Dynamic Speed Display 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

Daniels, S., Focant, N., June 2017

1.1 COLOUR CODE: GREEN

Results consistently show that dynamic speed display signs (DSDSs) have favourable effects on speeds. One study also shows a decrease of the number of crashes after installing DSDSs.

1.2 KEY WORDS

Dynamic speed display sign, DSDS, speed, speed management, evaluation, effectiveness, speed-activated displays, speed limit compliance, individual dynamic speed warning.

1.3 ABSTRACT

Dynamic speed display signs (DSDSs) measure the speed of approaching vehicles and communicate the vehicle's actual speed to drivers on a digital display along the road, possibly also including pictures or verbal messages such as "Slow down" or "Thank you". The underlying idea is that DSDSs help motorists self-enforce their speed. DSDSs should not be confused with dynamic speed limits (DSLs) which can impose different speed limits depending on traffic or weather circumstances. The essence of DSDSs is the individual feedback on driven speeds.

The number of studies on the effects of DSDSs published in peer-reviewed journals is limited. Most evaluations have been done by means of before-and-after studies, focusing rather on the resulting speed behaviour than on the (indirect) effect on crashes. No meta-analyses were found.

All reviewed studies consistently report significant decreases of mean speeds due to the presence of active DSDSs, although the size of the effect differs. The observed mean speed decrease ranges from 1km/h to 10 km/h. The observed decreases of the 85th percentile speed are of the same magnitude. The results of all the studies appear to be relatively homogenous which suggests that the measure is reasonably well transferable to other similar settings, including those in other countries.

All studies also evaluated the proportion of drivers who exceeded the speed limits by some amount and reported considerable reductions in the highest exceedances of the speed limits. Some studies concluded that drivers become less responsive towards the DSDS over time, but the most elaborate study did not find significant evolutions in mean speeds at the DSDS locations during the period of use. All studies agreed that the speed reductions observed while the DSDSs were in place disappeared after the devices were removed from the study sites. It was also found that drivers increase their speed again after passing the DSDS. DSDSs that extend the numeric feedback with verbal messages tend to outperform the ones with only numeric feedback.

One study calculated the effect on the number of crashes and found a significant overall reduction of 5%.

1.4 BACKGROUND

1.4.1 What are Dynamic Speed Display Signs?

Dynamic speed display signs (DSDSs) measure the speed of approaching vehicles and communicate the speed to drivers on a digital display along the road. The underlying idea is that DSDSs help motorists self-enforce their speed (Cruzado & Donnell, 2009). DSDSs differ from dynamic speed limit signs (DSL) (also called: variable speed limit (VSL) signs) which can impose different speed

limits depending on time, location and/or circumstances (e.g., severe weather conditions, or work zones) (Ardeshiri, 2014). The features of DSDSs range from standard signs that display the actual speed of the car to signs that (also) include verbal messages such as "Slow down" or "Thank you" depending on the monitored speed level. Signs with additional features such as smileys, different colours or additional pictures have also been used (Gehlert et al., 2012).

1.4.2 How can Dynamic Speed Display Signs affect road safety?

Gehlert et al. (2012) describe three psychological mechanisms that apply to all kinds of DSDSs: attracting attention, providing feedback and introducing social control. In addition, the way how the feedback about the speeding behaviour is presented (numbers, text messages, pictures…) might exert different effects on drivers.

1.4.3 How has the effects of Dynamic Speed Display Signs on road safety been studied?

The number of studies on the effects of DSDSs published in peer-reviewed journals is limited. Moreover, not all studies evaluate DSDSs in similar conditions. All coded studies assess the effects on speed behaviour in terms of effects on mean speeds, effects on the 85th speed percentile and effects on the proportion of drivers exceeding the posted speed limit to a certain extent. One study also evaluates the effect on crashes. Most evaluations have been done by means of before-and-after studies. No meta-analyses were found.

1.5 OVERVIEW OF RESULTS

1.5.1 Results of effect estimates

All reviewed studies consistently reported significant **decreases of mean speeds** due to the presence of active DSDSs, although the size of the effect differs. The observed decreases of the 85th percentile speed are of a similar magnitude. All studies also evaluated the proportion of drivers who exceeded the speed limits by some amount and reported considerable but varying reductions. The speed reductions observed while the DSDSs were in place **disappeared** after the devices were **removed** from the study sites (Cruzado & Donnell, 2009; Gehlert et al., 2012). **Two studies (Ardeshiri & Jeihani, 2014; Gehlert et al., 2012) report a systematic decrease of effects over time even when the DSDSs remain active. However, a more elaborate study (Hallmark et al., 2015) found no significant evolution of mean speeds over the duration of operation of DSDSs.** Ulmann & Rose (2005) found that motorists traveling **faster** than the posted speed limit appeared to reduce their speed **more strongly** in response to the DSDS than motorists traveling at or below the posted speed limit. Drivers with average speeds below the posted speed upstream of the DSDS were even found to increase their speeds at the DSDS (Ardeshiri & Jeihani, 2014). In their cross-sectional study Ardeshiri & Jeihani (2014) found that drivers **increase their speed again after passing the DSDS**.
DSDSs that add to the numeric feedback additional **coloured and/or verbal messages** that include some recommended action (e.g. 'SLOW DOWN') appear to result in stronger speed reductions than DSDSs with only numeric feedback (Gehlert et al., 2012).
Hallmark et al. (2015) calculated the effect on **crashes** by means of a before-and-after study. They found an overall reduction in the number of crashes of 5% (CMF 0.95) with a 95% CI [0.93-0.97]. Single vehicle crashes were studied separately and had decreased by 5 % (CMF 0.95) with a 95% CI [0.93-0.97].

1.5.2 Biases

All studies had at least minor limitations. Sample sizes in terms of studied locations were limited in most cases, varying from 1 (Gehlert et al., 2012) to 22 (Hallmark et al., 2015). Moreover the included road types represent a lot of potentially systematically different underlying conditions that all could somehow influence speed behaviour and therefore act as a confounding variable, i.e. offer a threat to the external validity of the findings. Examples of these conditions include variables related to the road

design, to traffic conditions and to the environment including weather conditions and seasonal variation.

1.6 TRANSFERABILITY

Most included studies originate from the US, one is a European study from Germany (Gehlert et al., 2012). All studies evaluate DSDSs that are located at specific locations such as curves, school zones, or transition zones. The results of all the studies appear to be relatively homogenous which suggests that the measure is reasonably well transferable to other similar settings, including those in other countries.

2 Scientific overview

2.1 THEORETICAL BACKGROUND

Gehlert et al. (2012) describe three psychological mechanisms that apply to all kinds of DSDSs:

- the dynamic presentation with movements or changing stimuli attracts **attention** and is therefore perceived by drivers - as compared to conventional signs - more often, more quickly and more consciously.
- the dynamic presentation allows for an individual as well as immediate **feedback** about car drivers' speed. It is well known that people take more notice of individualised feedback and feedback that follows immediately and contingent after the behaviour. The more general the feedback is and the more time passes the less likely people will link the feedback to their own behaviour.
- the feedback to car drivers is displayed openly and thus visible for other road users as well. That introduces some degree of **social control** which has been found to support the effectiveness of speed display signs.

In addition, the **way** the feedback about the speeding behaviour is presented (numbers, text messages, pictures…) might appeal differently to the motivation of drivers to choose a speed level.

2.2 ANALYSIS OF STUDY DESIGNS AND METHODS

Description of the main research methods

Table 1 provides a synoptic description of the background characteristics of the coded studies that deal with dynamic speed display signs (DSDSs).

The number of studies on the effects of DSDSs published in peer-reviewed journals is limited. Moreover, not all studies evaluate DSDSs in similar conditions. All studies that evaluated DSDSs dealt with specific locations such as curves (Hallmark et al., 2015), transition speed zones (Cruzado & Donnell, 2009) or mixed areas (curves, transition zones, school zones and approaches to signalized intersections) on high-speed roadways (Ullman & Rose, 2005).

All coded studies assess the effects on speed behaviour in terms of effects on mean speeds. Some of the found studies extend this to effects on the 85th speed percentile and effects on the proportion of drivers exceeding the posted speed limit to a certain extent. One study (Hallmark et al., 2015) also evaluates the effect on crashes.

Most evaluations have been done by means of before-and-after studies. One study applied a cross-sectional design, comparing locations with and without DSDSs (Ardeshiri & Jeihani, 2014). All studies established control groups or used a methodological framework to eliminate confounders such as trend effects. Four out of five included studies applied and reported significance tests. No meta-analyses were found.

While most studies evaluated rather short-term effects of DSDSs, Hallmark et al. (2015) collected data from 1 month until 24 months after installation. Two studies also evaluated the effect of removing the DSDSs again.

Table 1: Information on sample and design of coded studies (sorted by name of first author)

Author(s), year, country	Measure description and sample	Study design	Outcome indicators
Ardeshiri A., Jeihani M., 2014, USA	Effects of DSDSs at 3 locations	Cross-sectional comparison of locations upstream and downstream the DSDSs. t-tests + Bayesian network modelling.	• Mean speed
Cruzado I., Donnell E.T., 2009, USA	Effects of DSDSs at 12 locations	Before- after comparison of free-flow vehicle operating speeds	• Mean speed
Gehlert T., Schulze C., Schlag B., 2012, Germany	Effects of 3 different types of DSDSs at 1 location	Time series design	• Mean speed • V85 • Percentage of vehicles exceeding the speed limit
Hallmark, S.L; Hawkins, N. Smadi, O., 2015, USA	Effectiveness of two different DSDSs on curves at 22 locations on rural two-lane roadways in seven US states.	Before-after with comparison group	• Number of crashes • Mean speed • V85 • Percentage of vehicles exceeding posted or advisory speed limit
Ullman, G.L.; Rose, E.R., 2005, USA	Analysis of the effectiveness of dynamic speed display signs (DSDSs) installed in several permanent locations	Before-after with comparison group	• Mean speed • V85 • Percentage of vehicles exceeding the speed limit

2.3 STUDY RESULTS

Studies on DSDSs

Table 2 provides information on the main outcomes of coded studies on DSDSs. All reviewed studies consistently reported decreases of mean speeds due to the presence of active DSDSs, although the size of the effect differs. The observed mean speed decrease ranges from 1km/h till 10 km/h. The observed decreases of the 85th percentile speed are of the same magnitude.

All studies also evaluated the proportion of drivers who exceeded the speed limits by some amount and reported considerable but varying reductions.

Do effects remain when the DSDS is no longer active?

The results of the analyses indicate that the DSDSs are effective in reducing free-flow passenger car operating speeds while in place and activated. However, the speed reductions observed while the DSDSs were in place **disappeared** within a few weeks after the devices were removed from the study sites (Cruzado & Donnell, 2009; Gehlert et al., 2012).

Effects over time

Ardeshiri & Jeihani (2014) report a systematic decrease of effects when the DSDSs are longer in use (ranging from 1 to 12 days). Also Gehlert et al. (2012) found slight increases of speeds (about 0.5 km/h monthly) from 1 to 3 months after installation and concluded that drivers become less responsive towards the DSDS over time. However, Hallmark et al. (2015) studied a much larger sample of locations (22) over a longer period (respectively 1, 12 and 24 months after) and found no statistical difference between changes in mean speeds at the DSDSs for any of the time periods. This suggests that DSDS may have a long-term impact on speed, at least as long as they are active.

Essentially discouraging highest speeds?

Ulmann & Rose (2005) also compared speeds of individual vehicles tracked at the upstream control point against the speed of the same vehicle at the DSDS location and found that those motorists traveling **faster** than the posted speed limit appeared to reduce their speed more strongly in response to the DSDS than did motorists traveling at or below the posted speed limit.
Ardeshiri & Jeihani (2014) found that the cumulative probability of driving below 1.07 times of the speed limit was 95.8%. They concluded that, although this means that DSDS did not result in full speed limit compliance, they were well capable to reduce the highest speeds.

…but also increasing the lower speeds

Ardeshiri & Jeihani (2014) applied a Bayesian Network model to their data and found that 51.2% of drivers with average speeds below the posted speed upstream of the DSDS increased their speeds adjacent to the DSDS. The authors explain this by the fact that DSDSs might act as a reminder to some to raise their speed to meet the posted speed.

Speed increases after passing DSDS

In their cross-sectional study Ardeshiri & Jeihani (2014) installed a counter 335 meter downstream of the DSDS to measure the distance effect. They found that drivers increase their speed again to the original level after passing the DSDS.

Other modifying conditions

A number of modifying conditions could exist. This means that the effect of the DSDS can be higher or lower according to variables such as time of the day, day of the week, duration of DSDS operation and distance from the DSDS location.
Time of day (peak hours vs. off-peak) and day of the week (weekdays vs. weekends) appeared to be less significant compared to the road-specific variables (Ardeshiri & Jeihani, 2014). DSDSs that add additional coloured and/or verbal messages to the numeric feedback appear to result in stronger speed reductions than DSDSs with only numeric feedback (Gehlert et al., 2012). The verbal coloured DSDS reduces speed most followed by the numeric coloured DSDS and the numeric DSDS. The verbal coloured DSDS also exhibits no habituation effects (see 'Effects over time') in contrast to both numeric DSDS. The differences between the DSDS are explained with different priming mechanisms initiated by traffic signs (Gehlert et al., 2012). Verbal messages such as 'Slow', 'Slow down' or 'Thank You' translate speed behaviour into an unambiguous instruction as to how to change speeding behaviour. Numeric DSDS give no hint for action and leave the interpretation up to the driver (Gehlert

et al., 2012). This mechanism might also explain why Ulmann & Rose (2005) found higher reductions at school speed zones (-9 mph) than at other locations (-5 mph or less depending on the location).

Effects on crashes

Hallmark et al. (2015) calculated the effect on crashes by means of a before- and after study. They found an overall reduction in the number of crashes of 5% (CMF 0.95) with a 95% CI [0.93-0.97]. Single vehicles crashes were studied separately and had decreased by 5% (CMF 0.95) with a 95% CI [0.93-0.97]

Table 2: Summary of coded study results for dynamic speed display signs (DSDSs) (sorted by surname of first author)

Author(s), year, country	Exposure variable	Dependant / outcome type	Effects on road safety		Main outcome – description
Ardeshiri A., Jeihani M., 2014, USA	Active dynamic speed display sign	Mean speed	↗	Average speed decrease of 1.19 miles per hour	The DSDS is an effective short-term tool for short distances
Cruzado I., Donnell E.T., 2009, USA	Active dynamic speed display sign	Mean speed	↗	Average speed reduction of 10.1 km/h	DSDSs are effective in reducing free-flow passenger car operating speeds by an average of 6 mph (10 km/h) while in place and activated. Speed reductions faded after the devices were removed from the study sites.
Gehlert T., Schulze C., Schlag B., 2012, Germany	Active dynamic speed display sign	• Mean speed • V85 • Percentage of vehicles exceeding the speed limit	↗	• Average speed reduction of 1.0 to 3.1 km/h. • V85 reduction of 1 to 3 km/h • Reduction of 6.6 to 28.6 % of vehicles exceeding the speed limit	All DSDSs reduce average speed, 85th percentile speed, and the percentage of vehicles exceeding the speed limit. After dismounting the speed levels returned to its baseline for all three DSDSs.
Hallmark, S.L; Hawkins, N. Smadi, O., 2015, USA	Active dynamic speed display sign in curves	• Number of crashes • Mean speed • V85 • Percentage of vehicles exceeding posted or advisory speed limit	↗	• -5% crashes, 95% CI [-7%; -3%] • 1.96 mph reduction of mean speed ($p<0.05$) • 2.3 mph reduction of V85 ($p<0.05$) • 17.7% reduction of fraction of vehicles exceeding posted or advisory speed by 10 mph	On average, most sites had decreases in mean speeds, decreases in 85th percentile speed and large reductions in the number of vehicles traveling over the posted or advisory speed. The crash analysis showed a significant reduction of 5% of all crashes at the studied curves.
Ullman, G.L. ; Rose, E.R., 2005, USA	Active dynamic speed display sign	• Mean speed • V85 • Percentage of vehicles exceeding the speed limit	↗	• 1 to 4 mph reductions in mean speed and V85	DSDSs can yield small reductions in average and 85th percentile speeds as well as reductions in the percent of motorists who exceed the posted speed limit.

* Effects on road safety are coded as: positive (↗), negative (↘), non-significant (-) or no test for significance reported (/)

2.4 DESCRIPTION OF ANALYSIS

Vote-count analysis

Five key studies establishing the effects of DSDSs have been identified, coded, analysed and summarized. Only one study directly assessed the effect on the number of crashes. Each of the five studies assessed the effect on driving speed. All studies calculated effects on mean speeds, while three out of the five studies also assessed effects on 85th percentile speeds and effects on the proportion of vehicles exceeding the speed limit. A vote-count analysis was conducted for the effect on mean speeds, the effect on 85th percentile speeds and the effect on the percentage of vehicles exceeding the speed limit. Each study had one vote. For the sake of completeness, also the effect on the number of crashes was included. The results are presented in Table 3. The vote can take three different values:

- An increase in either average speeds, V85, percentage of vehicles exceeding the speed limit or the number of crashes (↗)
- A decrease (↘)
- No significant difference

Table 3: Results for effects of DSDS

	Total number of effects tested	Result (number of effects)			Result (% of effects)	
		↗	-	↘	↗	↘
Average speed	5	0	0	5	0	100
V85	3	0	0	3	0	100
Percentage of vehicles exceeding the speed limit	3	0	0	3	0	100
Number of crashes	1	0	0	1	°	100

The number of studies is small, but the results are consistent. All included studies reported decreases of mean speeds, decreases of the 85th percentile speed and decreases of the percentage of vehicles exceeding the speed limit. Together with the single result on the effects on the number of crashes, this leads to a still limited though very consistent overall picture which justifies a green colour code ("Results consistently show that the countermeasure reduces road safety risk").

3 Supporting document

This Supporting Document on dynamic speed display signs describes the literature search strategy (Section 3.1) and it presents references to the finally coded studies (Section 3.2).

Taxonomy	
Measure	Specific measure
Speed management and enforcement	*Dynamic Speed Display Signs*

3.1 LITERATURE SEARCH STRATEGY

A literature search for studies that assessed effects of DSDSs was carried out in three databases (ScienceDirect, TRID, Scopus) with combinations of search terms and operators. These studies were subsequently assessed and checked for their relevance. The tables below describe the search terms, the logical operators and the number of hits for the searches in the different databases.

Research terms and hits

Database: ScienceDirect **Date:** 03rd February 2017

Limitations/ Exclusions:

- Search field: TITLE-ABS-KEY
- Published: 1990 to current
- Document Type: ALL

Table 4: Search terms and hits in ScienceDirect

search no.	search terms / operators / combined queries	hits
#1	TITLE-ABSTR-KEY("variable message sign*") and TITLE-ABSTR-KEY(effectiveness or "road safety" or "efficiency" or "impact" or "effect")	45
#2	TITLE-ABSTR-KEY("dynamic message sign*") and TITLE-ABSTR-KEY(effectiveness or "road safety" or "efficiency" or "impact" or "effect").	3
#3	TITLE-ABSTR-KEY("dynamic speed*") and TITLE-ABSTR-KEY((effectiveness or "road safety" or "efficiency" or "impact" or "effect"))	69

Database: TRID **Date:** 06th February 2017

Limitations/ Exclusions:

- Published: 1990 to 2017
- Document source : ALL, Document Type: ALL, Subject area : ALL
- Language: English and French

Table 5: Search terms and hits in TRID

search no.	search terms / operators / combined queries	hits
#1	[Title] ((("variable message sign*") OR ("dynamic message sign")) AND (effectiveness OR "road safety" OR efficiency OR impact OR effect OR evaluation)	58
#2	[Title] ("dynamic speed*") AND (effectiveness OR "road safety" OR efficiency OR impact OR effect OR evaluation)	53

Database: Scopus **Date:** 06th February 2017

Limitations/ Exclusions:

- Search field: Abstract, title, keywords
- Published: 1990 to current
- Document Type: ALL
- Subject Area: ALL

Table 6: Search terms and hits in Scopus

search no.	search terms / operators / combined queries	hits
#1	(TITLE ((("variable message sign*") OR ("dynamic message sign"))) AND TITLE ((effectiveness OR "road safety" OR efficiency OR impact OR effect OR evaluation))) AND PUBYEAR > 1989	50
#2	(TITLE (("dynamic speed*")) AND TITLE ((effectiveness OR "road safety" OR efficiency OR impact OR effect OR evaluation))) AND PUBYEAR > 1989	59

The searches resulted in 92 unique papers.

Principles

Papers and reports were excluded if they didn't study DSDSs, just mentioned them rather indirectly or studied them from a perspective that was not meaningful for the purpose of the project. This was the case if they dealt mainly or completely with:

- In general:
  - Message within vehicles, on-board traffic messages
  - Driver, environmental or infrastructural factors affecting understandability / comprehension of the message
  - Visibility/readability/legibility of the message; viewing comfort; text layout ; display format ; impact of bilingual messages
  - Driver's opinion, driver's satisfaction
  - Energy efficiency, composition/materials
  - Environmental effect/impact
  - Guidelines
- Types of variable message signs that don't meet the criteria of DSDSs (e.g. no real-time speed measurement, no feedback to the driver)
- Dynamic or Variable speed limits (DSL/VSL), including weather-dependent VSL

Interesting papers from the literature search

Applying the abovementioned principles to the preselected papers resulted in 11 promising references for Dynamic speed display signs (DSDSs). Full paper versions of 9 of these references could be traced as shown in the table below.

Table 7: Preselection of studies based on title and abstract

Authors	Title	Year	Country	Available?	Scientific journal?	Relevant?	Codable?
Hallmark, S.L; Hawkins, N. Smadi, O. + Hallmark, S L; Hawkins, N; Smadi, O.	Evaluation of Dynamic Speed Feedback Signs on Curves: A National Demonstration Project + Speed Reduction Impact of Dynamic Speed Feedback	2015 + 2012	USA	V	No - FHWA report + No - 2012 15th International IEEE Conference on Intelligent Transportation Systems	Yes	Yes
Ardeshiri A. Jeihani M.	A speed limit compliance model for dynamic speed	2014	USA	V	Yes - Journal of Safety Research	Yes	Yes
Gehlert T., Schulze C., Schlag B.	Evaluation of different types of dynamic speed display signs	2012	Germany	V	Yes - Transportation Research Part F	Yes	Yes
Jeihani, M; Ardeshiri, A; Naeeni, A	Evaluating the Effectiveness of Dynamic Speed Display Signs.	2012	USA	V	No - Morgan State University National Transportation Center Research report	Yes	Yes
Cruzado I., Donnell E.T.	Evaluating effectiveness of dynamic speed display signs in transition zones of two-lane, rural highways in	2009	USA	V	Yes - Transportation Research Record: Journal of the Transportation Research Board	Yes	Yes
Schoenecker, T.; Sandberg, W.; Sebastian, K.; Soler, D.	Long-Term Effectiveness of Dynamic Speed Monitoring Displays (DSMD) for Speed Management at Speed Limit Transitions.	2008	USA	V	No - FHWA research, 15th World Congress on ITS, 2006	Yes	Yes (but little statistical details)
Ullman, G.L. ; Rose, E.R.	Evaluation of Dynamic Speed Display Signs.	2005	USA	V	Yes - Transportation Research Record: Journal of the Transportation Research Board	Yes	Yes
Rose, E R; Ullman, G L.	EVALUATION OF DYNAMIC SPEED DISPLAY SIGNS (DSDS).	2003	USA	V	No - Texas Department of Transportation, Research and Technology Implementation Office	Yes	Yes
Ardeshiri, Anam; Jeihani, Mansoureh.	Dynamic Speed Display Sign Impact on Speed Limit Compliance on Multiple Roadway Classes	2013	?	X			
Sandberg, W.; Schoenecker, T.; Sebastian, K.; Soler, D.	Long-Term Effectiveness of Dynamic Speed Monitoring Displays (DISMAYED) for Speed Management at Speed Limit Transitions.	2006	USA	X			

Coding

The remaining studies were checked, based on the full paper version. All checked studies are presented in Table 8. The table includes authors, title, year and source of the study. Studies highlighted in green were coded. The last column mentions the reason of exclusion for the not coded studies.

Table 8: Selection of studies to be coded

Authors	Title	Year	Source	Status	Reason of exclusion
Hallmark, S.L; Hawkins, N. Smadi, O.	Evaluation of Dynamic Speed Feedback Signs on Curves: A National Demonstration Project .	2015	FHWA report	Coded	
Ardeshiri A. Jeihani M.	A speed limit compliance model for dynamic speed display sign	2014	Journal of Safety Research	coded	
Gehlert T., Schulze C., Schlag B.	Evaluation of different types of dynamic speed display signs	2012	Transportation Research Part F	coded	
Jeihani, M; Ardeshiri, A; Naeeni, A	Evaluating the Effectiveness of Dynamic Speed Display Signs.	2012	Research report	Not coded	Similar to Ardeshiri & Jeihani, 2014
Cruzado I., Donnell E.T.	Evaluating effectiveness of dynamic speed display signs in transition zones of two-lane, rural highways in Pennsylvania	2009	Transportation Research Record: Journal of the Transportation Research Board	coded	
Schoenecker, T.; Sandberg, W.; Sebastian, K.; Soler, D.	Long-Term Effectiveness of Dynamic Speed Monitoring Displays (DSMD) for Speed Management at Speed Limit Transitions.	2008	Conference Proceeding	Not coded	Preference for journal papers
Ullman, G.L. ; Rose, E.R.	Evaluation of Dynamic Speed Display Signs.	2005	Transportation Research Record: Journal of the Transportation Research Board	coded	
Rose, E R ; Ullman, G L.	EVALUATION OF DYNAMIC SPEED DISPLAY SIGNS (DSDS).	2003	Research report	Not coded	Similar to Ullman & Rose, 2005

3.2 REFERENCES OF THE CODED STUDIES

Ardeshiri, A., Jeihani, M. (2014). A speed limit compliance model for dynamic speed display sign. J. Safety Res. 51, 33–40.

Cruzado, I., & Donnell, E. T. (2009). Evaluating effectiveness of dynamic speed display signs in transition zones of two-lane, rural highways in Pennsylvania.
Transportation Research Record, 2122, 1–8.

Gehlert, T., Schulze, C., Schlag, B. (2012). Evaluation of different types of dynamic speed display signs. Transp. Res. Part F Traffic Psychol. Behav. 15, 667–675.

Hallmark, S.L, Hawkins, N., Smadi, O. (2015). Evaluation of Dynamic Speed Feedback Signs on Curves: A National Demonstration Project. McLean, Virginia, USA: Federal Highway Administration.

Ullman, G.L., & Rose, E.R. (2005). Evaluation of dynamic speed display signs. Transportation Research Record, 1918, 92–97.