Crash Modification Factors for Chevrons in Iowa

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Problem Statement and Project Objective

Although chevron alignment signs have been utilized for some time along horizontal curves, their effectiveness is not well documented. The Crash Modification Factors Clearinghouse includes crash modification factors (CMFs) for chevrons from 0.41 to 1.92 (FHWA 2015).

The lack of documentation on the effectiveness of chevrons and the range of values for CMFs make it difficult for agencies to estimate the cost effectiveness of chevrons. As a result, the objective of this study was to develop a CMF for chevron alignment signs that can be used by Iowa agencies to help address crashes on curves.

Background

Chevrons provide additional emphasis and guidance for drivers. If spaced properly, chevrons can delineate the curve so that drivers can interpret the sharpness of the curve. Chevrons are intended to warn drivers of an approaching curve and because of their pattern and size define the direction and sharpness of a horizontal curve (Torbic et al. 2004).

Effectiveness

Zador et al. (1987) evaluated the effectiveness of chevrons and other treatments on 46 sites in Georgia and 5 sites in New Mexico. The authors found that, at night, drivers moved away from the centerline and vehicle speed and placement variability were reduced slightly with the use of chevrons and raised pavement markings.

Jennings and Demetsky (1983) evaluated chevrons along several rural Virginia curves. The roadway segments had average daily traffic (ADT) between 1,000 and 3,000 vehicles per day (vpd). The researchers found that overall speed and speed variance decreased with the use of chevrons. The researchers also recommended chevron installation for curves greater than 7 degrees.

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Re et al. (2010) evaluated application of chevrons and chevrons with a full-post retroreflective treatment at two curves on rural two-lane roadways in Texas. Both sites had paved shoulders and a posted speed limit of 70 miles per hour (mph) day and 65 mph at night. One site had an advisory speed of 45 mph and the other had an advisory speed of 50 mph. Speed data were collected before and at 10 days after installation of the treatment. Average speeds with chevrons were 1.6 mph lower and 85th percentile speeds decreased on average by 1.3 mph.

Srinivasan et al. 2009 evaluated sites on rural two-lane roadways where curve warning signs and/or chevrons had been installed in Connecticut and where chevrons had been either installed or the number of existing chevrons increased in Washington State. In Connecticut, the researchers found an overall reduction in total crashes of 7.7% with a 12.7% reduction in fatal and injury crashes. An 8.4% reduction in roadway departure crashes was also reported with an 11.5% reduction in dark conditions. In Washington, the researchers found similar results for total and roadway departure crashes (8.9 and 8.8%, respectively). Crash reductions were slightly higher under dark conditions (9.5% for total crashes and 10.1% for roadway departures).

Data from both states were combined and CMFs were developed. A CMF of 0.82 (standard error of 0.086) was reported for injury and fatal curve crashes, 0.73 (standard error of 0.073) for curve crashes during dark conditions, and 0.75 (standard error of 0.078) for roadway departures during dark conditions. The researchers also found an improvement in lane position when the chevrons were present.

Table 1 provides summary of CMFs developed for chevrons.

Data Collection

Site Selection

The Iowa Department of Transportation (DOT) recorded locations where chevrons had been implemented as part of the Iowa Traffic Safety Improvement Program (TSIP). Locations where chevrons had been applied were spatially located when sufficient information was provided to determine and start and end point for a particular curve. The researchers used this data to create an initial database of locations where chevron alignment signs had been installed.

The original intent was to conduct a before and after study. A closer examination of the data indicated that, rather than representing new installations, many of the sites listed had received sign upgrades for locations where chevrons were already present. The team consulted with several agencies to determine whether original installation dates could be determined. Most agencies did not record sign installation dates. Consequently, only an observational cross-sectional study could be conducted.

Table 1. CMFs for chevrons

Sign Type	Crash Type	CMF	Star Rating
Chevron and curve warning signs (Montella 2009)	All crashes on principal arterial/freeways/expressways	0.59 to 0.69	★★★
	ROR rashes on principal arterial/freeways/expressways	0.56	★★★
	Fatal/serious injury/minor injury on principal arterial/freeways/expressways	1.46	★★
	Nighttime on principal arterial/freeways/expressways	0.66	★★★
Chevron signs (Montella 2009, Srinivasan et al. 2009)	All crashes on principal arterial/freeways/expressways	0.63 to 1.27	★★★,★★
	ROR crashes on principal arterial/freeways/expressways	0.90	★★
	Property damage only on principal arterial/freeways/expressways	0.83	★★
	Fatal and injury crashes on principal arterial/freeways/expressways	1.46	★★
	Nighttime on principal arterial/freeways/expressways	1.92	★★
	Wet road crashes on principal arterial/freeways/expressways	0.41	★★★
	All crashes on rural two-lane	0.96	★★★★
	Head-on/sideswipe on rural two-lane	0.94	★★★★
	Fatal and injury crashes on rural two-lane	0.84	★★★★
	Nighttime on rural two-lane	0.75	★★★★
	Nighttime head-on/sideswipe on rural two-lane	0.78	★★★★

CMFs referenced with a star (★) are based on both the referenced study and information from that study, which has been synthesized in the CMF Clearinghouse (www.cmfclearinghouse.org) as part of their "star quality rating" system. The number of stars, based on a scale from 1 to 5, where 5 indicates the highest or more reliable rating, is a qualitative rating used by the clearinghouse based on study design, sample size, standard error, potential bias, and data source. (See www.cmfclearinghouse.org/sqr.cfm for a detailed explanation.)

The Institute of Transportation (InTrans) and the Iowa DOT developed a curve database for the state that includes curve segment locations and roadway information. All two-lane paved horizontal curved roadway segments were selected and reviewed. Locations were also located in Google Earth and the satellite view and Google Street View were used to identify presence or absence of chevrons.

Locations were checked against Google Street View imagery to confirm the presence of chevrons. Since image dates vary in Google Street View and Google satellite view, presence of chevrons was confirmed using as many sources as possible. A total of 161 curve segments were found with chevrons. The team decided that curves with imagery dates no later than 2011 would be considered as treatment sites. In other words, curves with imagery dates from the beginning of 2012 through the present were eliminated.

These dates were selected since this allows at least 5 years of crash data to be collected. This selection process left 102 curves with chevrons.

Control Group Selection and Comparison Test

Control curves were selected that were similar to the treatment curves but did not have chevrons present (as verified in Google Earth and Street View). Potential curves were also located in the Iowa DOT curve database so that traffic characteristics could be compared. Other characteristics that were considered included radius and degree and length of each of the treatment curves.

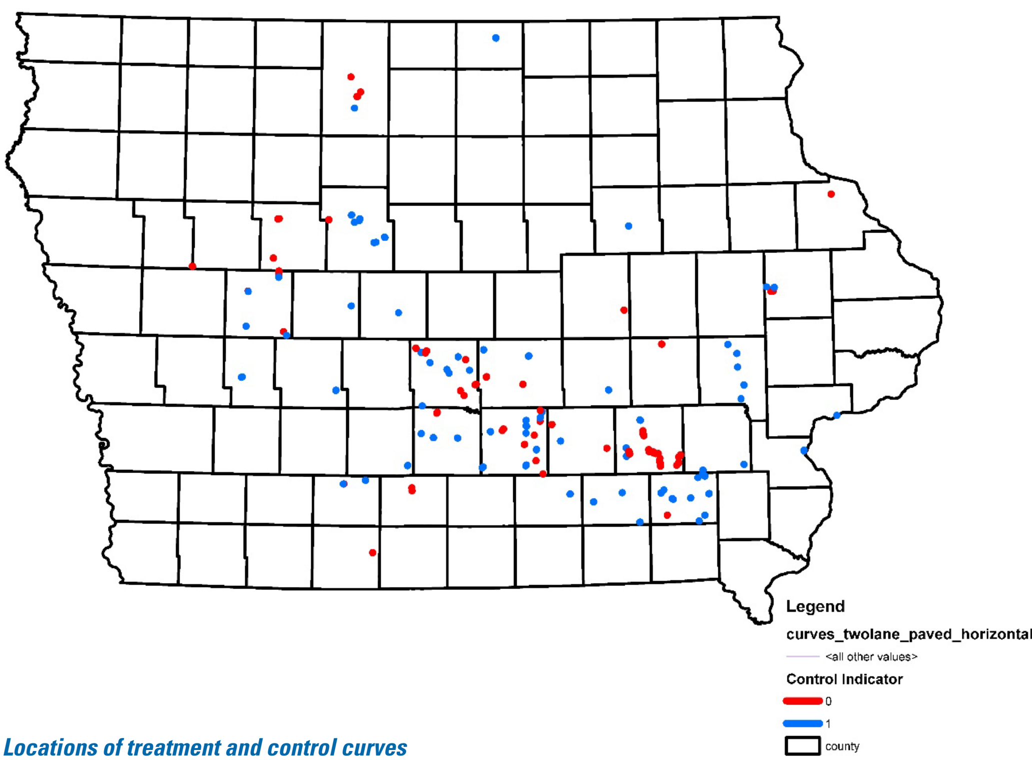
Propensity score matching was performed to find balance between treatment and control groups. Propensity score matching can be defined as a statistical technique in which a treatment case is matched with one or more control cases based on each case's propensity score (Randolph et al. 2014).

After conducting the propensity score test on the treatment and control curves, 77 treatment curves and 77 corresponding control curves were available and determined to be well matched. The locations of treatment and control sites are shown on the map.

Roadway and Traffic Characteristics

The curve database provides curve characteristics including radius, degree, etc. The Iowa DOT maintains a roadway inventory, the Geographic Information Management System (GIMS) data. The locations of each of the treatment and control curves were mapped in GIMS and traffic volume data were extracted. Information on traffic volume, lane characteristics, and roadway cross-sectional data were obtained from the GIMS data. Descriptive statistics for the entire dataset and the treatment and control curves, separately, are provided in Table 2.

The type of curve advisory sign was noted for each curve using Google Street View imagery. Posted tangent and advisory speeds were also obtained either from GIMS or a review of Google Street View imagery.



Locations of treatment and control curves

Table 2. Variables used in analysis

Variable	Description	Mean	Std dev	Min	Max
Treatment	Indicates whether the curve has chevron	NA			
URBANAREA	Indicates whether the curve is in urban area	NA			
Radius	Radius of each curve (miles)	0.21	0.15	0.02	0.98
DEGREE	Degree of each curve	7.60	6.28	1.45	46.98
LENGTH_mil	Length of each curve (miles)	0.13	0.07	0.04	0.46
AADT	Average annual daily traffic (vehicles per day)	885.45	937.39	80	5300
10ft lane	Indicator variable for 10-foot lanes	NA			
11ft lane	Indicator variable for 11-foot lanes	NA			
12ft lane	Indicator variable for 12-foot lanes	NA			
13ft lane	Indicator variable for 13-foot lanes	NA			
Concrete	Indicator variable for concrete pavement	NA			
Asphalt	Indicator variable for asphalt pavement	NA			
SHDWIDTHR	Shoulder width	4.14	3.33	1	11
Posted Speed	Posted speed limit	53.12	4.92	35	55
Advisory Speed	Advisory speed limit	43.12	5.49	20	55
Num_of_chevr	Total number of chevrons on the curve	2.53	2.93	0	12
Num_of_Sign	Total number of signs on the curve	1.50	0.89	0	4
GravelShd	Indicator variable for gravel shoulders	NA			
PavedShd	Indicator variable for paved or combination shoulders	NA			

NA: Not applicable for categorical variables
Std dev: Standard deviation
Min: Minimum
Max: Maximum

Crash Data

Crashes occurring along each curve were obtained for 10 years: 2005 through 2014. Crashes at intersections along the study curves were excluded from the study. Crash severity levels were designated as follows: Fatal injury (K), Disabling injury (A), Visible injury (B), Possible injury (C), and Property-Damage-Only (PDO). Crashes at intersections within the study sections were excluded manually from the study as the crashes occurring at intersections are not likely to be a result of horizontal curvature.

Methodology and Results

An observational cross-sectional study was conducted. Models were developed for total non-intersection crashes. Different crash severity types were also evaluated: all severities, injury crashes, and property damage only. The data were insufficient to create a separate model for fatal crashes.

In the absence of any pre-installation data for any transportation safety research, cross-sectional studies are commonly used to estimate the expected number of crashes on a roadway segment, interchange, or intersection. A weakness of a cross-sectional study is that it is difficult to determine the reason that certain safety countermeasures exist at one location and not at other similar locations.

As such, the observed difference in crash experience can be due to known or unknown factors other than the countermeasure of interest (in this case chevron alignment signs). Contemporaneous factors such as traffic volume or geometric characteristics can be controlled for in principle by estimating a multivariate regression model. However, the issue is not completely resolved since it is difficult to properly account for unknown, or known but unmeasured, factors in the dataset.

Cross-sectional crash models using negative binomial generalized linear regression analysis was built with an indicator variable for presence and absence of chevron alignment signs.

Length of an individual curve was included in the model as an offset variable to account for differing lengths. Traffic volume was also included in the model. Apart from annual average daily traffic (AADT), the curve length and the variable representing radius of each of the curves were also found to be factors influencing the crashes on the curves.

The resulting SPFs were used to calculate annual predicted crashes for each of the study curves per unit length as shown in Table 3.

CMFs, percentage reduction of crashes, and the standard deviations for the different models are shown in Table 4.

As shown, increases in total and injury crashes were observed with CMFs greater than 1.0. There was a minor decrease in PDO crashes. However, none of the results were statistically significant.

Summary

The results of the study did not reflect the safety benefits of the chevron sites effectively. The study encountered issues common to cross-sectional studies such as the fact that higher crash locations are more likely to have the countermeasure being studied. Moreover, it was also seen that the effect of radius was more significant on treatment curves than control curves. This suggests that chevrons were targeted to high crash locations and the effect cannot be well captured using a cross-sectional analysis.

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Table 3. Final models developed for SPFs

Crash Severity	Statistically significant variables and parameter estimates	Predicted crashes (no chevrons)	Predicted crashes (with chevrons)
Total	*N=Length×(EXP(-3.540+(1.023×LN(AADT)+ (-3.319×Radius)+(0.159×Treatment)))*	165	193
Injury	*N=length×(EXP(-3.223+(0.806×LN(AADT)+ (-3.483×Radius)+(-0.535×12ft lane)+(0.301×Treatment)))*	39	52
PDO	*N=length(EXP(-5.416+(1.178×LN(AADT))+ (-3.415×Radius)+(-0.008×Treatment)))*	78	77

Table 4. CMF statistics

Crash Severity	CMF	Standard Error	95% Confidence Interval	Change in Crashes
Total	1.17	0.187	(0.80,1.34)	17% increase
Injury	1.35	0.222	(0.92,1.79)	35% increase
PDO	0.99	0.245	(0.51,1.47)	1% decrease

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