Installation of chevron signs

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Please note: The studies included in this synopsis were selected from those identified by a systematic literature search of specific databases (see supporting document). The main criterion for inclusion of studies in this synopsis and the DSS was that each study provides *a quantitative effect estimate*, preferably on the number or severity of crashes or otherwise on road user behaviour that is known to be related to the occurrence or severity of a crash. Therefore, key studies providing qualitative information might not be included in this synopsis.

1. Summary

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1.1 COLOUR CODE: GREEN

The effects of the installation of chevron signs at curves are mostly positive in reducing crash frequency and vehicles' mean speed. The presence of chevrons also leads drivers to keep a proper lane position. Furthermore, the coded studies encompass several topics and have good levels of quality and consistency. For the reasons mentioned above, the overall impact of chevron signs can be characterized as effective.

1.2 KEYWORDS

Chevron sign; traffic sign; speed reduction; lateral position; curve warning; bendiness

1.3 ABSTRACT

Chevron signs are widely used as safety devices to warn drivers of a dangerous curve by delineating the alignment of the road around that curve. Therefore, the presence of chevrons, either alone or combined with other devices, affects the level of road safety. Chevrons cause a reduction in the number of crashes and in driving speed, and have beneficial effects on lateral position. Seven high quality studies regarding various chevron sign implementations were coded. On the basis of both study and effect numbers, it can be argued that chevron signs have positive impacts on road safety. However, there were isolated cases where contradictory results were seen, indicating increases in speed. The results seem generally transferable.

1.4 BACKGROUND

1.4.1 Definition of chevron signs

Chevron signs are a common type of delineation treatment and are typically placed on the outside of a curve to warn a driver of an approaching bend and to aid and assist drivers in safe and efficient horizontal curve negotiation. A horizontal curve requires a change in vehicle path alignment and a potential reduction in vehicle speed. The change from a straight road section to a curve may present a challenging task during adverse driving conditions or to inattentive drivers. Delineation treatments provide advance warning on the approach to a curve and positive guidance throughout the curve. Chevron signs can be implemented as solitary signs or groups along the length of a curve, to give drivers a sense of perception and better space estimation.

1.4.2 How do chevron signs affect road safety?

Chevron signs are used to provide additional emphasis and guidance for a change in horizontal alignment, and have several impacts on road safety. Firstly, the installation of chevrons yields a reduction in crash frequency, especially for curves with small radii and large direction changes (wide deflection angles). Secondly, the presence of chevrons leads drivers to reduce mean speed and to keep a more stable lane position. Finally, chevrons have positive effects on drivers' behaviour, especially on their eye movement and performance. Results show that drivers pay more attention to the roadside near chevrons;

they are also more relaxed and their reduction in speed is more marked when chevrons are present. This finding indicates that chevron alignment signs do provide advanced warnings and positive guidance, and encourage drivers to reduce their speed more through curves, which improves safety in curve delineation.

1.4.3 Which safety outcomes are affected by chevron signs?

The reviewed studies focus on various outcomes. In some studies, the main focus is on estimating the reduction of the number of crashes as a result of the presence of chevrons, either with an absolute difference between before and after the installation, or with the calculation of the crash modification factors. Additionally, some studies investigate the effects of chevron signs on mean speed and lateral position. One study analyses the number of vehicles exceeding the speed limit. Finally, one simulation study investigates the impact of chevron alignment signs on drivers' eye movement and degree of deceleration.

1.4.4 How is the effect of chevron signs on road safety studied?

The international literature has examined a variety of different approaches to studying the effect of chevron sign presence. Often this measure is examined in conjunction with others (e.g. curve warning signs, sequential flashing beacons, flashing yellow curve signs, etc.). The examination of the measure is adjusted to the models selected to capture the entire situation for the given case.

The most common approach to testing the effectiveness of chevron signs is a comparison before and after their installation, or between exposed and non-exposed sites.

1.5 OVERVIEW OF RESULTS

The installation of chevron signs tends to increase the level of road safety. Typically, the various study findings link chevrons to decreased crash frequency. One study shows a reduction in total crashes, and night-time, daytime, rainy, non-rainy (dry weather), run-off-road, and property damage-only crashes, with a major effect for curves with small radii and large direction changes (big deflection angles).

With regard to mean vehicle speed the majority of studies show a significant crash reduction, with a beneficial effect on road safety. Different measures of effectiveness were analysed, and results show a positive effect for chevrons and full-post chevrons[1], for FY (flashing yellow) chevrons and for FY signposts (in addition to chevrons). Conversely, the combination of FY chevrons and FY curve signs was found to have small and inconsistent effects. Moreover, one study finds that speed reduction is affected by curve direction, but not by curve radius. Another study observes small benefits during the day and a more noticeable effect at night-time and on sharp curves. Similarly, beneficial effects were also found for lateral vehicle position. No significant effects were coded in the number of vehicles exceeding the speed limit. Finally, one study analysed driver behaviour in terms of eye movement and degree of deceleration in braking or releasing the accelerator. Findings showed a positive effect of chevrons on road safety by reducing road crash percentages, mean speed and speeding instances, amongst other effects.

1.6 TRANSFERABILITY

The coded studies are based on data from several countries, including Italy, the USA, China and South Korea. Although this is a good sample for general trends in developed countries,

[1] [1] Full-post placing retroreflective material on chevron signposts

there is a lack of studies representing less motorized countries. Some studies examine all motor vehicles, without differentiating for types of road users. Conversely, other studies focus solely on cars and heavy vehicles, whilst the studies using the simulator collect only car data.

1.7 NOTES ON ANALYSIS METHODS

The method of capturing the impact of chevron signs on road safety varies considerably between studies. This is utilised mainly in terms of the mathematical models, but additionally the outcomes are evaluated as dependent variables. There is also a certain margin for investigating different road user categories and/or other geographical regions. The combination of the above makes the results for chevron signs generally transferable, although relative caution is always required.

2. Scientific overview

2.1 ANALYSIS OF STUDY DESIGNS AND METHODS

After appropriate use of various search tools and databases, seven (7) high quality studies were selected and coded to evaluate the effectiveness of the installation of chevrons signs on road safety. Four studies (Rè et al., 2010; Gates et al., 2004; Zhao et al., 2015; Rose et Carlson, 2005) investigated the effects of chevrons on speed reduction; two of these studies (Rè et al., 2010; Zhao et al., 2015) also analysed the vehicle lateral lane position, while a third (Rose et Carlson, 2005) examined the number of vehicles exceeding the speed limit. Another study (Montella, 2009) focused on crash reduction per different types of crashes (total, night-time, daytime, rainy, non-rainy, run-off-road, non-run-off-road, injury and property damage-only), on roads with different geometrical characteristics. In the sixth study (Wu et al., 2013) a comparative analysis was conducted to examine the changes in drivers' eye movement (fixed points and fixed duration) and driving performance (degree of deceleration) due to the presence of chevron signs. Finally, the last study (Choi et al., 2015) analysed the crash frequency and developed the crash modification factors for different freeways.

In order to examine the relationship between the various chevron exposures and outcome indicators, the majority of the studies used multivariate statistical models (i.e. generalized linear model with negative binomial distribution error structure, MANOVA, etc.). Two studies (Wu et al., 2013; Choi et al., 2015) did not mention any statistical analysis, but comparisons before and after the installation and between exposed and non-exposed sites were conducted.

2.2 LITERATURE REVIEW

The first of the studies examining speed reduction (Rè et al., 2010) reports a significant difference from the baseline evaluation, but results between the two different treatments (chevrons and full-post chevrons) are quite similar. The same findings are provided for the vehicle lateral lane position. Similarly, the second relevant study (Gates et al., 2004) shows beneficial effects on speed both for FY chevrons and for FY signposts (in addition to FY chevrons). Conversely, the combination of FY chevrons and FY curve signs was found to have a small and inconsistent effect.

The third study (Zhao et al., 2015) describes significant positive effects on speed reduction, further affected by curve direction, but not curve radius. Findings demonstrate that the presence of chevrons also encourages participants to drive with better lane positioning, which was more appropriate to negotiate the respective curves. Conversely, Rose and Carlson (2005) find that additional chevron signs on a curve provide small benefits in reducing speed during the day, and more noticeable benefits at night. They also find more pronounced benefits on sharp curves than on moderate curves. Little benefit is found in the percentages of vehicles exceeding the speed limit.

When examining chevron signs, another popular outcome is crash frequency data. Montella (2010) found a significant crash reduction in total, night-time, daytime, rainy, non-rainy, run-off-road, and property damage-only crashes. Similarly, Choi et al. (2015) report a positive effect on road safety in terms of crash reduction, but no statistical analyses were performed.

With regard to various behavioural variables, the last study (Wu et al., 2013) presented findings for exposure to the presence of chevrons using a driving simulator. Results showed that drivers pay more attention to the roadside near chevrons (chevrons attracted more fixation points from the drivers, and the duration of fixation points was also longer with the presence of chevrons). Regarding the degree of deceleration, the brake and accelerator data show that applying the brake and releasing the accelerator are more frequent in the scenario with chevrons, namely the pedals were used more repeatedly. This finding indicates that chevron signs do provide advance warning and positive guidance and make drivers tend to reduce their speed more through curves, improving road safety.

An overview of the main features of the coded studies (sample, method, outcome and results) is presented in Table 1.

Number	Author(s); Year; Country;	Sampling frame for chevron signs investigation	Method for chevron signs investigation	Outcome indicator	Main Result
1	Choi Y.Y., Kho S.Y., Lee C., Kim D.K.; 2015; South Korea	To create the dataset, data for the crash count, crash location and AADT were collected from the database of the Korea Expressway Corporation. The analyses were performed on three freeways; the number of sites considered were 100, with a total length of 27.6 Km.	Before-after Empirical Bayes method	Crash Frequency [absolute difference]; CMF	The developed CMF value for chevron signs was 0.721. This result showed that chevron signs had a positive effect on road safety because they caused a reduction in the number of crashes.
2	Gates T.J., Carlson P.J., Hawkins H.G. Jr.; 2004; USA	14 sites were used for field evaluations of various enhanced conspicuity sign applications. This included 4 curves on rural two-lane roadways, 2 curves on freeway exit ramps, 4 urban/suburban stop-controlled intersections, 3 rural stop-controlled intersections, and one rural speed zone.	Absolute difference comparison between before and after the installation [with ANOVA]	Mean Speed ~500 ft. Upstream of PC [absolute difference]	FY chevrons produced beneficial effects on speeds at most of the installations, while the combination of FY chevrons and FY curve signs were found to have small and inconsistent effects. Reflectorization of the chevron signposts with FY sheeting (in addition to FY chevrons) had mostly beneficial effects on speeds, especially during twilight and night time periods
3	Montella A.; 2009; Italy	A divided motorway (A16) with two lanes for each direction, access control, and interchanges. The treatment sites are in the section Naples–Candela, with a length of 127.5 km. 383 crashes in 15 curves were considered.	Generalized linear model with negative binomial distribution error structure	Crash Reduction [percent accident reduction]	Treatments lead to statistically significant crash reductions in in total, night time, daytime, rainy, non-rainy, run-off-road, and property damage-only crashes. Effectiveness is greater for curves with radius less than or equal to 300 m and for curves with deflection angle greater than 60 gon. (54 degrees).
4	Ré J.M.,Hawkins H.G. Jr.,Chrysler S.T.; 2010; USA	Two separate horizontal curves, on a rural two-lane road, were considered. Vehicle speed and lateral position data were measured using a traffic classifier and three roadway sensors. Data collection equipment was placed at PC and MP curve locations.	Absolute difference comparison between exposed and non-exposed sites [With MANOVA & the Tukey's HSD test]	Mean speed [absolute difference]; Mean lateral position [absolute difference]	Both chevron treatments consistently achieved significantly different results from the baseline evaluation, but results between chevrons and full-post chevrons were quite similar. Researchers concluded that full-post chevrons did not achieve substantial benefits over chevrons.

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Number	Author(s); Year; Country;	Sampling frame for chevron signs investigation	Method for chevron signs investigation	Outcome indicator	Main Result
5	Rose E.R., Carlson P.J.; 2005; USA	Three curves, located in rural areas, were chosen for this study: one gentle, one moderate and one sharp curve. Researchers obtained speed data for at least 24 hours at four locations on each curve using automated counters connected to pneumatic tubes.	Absolute difference comparison between before and after the installation [with ANOVA and z-test]	Mean Speed [absolute difference]; Exceeding speed limit vehicles [absolute difference]	Having additional chevrons in view on a curve does provide the benefit of a small reduction in mean speeds. A stronger effect was observed at the PC for night data and on sharp curves more than on moderate curves. Little benefit was found in the percentages of vehicles exceeding the speed limit.
6	Wu Y., Zhao X., Rong J., Ma J.; 2013; China	Simulation tests were performed on an interchange of the Fourth Ring Road, in different daytime scenarios. The ramp, with a radius of 85 m, is about 340 m long, and has just one lane. 20 healthy young men, aged 21-31, participated at the experiment.	Absolute difference comparison between exposed and non-exposed sites [t-test]	Fixed Points [absolute difference]; Fixed Duration [absolute difference]; Overall mean of MADOSV [absolute difference]; Degree of deceleration [absolute difference]	Drivers pay more attention to the roadside near chevrons (chevrons attracted more fixation points from the drivers and the duration of fixation points were also longer with the presence of chevrons). They are also more relaxed and tend to drop their speed more when chevrons are present.
7	Zhao X., Wu Y., Rong J., Ma J.; 2015; China	The driving simulator experiment was performed using the fixed-base driving simulator in the Key Lab of Traffic Engineering, Beijing University of Technology. Horizontal curves with different roadway geometries, on two-lane rural undivided highway, were considered. 30 healthy male drivers, age range of 20-34 years, participated at the experiment.	Absolute difference comparison between exposed and non-exposed sites [ANOVA with repeated measures]	Average Speed [Absolute difference]; Average Lane Position [Absolute difference]	A significant interaction between Chevrons presence and curve direction was found for the average speed. Chevrons presence also encourage participants to drive in a more proper lane position, but in sharp curves this function was diminished.

Table 1: Description of coded studies

2.3 LIMITATIONS

There are a few limitations in the current literature examining the effects of chevron signs on road safety. Firstly, four studies use speed as a measure of effectiveness. This is a secondary parameter that does not directly provide a clear image regarding the number of crashes. Similarly, the only study examining crash reduction (Montella A., 2009) has a fairly limited crash sample (n=35) with only a few crashes happening in areas where chevron signs were explicitly installed.

As a further limitation, there are no studies concerning less motorized countries, such as South America or Africa. The impact of installing chevron signs in these environments should be captured from similar studies for a more collective approach.

2.4 RESULTS FOR CHEVRON SIGNS

The effects of the presence of chevrons on road safety can be summarized as follows:

- 1 study with a significant decrease in crash frequency (due to different measures, such as chevron signs, curve warning signs and sequential flashing beacons);
- 4 studies with a significant reduction in mean speed (due to chevron signs, full-post chevrons, FY chevrons, FY chevron posts);
- 2 studies with a significant positive effect in lateral lane position;

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- 1 study with a little benefit in percentages of vehicles exceeding the speed limit;
- 1 study with a positive effect on drivers' attention to the roadside near chevrons (increase of fixed points, fixed duration and degree of deceleration), but without any statistical analyses;
- 1 study with a positive effect on the number of crashes, but without any statistical analyses.

The complete detailed results from the coded studies appear in Table 2, presented in the supporting document.

After collectively reviewing the results, in possible consideration of a meta-analysis, the following points were observed:

a) There is an adequate number of studies. However:
b) These studies have used different models for analysis.
c) There are different indicators, and even when they coincide they are not measured in the same way.
d) The sampling frames were different.

2.5 DESCRIPTION OF ANALYSIS CARRIED OUT

2.5.1 Vote-count analysis

After considering the previous points, it was decided that a meta-analysis could not be carried out in order to find the overall impact of chevrons on road safety. Therefore, the vote count analysis was conducted. In vote count analyses, each study is considered to have one vote for or against the countermeasure. The results are summarized in Table 2.

Outcome definition	Tested in number of studies	Result (number of studies)		
		↑	-	↓
Crash Reduction	2	-	-	1
Mean Speed	4	-	-	4
Mean Lateral position	2	-	-	2
Exceeding speed limit vehicles	1	-	1	-
Behavioural Safety Indicators [Simulation]	1	-	-	-
Total Studies = 7				

Table 2: Vote count analysis results for chevron signs

2.5.2 Overall estimate for road safety

On the basis of the coded studies, it can be asserted that the installation of chevron signs has a positive overall effect on road safety, with one single inconclusive result regarding the number of vehicles exceeding the speed limit. Results are mostly consistent and show a decrease in number of crashes and in mean speed, as well as beneficial effects on lateral lane position. This leads to the assessment of the green colour code for chevron signs. The variation between indicators, models, framing and general details between studies are factors that made the circumstances for conducting a meta-analysis inappropriate.

2.6 CONCLUSION

The vote-count analysis carried out shows that chevron signs are usually associated with a reduction in crash frequency and mean speed. In addition, the presence of chevrons encourages drivers to maintain a lane position that enables them to better negotiate curves. Beneficial effects are also observed on behavioural safety indicators, such as drivers' eye movement (fixed points and fixed duration) and driving performance (degree of deceleration). No significant correlation was found between chevron presence and number of vehicles exceeding the speed limit.

3. Supporting document

3.1 SUPPORTING QUANTITATIVE TABLE

Table 3 is shown below, which includes all quantitative effects from the coded studies for the measures of chevron sign installation.

Number	Author(s); Year; Country;	Outcome indicator	Exposure	Quantitative Estimate			Effect on road safety
1	Choi Y.Y., Kho S.Y., Lee C., Kim D.K.; 2015; South Korea	Crash Frequency [absolute difference]	Chevron signs	All freeways		Abs. Dif.: CF= 13	↓*
				Freeway 1		Abs. Dif.: CF= 10	↓*
				Freeway 2		Abs. Dif.: CF= 7	↓*
				Freeway 3		Abs. Dif.: CF= -4	↑*
		CMF	Chevron signs	All freeways		CMF=0.721; SE=0.308	↓*
				Freeway 1		CMF=0.343; SE=0.208	↓*
				Freeway 2		CMF=0.668; SE=0.176	↓*
				Freeway 3		CMF=1.297; SE=0.424	↑*
2	Gates T.J., Carlson P.J., Hawkins H.G. Jr.; 2004; USA	Mean Speed ~500 ft. Upstream of PC [absolute difference]	FY chevrons	site 1	Daytime	Abs. Dif.: MS=0 mph, a=0.05	-
					Twilight	Abs. Dif.: MS=0.5 mph, a=0.05	-
					Night-time	Abs. Dif.: MS=-0.5 mph, a=0.05	-
				site 2	Daytime	Abs. Dif.: MS=-0.6 mph, a=0.05	↓
					Twilight	Abs. Dif.: MS=-1.3 mph, a=0.05	-
					Night-time	Abs. Dif.: MS=-1.1 mph, a=0.05	↓
			Simultaneous installation of FY chevrons and FY curve signs	site 3	Daytime	Abs. Dif.: MS=0.1 mph, a=0.05	-
					Twilight	Abs. Dif.: MS=-0.9 mph, a=0.05	↓
					Night-time	Abs. Dif.: MS=-0.2 mph, a=0.05	-
				site 4	Daytime	Abs. Dif.: MS=1.3 mph, a=0.05	↑
					Twilight	Abs. Dif.: MS=2.1 mph, a=0.05	↑
					Night-time	Abs. Dif.: MS=0.2 mph, a=0.05	↑
			FY chevrons and FY chevron posts	site 5	Daytime	Abs. Dif.: MS=0.5 mph, a=0.05	-
					Twilight	Abs. Dif.: MS=-1.7 mph, a=0.05	-
					Night-time	Abs. Dif.: MS=-1.6 mph, a=0.05	↓
3	Montella A.; 2009; Italy	Crash Reduction [Percent Accident Change]	Aggregate effect of curve warning signs, chevron signs, and sequential flashing beacons	Total crashes	R ≤ 300 m	PAC=52.2, CI [95%] = [36.7; 67.6]	↓
					R > 300 m	PAC=25.4, CI [95%] = [4.1; 46.6]	↓
					defl.ang. ≤ 60 gon	PAC=24.3, CI [95%] = [1.7; 46.6]	↓
					defl.ang. > 60 gon	PAC=51, CI [95%] = [35.9; 66.1]	↓
				Night-time crashes	R ≤ 300 m	PAC=79, CI [95%] = [62.3; 95.7]	↓
					R > 300 m	PAC=−2.3, CI [95%] = [−50.2; 45.6]	-
					defl.ang. ≤ 60 gon	PAC=−8.6, CI [95%] = [−62.5; 45.4]	-
					defl.ang. > 60 gon	PAC=73.5, CI [95%] = [55.4; 91.6]	↓
				Daytime	R ≤ 300 m	PAC=42.5, CI [95%] = [21.8; 63.1]	↓

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Number	Author(s); Year; Country;	Outcome indicator	Exposure	Quantitative Estimate			Effect on road safety
				crashes	R > 300 m	PAC=36.5, CI [95%] = [14.1; 58.8]	↓
					defl.ang. ≤ 60 gon	PAC=36.2, CI [95%] = [13; 59.5]	↓
					defl.ang. > 60 gon	PAC=42.3, CI [95%] = [22.3; 62.4]	↓
				Rainy crashes	R ≤ 300 m	PAC=46.5, CI [95%] = [22; 71]	↓
					R > 300 m	PAC=48.9, CI [95%] = [25.2; 72.5]	↓
					defl.ang. ≤ 60 gon	PAC=45.5, CI [95%] = [20; 71]	↓
					defl.ang. > 60 gon	PAC=49.4, CI [95%] = [26.6; 72.3]	↓
				Non-rainy crashes	R ≤ 300 m	PAC=58, CI [95%] = [39.1; 76.8]	↓
					R > 300 m	PAC=2.4, CI [95%] = [−32.0; 36.9]	-
					defl.ang. ≤ 60 gon	PAC=2.4, CI [95%] = [−34.1; 39]	-
					defl.ang. > 60 gon	PAC=53.1, CI [95%] = [33.8; 72.4]	↓
				ROR crashes	R ≤ 300 m	PAC=55.5, CI [95%] = [39; 72]	↓
					R > 300 m	PAC=27.2, CI [95%] = [4.9; 46.9]	↓
					defl.ang. ≤ 60 gon	PAC=23.6, CI [95%] = [−1.0; 48.1]	-
					defl.ang. > 60 gon	PAC=55.7, CI [95%] = [40.2; 71.3]	↓
				Non-ROR crashes	R ≤ 300 m	PAC=38.4, CI [95%] = [0; 76.9]	↓
					R > 300 m	PAC=13.3, CI [95%] = [−46.6; 73.2]	-
					defl.ang. ≤ 60 gon	PAC=32.3, CI [95%] = [−18.8; 83.3]	-
					defl.ang. > 60 gon	PAC=28, CI [95%] = [−14.8; 70.9]	-
				Injury crashes	R ≤ 300 m	PAC=39.2, CI [95%] = [12.4; 66]	↓
					R > 300 m	PAC=−26.6, CI [95%] = [−87.4; 34.3]	-
					defl.ang. ≤ 60 gon	PAC=−52.6, CI [95%] = [−128.8; 23.6]	-
					defl.ang. > 60 gon	PAC=43.2, CI [95%] = [18.6; 67.8]	↓
				PDO crashes	R ≤ 300 m	PAC=61.9, CI [95%] = [44.5; 79.4]	↓
					R > 300 m	PAC=38.8, CI [95%] = [17.5; 60]	↓
					defl.ang. ≤ 60 gon	PAC=41.8, CI [95%] = [20.6; 63]	↓
					defl.ang. > 60 gon	PAC=57, CI [95%] = [38.8; 75.3]	↓
			Chevron signs only	Total crashes		PAC=2.6, CI [95%] = [−48.3; 53.6]	-
				Night-time crashes		PAC=−92.0, CI [95%] = [−242.2; 58.2]	-
				Daytime crashes		PAC=37, CI [95%] = [−5.4;79.4]	-
				Rainy crashes		PAC=59.4, CI [95%] = [16; 100]	↓
				Non-rainy crashes		PAC=−27.1, CI [95%] = [−100.1; 45.9]	-
				ROR crashes		PAC=10, CI [95%] = [−41.8; 61.9]	-
				Non-ROR crashes		PAC=−29.1, CI [95%] = [−154.3; 96.1]	-
				Injury crashes		PAC=−46.3, CI [95%] = [−171.5; 78.8]	-

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Number	Author(s); Year; Country;	Outcome indicator	Exposure	Quantitative Estimate				Effect on road safety
				PDO crashes			PAC=16.6, CI [95%] = [−35.0; 68.2]	-
			Simultaneous installation of chevron signs and curve warning signs	Total crashes			PAC=40.8, CI [95%] = [20.8; 60.8]	↓
				Night-time crashes			PAC=34, CI [95%] = [−3.7; 71.7]	-
				Daytime crashes			PAC=44.4, CI [95%] = [21.7; 67.1]	↓
				Rainy crashes			PAC=51.1, CI [95%] = [26.6; 75.5]	↓
				Non rainy crashes			PAC=30.6, CI [95%] = [−0.2; 61.4]	-
				ROR crashes			PAC=43.6, CI [95%] = [23.1; 64.1]	↓
				Non-ROR crashes			PAC=23.6, CI [95%] = [−37.3; 84.5]	-
				Injury crashes			PAC=−46.3, CI [95%] = [−171.5; 78.8]	-
				PDO crashes			PAC=53.6, CI [95%] = [34.7; 72.4]	↓
			Simultaneous installation of chevron signs, curve warning signs and sequential flashing beacons	Total crashes			PAC=47.6, CI [95%] = [30.6; 64.6]	↓
				Night-time crashes			PAC=76.9, CI [95%] = [58.5; 95.3]	↓
				Daytime crashes			PAC=37.3, CI [95%] = [14.8; 59.9]	↓
				Rainy crashes			PAC=43.6, CI [95%] = [17.6; 69.5]	↓
				Non-rainy crashes			PAC=52.3, CI [95%] = [30.9; 73.6]	↓
				ROR crashes			PAC=48.2, CI [95%] = [29.2; 67.2]	↓
				Non-ROR crashes			PAC=46.7, CI [95%] = [10.2; 83.3]	↓
				Injury crashes			PAC=38.2, CI [95%] = [11.5; 65]	↓
				PDO crashes			PAC=56.2, CI [95%] = [35.6; 76.8]	↓
4	Ré J.M.,Hawkins H.G. Jr.,Chrysler S.T.; 2010; USA	Mean Speed [absolute difference]	Chevron signs	site 1			Abs. Dif.: MS= 1.51 mph	↓
				site 2			Abs. Dif.: MS= 1.55 mph	↓
				Overall			Abs. Dif.: MS= 1.28 mph	↓
			Full-post chevrons	site 1			Abs. Dif.: MS= 1.96 mph	↓
				site 2			Abs. Dif.: MS= 2.65 mph	↓
				Overall			Abs. Dif.: MS= 2.20 mph	↓
		Mean Lateral position [absolute difference]	Chevron signs	site 1			Abs. Dif.: MLP= -14.47 in	↓
				site 2			Abs. Dif.: MLP= -16.08 in	↓
				Overall			Abs. Dif.: MLP= -15.47 in	↓
			Full-post chevrons	site 1			Abs. Dif.: MLP= -13.76 in	↓
				site 2			Abs. Dif.: MLP= -16.33 in	↓
				Overall			Abs. Dif.: MLP= -15.14 in	↓
5	Rose E.R., Carlson P.J.; 2005; USA	Mean Speed [absolute difference]	Additional chevron signs	Curve 1	AC-Approach of Curve	Daytime	Abs. Dif.: MS= 1.6 mph, a=0.05	-
						Night-time	Abs. Dif.: MS= 3.8 mph, a=0.05	-
					PC-Point of Curve	Daytime	Abs. Dif.: MS= 2.5 mph, a=0.05	↓
						Night-time	Abs. Dif.: MS= 5.3 mph, a=0.05	↓

Installation of chevron signs

Number	Author(s); Year; Country;	Outcome indicator	Exposure	Quantitative Estimate				Effect on road safety
					MC-Middle of Curve	Daytime	Abs. Dif.: MS= 2.1 mph, a=0.05	↓
						Night-time	Abs. Dif.: MS= 6.4 mph, a=0.05	↓
				Curve 2	AC-Approach of Curve	Daytime	Abs. Dif.: MS= 0 mph, a=0.05	↓
						Night-time	Abs. Dif.: MS= 1.2 mph, a=0.05	↓
					PC-Point of Curve	Daytime	Abs. Dif.: MS= 0.7 mph, a=0.05	↓
						Night-time	Abs. Dif.: MS= 2.6 mph, a=0.05	↓
					MC-Middle of Curve	Daytime	Abs. Dif.: MS= -0.5 mph, a=0.05	-
						Night-time	Abs. Dif.: MS= 0.8 mph, a=0.05	-
				Curve 3	AC-Approach of Curve	Daytime	Abs. Dif.: MS= 0.3 mph, a=0.05	↓
						Night-time	Abs. Dif.: MS= 1.6 mph, a=0.05	↓
					PC-Point of Curve	Daytime	Abs. Dif.: MS= 2.7 mph, a=0.05	↓
						Night-time	Abs. Dif.: MS= 3.8 mph, a=0.05	↓
					MC-Middle of Curve	Daytime	Abs. Dif.: MS= 0.7 mph, a=0.05	↓
						Night-time	Abs. Dif.: MS= 1.4 mph, a=0.05	↓
		Exceeding speed limit vehicles [absolute difference]	Additional chevron signs	Curve 1	AC-Approach of Curve	Daytime	Abs. Dif.: ESL= 6 mph, a=0.05	↓
						Night-time	Abs. Dif.: ESL= 3.8 mph, a=0.05	-
					PC-Point of Curve	Daytime	Abs. Dif.: ESL= 3.7 mph, a=0.05	↓
						Night-time	Abs. Dif.: ESL= 4.4 mph, a=0.05	↓
					MC-Middle of Curve	Daytime	Abs. Dif.: ESL= 2.9 mph, a=0.05	↓
						Night-time	Abs. Dif.: ESL= 5.8 mph, a=0.05	↓
				Curve 2	AC-Approach of Curve	Daytime	Abs. Dif.: ESL= 2.8 mph, a=0.05	-
						Night-time	Abs. Dif.: ESL= 4.5 mph, a=0.05	-
					PC-Point of Curve	Daytime	Abs. Dif.: ESL= 0.6 mph, a=0.05	-
						Night-time	Abs. Dif.: ESL= 0 mph, a=0.05	-
					MC-Middle of Curve	Daytime	Abs. Dif.: ESL= 0 mph, a=0.05	-
						Night-time	Abs. Dif.: ESL= 0 mph, a=0.05	-
				Curve 3	AC-Approach of Curve	Daytime	Abs. Dif.: ESL= 0.1 mph, a=0.05	-
						Night-time	Abs. Dif.: ESL= 1.8 mph, a=0.05	-
					PC-Point of Curve	Daytime	Abs. Dif.: ESL= 0 mph, a=0.05	-
						Night-time	Abs. Dif.: ESL= 0 mph, a=0.05	-
					MC-Middle of Curve	Daytime	Abs. Dif.: ESL= 0 mph, a=0.05	-
						Night-time	Abs. Dif.: ESL= 0 mph, a=0.05	-
6	Wu Y., Zhao X., Rong J., Ma J.; 2013; China	Fixed Points [absolute difference]	Chevron signs	Abs.Dif.: FP= 12.3%				↓*
		Fixed Duration [absolute difference]	Chevron signs	Abs.Dif.: FD= 6.2%				↓*
		Overall mean of MADOSV [absolute difference]	Chevron signs	Abs.Dif.: OM= 0.01; SDs=0.03; p= 0.12				-
		Degree of	Chevron signs	Releasing the accelerator			Abs.Dif.: DD= 5.1	↓*

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Number	Author(s); Year; Country;	Outcome indicator	Exposure	Quantitative Estimate			Effect on road safety
		deceleration [absolute difference]		Braking		Abs.Dif.: DD= 2.7	↓ *
7	Zhao X., Wu Y., Rong J., Ma J.; 2015; China	Average Speed [Absolute difference]	Chevron signs	From PC to PT	Left curve	Abs.Dif.: AS= 4.97 km/h, F(1,29) = 6.644, p=0.011	↓
					Right curve	Abs.Dif.: AS= 1.11 km/h, F(1,29) = 6.644, p=0.012	-
				AC-Approach of Curve [300 m before the curve entrance]		Abs.Dif.: AS= 1.86 km/h, F(1,29) = 6.000, p=0.015	↓
				PC-Point of Curve		Abs.Dif.: AS= 1.34 km/h, F(1,29) = 1.969, p=0.162	-
				MC-Middle of Curve		Abs.Dif.: AS= 4.12 km/h, F(1,29) = 22.769, p<0.001	↓
				PT-Point of Tangent		Abs.Dif.: AS= 2.74 km/h, F(1,29) = 16.342, p<0.001	↓
		Average Lane Position [Absolute difference]	Chevron signs	From PC to PT	Left curve	Abs.Dif.: ALP=-0.16 m, F(1,29) = 77.221, p<0.001	↓
					Right curve	Abs.Dif.: ALP=0.38 m, F(1,29) = 77.221, p<0.001	↓
				From AC to PC		Abs.Dif.: ALP=0.01 m, F(1,29) = 0.028, p=0.867	-
				From PC to MC		Abs.Dif.: ALP=0.1 m, F(1,29) = 4.93, p=0.028	↓
				From MC to PT		Abs.Dif.: ALP=0.11 m, F(1,29) = 0.593, p=0.442	-
↑	denotes positive road safety effects			-	denotes unclear or marginal road safety effects		
↓	denotes negative road safety effects			* denotes that no statistical analysis was conducted for the significance of the effects			

Table3: Quantitative results of coded studies for chevrons and impacts on road safety

3.2 METHODOLOGY

Measure: Chevron signs

3.2.1 Literature search strategy

The search strategy aimed at identifying recent studies regarding the installation of chevron signs at curves. Three main databases were consulted: Scholar, TRID and Science Direct. In general, only recent (after 1990) journal studies were considered.

Limitations/ Exclusions:

- Search field: TITLE-ABS-KEY
- Published: 1990 to current
- Document Type: "Review" and "Article"
- Language: "English"
- Source Type: "Journal"
- Only Transport Journals were considered
- Subject Area: "Engineering"

Database: TRID **Date:** 6th January 2017

search no.	search terms / operators / combined queries	Hits
#1	Chevron signs	54
#2	Chevron signs at curves	29
#3	Installation of chevron signs at curves	4

Database: Google Scholar **Date:** 6th January 2017

search no.	search terms / operators / combined queries	Hits
#1	"chevron signs"	213
#2	installation "chevron signs"	158
#3	installation "chevron signs" at curve	132

Database: ScienceDirect **Date:** 6th January 2017

search no.	search terms / operators / combined queries	Hits
#1	"chevron signs"	21
#2	"chevron signs" and "curves"	8

3.3 RESULTS OF LITERATURE RESEARCH

Database	Hits
Google Scholar	213
TRID	54
ScienceDirect	21
Total number of studies to screen title	288

3.4 SCREENING

The abstracts of relevant studies from the initial literature search results were examined to narrow the scope and to detect studies that would be more appropriate at a first stage. Those abstracts give hints as to whether the full text warrants close examination for coding and inclusion in the project.

Total number of studies to screen title	**288**
Number of articles remaining after screening of the title = Total number of studies to screen abstract	182
Remaining studies after abstract screening	34
Total number of studies to screen full text	34

3.5 ELIGIBILITY

Total number of studies to screen full-text	**34**
Full-text could be obtained	**25**
Reference list examined Y/N	**Yes**
Eligible papers prioritized	**7**

3.6 PRIORITIZING CODING

- Prioritizing Step A (most recent studies)
- Prioritizing Step B (Journals over conferences and reports)
- Prioritizing Step C (Prestigious journals over other journals and conference papers)
- Prioritizing Step D (Studies from Europe)

No meta-analyses were found.

3.7 LIST OF CODED STUDIES

1. CHOI Y.Y., KHO S.Y., LEE C., KIM D.K., 2015; Development of crash modification factors of alignment elements and safety countermeasures for Korean freeways. Transportation Research Board 94th Annual Meeting.
2. GATES T.J., CARLSON P.J., HAWKINS H.G. Jr., 2004; Field Evaluations of Warning and Regulatory Signs with Enhanced Conspicuity Properties. Transportation Research Record: Journal of the Transportation Research Board, n.1862, pp. 64–76.
3. MONTELLA A. 2009; Safety Evaluation of Curve Delineation Improvements Empirical Bayes Observational Before-and-After Study. Transportation Research Record: Journal of the Transportation Research Board, n.2103, pp. 69–79.
4. RÉ J.M., HAWKINS H.G. Jr., CHRYSLER S.T., 2010; Assessing Benefits of Chevrons with Full Retroreflective Signposts on Rural Horizontal Curves. Transportation Research Record: Journal of the Transportation Research Board, n. 2149, pp. 30–36.
5. ROSE E.R., CARLSON P.J., 2005; Spacing Chevrons on Horizontal Curves. Transportation Research Record: Journal of the Transportation Research Board, n. 1918, pp. 84–91

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6. WU Y., ZHAO X., RONG J., MA J., 2013; Effects of Chevron Alignment Signs on Driver Eye Movements, Driving Performance, and Stress. Transportation Research Record: Journal of the Transportation Research Board, n. 2365, pp. 10–16.
7. ZHAO X., WU Y., RONG J., MA J., 2015; The effect of chevron alignment signs on driver performance on horizontal curves with different roadway geometries. Accident Analysis and Prevention, volume 75, February 2015, pp.226–235.