-1.5
85th percentile speed	60	53	-7	60	52	-8	59	57	-2	60	58	-2
Percent vehicles exceeding posted or advisory speed limit												
By 5 mph	15.5%	0.8%	-14.7%	17.3%	0.6%	-16.7%	11.8%	6.8%	-4.9%	15.4%	8.4%	-7.0%
By 10 mph	2.6%	0.2%	-2.4%	4.4%	0.1%	-4.3%	1.7%	1.0%	-0.7%	3.7%	1.3%	-2.3%
By 15 mph	0.8%	0.0%	-0.8%	1.0%	0.0%	-1.0%	0.4%	0.1%	-0.3%	0.6%	0.2%	-0.4%
By 20 mph	0.1%	0.0%	-0.1%	0.2%	0.0%	-0.2%	0.0%	0.0%	0.0%	0.1%	0.0%	-0.1%

Table 133 gives the change in speeds for the daytime period compared with changes for the nighttime period for Florida site SR 20 (Tallahassee). The difference between nighttime and daytime speeds for the before period at the PC are minimal, with differences in mean and 85th percentile speeds of 1 mph or less and differences in fraction of vehicles traveling over the advisory speed of 1 percent or less. At 12 months, daytime speeds are slightly greater than daytime, but differences in mean and 85th percentile speeds are 1 mph or less and decreases in the fraction of vehicles of 3 mph or less. Changes at the CC are similar, with nighttime speeds slightly greater than daytime speeds at both the before and 12-month after period. In all cases, differences were not statistically significant at the 95-percent level of significance.

Table 134 shows changes in speed for the daytime period compared with the nighttime period. At the PC, decreases in mean speed and 85th percentile speeds were about 2 mph for both the daytime and nighttime period. Changes in the fraction of vehicles exceeding the posted speed limit by 5, 10, 15, and 20 mph for the daytime and nighttime periods were within 2 percent. Results were similar for the CC. Decreases in mean speed and 85th percentile speeds were about 2 mph for both the daytime and nighttime period. Decreases in the fraction of vehicles exceeding the posted speed by 5 mph or more were slightly greater for the daytime period than for the nighttime period (13.7 percent versus 7.8 percent). Decreases in the fraction of vehicles exceeding the posted speed by 10 mph or more were greater for the nighttime period than for the daytime period (4.1 percent versus 2.5 percent).

In summary, comparison of nighttime speeds to daytime speeds for the seven sites that were evaluated indicated that at the PC, in the majority of cases (57 percent) daytime speeds were similar to nighttime speeds. In 29 percent of the cases, nighttime speeds were slightly or moderately higher than daytime speeds, while in 14 percent of cases daytimes speeds were moderately higher.

Results were exactly the same at the CC. Speeds were similar for nighttime and daytime in the majority of cases (57 percent), while nighttime speeds were higher in 29 percent of the cases and daytime speeds were higher in 14 percent of cases.

When comparing changes in daytime speeds for the 12-month after period compared to the before period to changes in nighttime speeds also for the 12-month after period, little difference resulted in 43 percent of the cases for both the PC and the CC. At the PC, in 29 percent of the cases, decreases in nighttime speeds were moderately higher than decreases in daytime speeds, and daytime decreases were moderately higher for the daytime after periods compared with nighttime. At the CC, the nighttime speeds increased in 14 percent of the cases compared with changes in daytime speeds

Consequently, it can be assumed that few differences occurred between the daytime and nighttime periods. As a result, there is little evidence to suggest that nighttime and daytime periods should be compared separately.

Table 133. Comparison of speed changes daytime versus nighttime for Florida SR 20 - Tallahassee

	At Point of Curvature						At Center of Curve					
	Before			12 mo			Before			12 mo		
	Day	Night	Change	Day	Night	Change	Day	Night	Change	Day	Night	Change
Mean speed	57.3	57.3	0.0*	55.2	55.6	0.4*	58.2	58.6	0.4*	56.7	57.6	0.9*
85th percentile speed	61	62	1.0	59	60	1	62	63	1.0	61	62	1.0
Percent vehicles exceeding posted or advisory speed limit												
By 5 mph	26.3%	26.6%	0.3%*	13.1%	16.4%	3.4%*	36.2%	38.0%	1.9%*	22.4%	30.2%	7.8%*
By 10 mph	4.4%	5.7%	1.2%*	2.1%	3.0%	0.9%*	6.3%	9.4%	3.1%*	3.8%	5.2%	1.5%*
By 15 mph	0.6%	1.9%	1.3%*	0.4%	0.7%	0.4%*	0.6%	2.2%	1.6%*	0.4%	1.1%	0.7%*
By 20 mph	0.1%	0.5%	0.3%*	0.1%	0.2%	0.1%*	0.0%	0.8%	0.7%*	0.1%	0.3%	0.2%*

*Not statistically significant at 95-percent level of significance

Table 134. Comparison of speed changes for daytime changes versus nighttime changes for Florida SR 20—Tallahassee

	At Point of Curvature						At Center of Curve					
	Daytime			Nighttime			Daytime			Nighttime		
	Before	12 mo	Change	Before	12 mo	Change	Before	12 mo	Change	Before	12 mo	Change
Mean speed	57.3	55.2	-2.1	57.3	55.6	-1.7	58.2	56.7	-1.5	58.6	57.6	-1.0
85th percentile speed	61	59	-2	62	60	-2	62	61	-1	63	62	-1
Percent vehicles exceeding posted or advisory speed limit												
By 5 mph	26.3%	13.1%	-13.2%	26.6%	16.4%	-10.2%	36.2%	22.4%	-13.7%	38.0%	30.2%	-7.8%
By 10 mph	4.4%	2.1%	-2.4%	5.7%	3.0%	-2.7%	6.3%	3.8%	-2.5%	9.4%	5.2%	-4.1%
By 15 mph	0.6%	0.4%	-0.2%*	1.9%	0.7%	-1.1%	0.6%	0.4%	-0.2%*	2.2%	1.1%	-1.1%*
By 20 mph	0.1%	0.1%	-0.0%*	0.5%	0.2%	-0.3%*	0.0%	0.1%	0.1%*	0.8%	0.3%	-0.5%*

*Not statistically significant at 95-percent level of significance

APPENDIX C. COMPARISON OF PASSENGER VEHICLES VERSUS TRUCK SPEED REDUCTION

Speeds were also compared for heavy trucks and passenger vehicles to determine whether speed changes between the two vehicle types were different. Sites in Oregon and Washington had a significant number of logging and other heavy trucks. Data were aggregated by passenger vehicle and heavy trucks for five sites.

The traffic counters used to collect data can classify vehicles according to FHWA's 13 vehicle types. Vehicle types 1, 2, and 3 were included as passenger vehicles, and vehicle types 4 through 13 were considered to be heavy vehicles (referred to as heavy trucks). Data were evaluated for the before period and 12-month after period for the five sites. The 12-month after period was used because the signs would have been place at that point for some time and any novelty effect would have worn off. Data for each period were disaggregated by vehicle type. Data were evaluated for both the PC and CC for each site.

The tables in this appendix show the actual change in the fraction of vehicles traveling 5, 10, 15, or 20 mph or more over the posted or advisory speed rather than showing percent change as was done in the main section of the report.

Table 135 shows results for Washington SR 7. At the PC, little change was observed for the heavy trucks, while passenger vehicles had a moderate change with a decrease in mean speed of 2 mph and a decrease in 85th percentile speed of 3 mph. At the CC, both the passenger vehicles and trucks had increases in speed, but trucks had an increase that was twice that of passenger vehicles (increase of 3 mph in mean compared with an increase of 6 mph for heavy trucks with an increase in 85th percentile speeds of 2 and 4 mph).

Table 136 show results for Washington US 101. Passenger vehicles had a decrease in mean speed of almost 5 mph while the mean speed for heavy trucks decreased by 6.5 mph. However, the 85th percentile speed decreased by the same amount for passenger vehicles and heavy trucks (6 mph). At the CC, mean and 85th percentile decreases were similar.

Speed changes for Oregon OR 238 are shown in Table 137 and were similar for passenger vehicles and heavy trucks at both the PC and CC. Decreases in mean and 85th percentile were 2 to 3 mph at the PC and 0 to 1 mph at the CC. Decreases in the number of vehicles exceeding the posted speed limit were greater for heavy trucks at the PC, and increases were greater for passenger vehicles at the CC.

Table 138 shows results for Oregon US 101. Changes were also similar for both the PC and CC, with 1- to 2-mph decreases at the PC and 5- to 7-mph decreases at the CC. Heavy trucks had a greater decrease in the fraction of vehicles exceeding the advisory speed by 5, 10, 15, or 20 mph for the PC and CC.

Table 139 shows speed metrics were similar for passenger vehicles and heavy trucks at the PC for Oregon OR 42 with reductions in average speed and 85th percentile speeds of 2 mph. Decreases in the fraction of vehicles exceeding the advisory speed were also similar for passenger vehicles and heavy trucks. At the CC, a decrease of 7 mph for the average and 85th percentile speeds resulted for the passenger vehicles, while trucks had decreases of 4 to 8 mph.

Table 135. Speed changes for Washington SR 7 PC by heavy truck versus passenger vehicle.

	Point of Curvature						Center of Curve					
	Passenger Vehicle			Heavy Truck			Passenger Vehicle			Heavy Truck		
	Before	12 mo	Change	Before	12 mo	Change	Before	12 mo	Change	Before	12 mo	Change
Mean speed	43.5	41.4	-2.1	40.6	41.5	0.9	38.7	42.1	3.4	35.7	41.7	6
85th percentile speed	50	47	-3	47	47	0	47	49	2	44	48	4
Percent vehicles exceeding posted or advisory speed limit												
By 5 mph	74.6%	58.8%	-15.8%	58.7%	61.8%	3.2%	57.3%	58.2%	0.9%	40.2%	61.3%	21.1%
By 10 mph	46.9%	26.8%	-20.1%	33.2%	27.5%	-5.7%	27.8%	28.0%	0.3%	13.6%	28.9%	15.3%
By 15 mph	16.5%	8.9%	-7.7%	5.8%	8.4%	2.6%	6.4%	14.4%	8.0%	1.0%	10.2%	9.2%
By 20 mph	2.8%	1.5%	-1.3%	0.5%	0.8%	0.3%	0.9%	6.1%	5.2%	0.0%	3.2%	3.2%

Table 136. Speed changes for Washington US 101 PC by heavy truck versus passenger vehicle.

	Point of Curvature						Center of Curve					
	Passenger Vehicle			Heavy Truck			Passenger Vehicle			Heavy Truck		
	Before	12 mo	Change	Before	12 mo	Change	Before	12 mo	Change	Before	12 mo	Change
Mean speed	48.6	43.8	-4.8	48.1	41.6	-6.5	38.9	36.9	-2.0	37.8	35.2	-2.6
85th percentile speed	55	49	-6	53	47	-6	43	41	-2	41	41	0
Percent vehicles exceeding posted or advisory speed limit												
By 5 mph	97.9%	95.0%	-2.9%	99.1%	86.6%	-12.5%	85.8%	72.3%	-13.5%	84.6%	61.2%	-23.5%
By 10 mph	94.4%	81.8%	-12.6%	94.9%	68.9%	-26.1%	43.3%	27.3%	-16.0%	29.7%	17.9%	-11.8%
By 15 mph	78.8%	46.1%	-32.6%	77.3%	34.4%	-42.9%	10.4%	4.6%	-5.9%	2.4%	2.1%	-0.2%
By 20 mph	46.4%	13.5%	-32.9%	37.5%	6.8%	-30.7%	1.8%	0.5%	-1.3%	0.3%	0.4%	0.1%

Table 137. Speed changes for Oregon OR 238 PC by heavy truck versus passenger vehicle.

	Point of Curvature						Center of Curve					
	Passenger Vehicle			Heavy Truck			Passenger Vehicle			Heavy Truck		
	Before	12 mo	Change	Before	12 mo	Change	Before	12 mo	Change	Before	12 mo	Change
Mean speed	41.8	39.1	-2.7	40.4	37.4	-3	36.9	36.5	-0.4	35.9	35.4	-0.5
85th percentile speed	46	44	-2	45	42	-3	41	40	-1	39	39	0
Percent vehicles exceeding posted or advisory speed limit												
By 5 mph	95.3%	85.0%	-10.4%	90.5%	71.1%	-19.4%	74.1%	69.3%	-4.8%	64.3%	61.6%	-2.7%
By 10 mph	72.0%	47.5%	-24.5%	63.8%	34.2%	-29.5%	24.1%	21.6%	-2.5%	13.4%	11.9%	-1.4%
By 15 mph	25.9%	10.5%	-15.4%	16.1%	6.4%	-9.7%	2.9%	2.3%	-0.6%	0.6%	1.9%	1.3%
By 20 mph	3.3%	0.8%	-2.5%	0.3%	0.0%	-0.3%	0.1%	0.1%	0.0%	0.3%	0.3%	0.0%

Table 138. Speed changes for Oregon US 101 PC by heavy truck versus passenger vehicle.

	Point of Curvature						Center of Curve					
	Passenger Vehicle			Heavy Truck			Passenger Vehicle			Heavy Truck		
	Before	12 mo	Change	Before	12 mo	Change	Before	12 mo	Change	Before	12 mo	Change
Mean speed	55.9	54.3	-1.6	53.9	51.7	-2.2	55.0	49.6	-5.4	53.9	47.0	-6.9
85th percentile speed	61	60	-1	60	58	-2	61	55	-6	60	53	-7
Percent vehicles exceeding posted or advisory speed limit												
By 5 mph	89.5%	81.9%	-7.6%	80.3%	64.2%	-16.2%	86.1%	52.5%	-33.6%	80.1%	36.8%	-43.3%
By 10 mph	67.1%	51.1%	-16.0%	51.7%	32.6%	-19.1%	55.0%	19.1%	-36.0%	49.0%	9.3%	-39.7%
By 15 mph	27.0%	17.8%	-9.2%	19.4%	11.1%	-8.4%	20.5%	3.0%	-17.5%	15.5%	1.4%	-14.0%
By 20 mph	4.4%	3.0%	-1.4%	4.1%	2.9%	-1.2%	3.2%	0.3%	-2.9%	2.3%	0.0%	-2.3%

Table 139. Speed changes for Oregon OR 42 PC by heavy truck versus passenger vehicle.

	Point of Curvature						Center of Curvature					
	Passenger Vehicle			Heavy Truck			Passenger Vehicle			Heavy Truck		
	Before	12 mo	Change	Before	12 mo	Change	Before	12 mo	Change	Before	12 mo	Change
Mean speed	43.5	41.2	-2.3	42.4	40.2	-2.2	53.1	46.1	-7	49.8	45	-4.8
85th percentile speed	48	46	-2	47	45	-2	59	52	-7	55	51	-4
Percent vehicles exceeding posted or advisory speed limit												
by 5 mph	79.4%	62.8%	-16.5%	70.7%	56.1%	-14.6%	97.7%	85.9%	-11.8%	96.3%	83.9%	-12.4%
by 10 mph	42.0%	24.9%	-17.1%	34.2%	18.3%	-15.9%	91.2%	63.5%	-27.7%	82.1%	54.7%	-27.3%
by 15 mph	11.1%	5.2%	-5.9%	6.6%	3.0%	-3.6%	76.2%	28.6%	-47.6%	52.5%	21.0%	-31.5%
by 20 mph	1.5%	1.3%	-0.2%	0.5%	0.6%	0.1%	43.2%	7.9%	-35.2%	20.3%	4.1%	-16.2%

ACKNOWLEDGMENTS

The authors would like to thank the Federal Highway Administration, the Midwest Transportation Consortium, the Iowa Department of Transportation, the Iowa Highway Research Board, and the Texas Department of Transportation for sponsoring this research. We would also like to thank the corresponding State and local agencies who worked with us to select and install treatments.

The Center for Transportation Research and Education also thanks the Texas Transportation Institute and Portland State University for their partnership on this research.

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HRDS-10/01-15(WEB)E