Guidance for Radar Speed Sign Deployments

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ABSTRACT

Radar speed signs have seen increased application in recent years in communities across the United States. These devices, which measure (by radar) and display the speed of vehicles passing by, are typically trailer-based units or permanent pole/post-mounted digital display boards. Such devices are used to reduce traffic speeds by making drivers aware of how fast they are moving relative to the speed limit and inducing them to adjust their speed accordingly. Typically, the deployment of radar speed signs has been conducted in an unscientific manner, with devices placed where there is a perceived problem with little quantification of the problem itself. Consequently, it was deemed necessary to establish criteria regarding when/how such signage can be deployed and operated to address safety and speed issues effectively. The objectives of this research were to determine the situations where the use of radar speed signs is applicable, whether they have been effective in similar applications, and where such signs should be located (setting). Based on this information, guidance was developed to direct future applications of radar speed signs. Two levels of guidance were developed: general guidance and location-specific guidance. General guidance applies where a radar speed sign may be used to address excessive mean speed and 85^{th} percentile speed issues, ADT levels, speed limit compliance issues, accident history, pedestrian presence, and existing posted speed limits. Location-specific guidance applies to use in school and park zones, work zones, and general street locations such as transition zones, curve warning sign locations, and signal approaches.

INTRODUCTION

Radar speed signs have seen increased application in recent years in communities across the United States. While referred to in this paper as radar speed signs, such devices also carry a number of different names, including mobile roadside speedometers, speed trailers, dynamic speed display signs, speed displays, speed feedback signs, driver feedback signs, and speed monitoring displays. Regardless of the naming convention, each describes the same general device. These devices, which measure (by radar) and display the speed of vehicles passing by, are typically mobile (trailer-based) units or are permanent pole/post-mounted digital display boards. Smaller portable pole/post-mounted displays intended for brief deployments have also recently become available. An example of each type of these units is presented in Figure 1. Such devices are used to reduce traffic speeds by making drivers aware of how fast they are moving relative to the speed limit and inducing them to adjust their speed accordingly. This is considered a "feedback loop", a very effective way of permitting human beings to measure performance against a benchmark by displaying performance.

Trailer-based unit (Veneziano)

Pole-mounted unit (Turnbull)

Temporary pole-mounted unit (Veneziano)

FIGURE 1 Radar Speed Sign Examples

While these radar speed signs, particularly trailer-based and portable sign-mounted versions, can be deployed anywhere that excessive vehicle speeds are a concern, two primary applications have been documented in the literature: school zones and work zones, both in urban and rural settings. These are locations where excessive vehicle speeds are of significant safety concern. Consequently, much research has been performed on the effectiveness of radar speed signs in reducing vehicle speeds in these applications. This research and its results are discussed in detail in the literature review section of this paper.

In addition to these uses, a common application of such signage in a rural context is the transition zone between high speed roadways and lower speed roads inside of municipal boundaries. These high-to-low speed transition areas are prevalent in many rural areas and present local communities with a safety challenge. To address issues of speeding in such locations, many communities deploy different types of radar speed signs to alert motorists to their current speed compared to the posted speed limit. In such applications, determining locations where such signage is warranted versus locations where it may not provide a significant impact is important.

Typically, the deployment of radar speed signs has been driven by subjective judgment rather than engineering studies. In other words, devices are typically placed where there is a perceived problem with little quantification of the problem itself. For example, if speeding is perceived to be a problem by residents of a residential neighborhood, police may place a radar speed trailer in the area in response to resident complaints. While this serves to placate residents and likely will have some impact on reducing speeds in the short term, excessive use of signage in such cases, particularly for an extended period of time, could lead motorists to disregard the feedback in the long term. Consequently, it is necessary to establish criteria regarding when/how such signage can be deployed and operated to address safety and speed issues effectively. In the context of this work, those criteria are referred to as guidance. California Department of Transportation (Caltrans) District 2 personnel determined that there was a need to develop such guidance for the use of radar speed signage in their district. This guidance would also be considered applicable to other districts throughout California, and should also be of interest to others outside the state.

RESEARCH OBJECTIVE

Radar speed signs are typically deployed on a case-by-case basis and decisions regarding when and where to deploy them are often driven by motives other than engineering studies or hard data. This is due, at least in part, to the limited documentation that provides deployment guidance. However, a good amount of documentation does exist regarding the effectiveness of radar speed signs in various applications. This information can be employed in developing more specific guidance for practitioners regarding when radar speed signs may be applicable and what their expected impacts might be.

The objectives of this research were to establish what situations may be applicable for use of radar speed signs, whether they have been effective in similar applications, and where such signs should be located (setting). These objectives were pursued through a review of research reports and documentation conducted nationally and internationally, as well as the engineering practices and policies employed in California and by other states and localities. Based on this review, as well as a review of maintenance practices and evaluation of the effectiveness of such signage in applications similar to those intended for use in California, guidance was developed to direct future applications of radar speed signs.

LITERATURE REVIEW

Studies regarding the effectiveness of radar speed signage in reducing speeds and/or crashes for a specific application were beyond the scope of this work. Therefore, one of the approaches taken in developing guidance for radar speed signs was to consult the findings of past research. To accomplish this, a review of available literature was undertaken. The work presented in the following sections synthesizes the results of studies for use in developing guidance/criteria for consultation and application in California. To a significant extent, previous research studies have examined the impacts of various applications on speeds. Unfortunately, as the following review indicates, studies related to safety (i.e., crash reductions) were essentially non-existent.

Speed Impacts

Given that the intent of radar speed signs is to slow down traffic, it was not surprising that the majority of results identified during the literature review discussed the impacts that these devices had on motorist speeds. Research results for a variety of deployment types and settings were presented, with some projects examining multiple applications (1), (2), (3), (4), (5), (6), (7), (8), (9), (10), (11), (12), (13), (14), (15), (16), (17), (18), (19), (20), (21), (22), (23), (24), (25), (26), and (27). While a detailed discussion of the results of each of these research projects is not feasible here given space constrains, key findings of these efforts are summarized in Table 1, Table 2 and Table 3.

TABLE 1 Summary of Work Zone Radar Speed Sign Results

Trailer Based						
Study	**Application**	**Locale**	**Traffic**	**Speed Limit**	**Mean Speed Change**	**General Effectiveness**
Pesti and McCoy	Rural 4-lane divided interstate	Nebraska	38000 (ADT)	55 mph	3 - 4 mph reduction	20 - 40% increase in vehicles complying w/ speed limit Long-term reductions in speeds over 5 weeks
McCoy, Bonneson and Kollbaum	Urban 4-lane divided interstate	South Dakota	9000 (AADT)	55 mph	4 to 5 mph reduction	Before - 74+% speeding After - reduced by 20 - 25%
Carlson, et.al	Rural 4 lane divided U.S highway Short term work zones (1-12 hours)	Texas	7000 (AADT)	55 mph	2 mph (cars) 3 mph (trucks)	Speeding before versus after: Cars - 5.5 - 7.0% reduction Trucks - 9.6 - 24.4% reduction
Teng, et al.	Interstate and principal arterial	Las Vegas, NV	n/a	45 mph (principal arterial) 55 mph (interstate)	8-9 mph reduction	Size of displayed messages and use of flashing showed significant impact on speeding likelihood and speed reduction
Saito and Bowie	Urban interstates (number of lanes varied)	Utah	n/a	55-65 mph	7 mph reduction	Display appeared to lose effectiveness after one week
Chitturi and Benekohal	Rural 4-lane divided interstate	Illinois	n/a	n/a	4.4 mph reduction (immediate) 6.7 mph reduction (3 weeks)	All speed reductions found to be statistically significant
Fountaine, et al.	Rural two and four lane short-term work zones	Texas	n/a	n/a	5 mph reduction	Reduced percent of vehicles exceeding speed limit
Changeable Message Sign-Radar Combination						
Study	**Application**	**Locale**	**Traffic**	**Speed Limit**	**Mean Speed Change**	**General Effectiveness**
Garber and Srinivasan	Suburban interstates and primary highway	Virginia	n/a	45 mph (primary) 55 mph (interstates)	Interstate - 5 - 10 mph reduction Primary - 8 - 12 mph reduction	Speed reductions at all sites and exposure durations found to be statistically significant
Garber and Patel	Rural 4-lane divided interstate Three signs used at beginning, midpoint and end of the work zone. Employed messages rather than vehicle speeds	Virginia	8400 - 33000 (AADT)	45 - 55 mph	4 - 17 mph mean speed reduction between 1st and 2nd sign 1 - 3 mph mean speed reduction between 2nd and 3rd sign	6 - 11 mph reduction in 85% speeds between 1st and 2nd sign 2 - 3 mph reduction in 85% speeds between 2nd and 3rd sign
Wertjes	Rural 4-lane divided interstate	South Dakota	4560 (ADT)	55 mph	In advance of taper - 1.7 mph reduction At taper - 1.6 mph reduction End of taper - 0 mph reduction	85th percentile speeds reduced In advance of taper - 68.2 - 66.5 mph At taper - 63.5 - 61.9 mph End of taper - 59.3 - 59.4 mph
Wang, et al.	Rural, 2-lane highway	Georgia	n/a	45 mph	7 - 8 mph reduction	Speed variance decreased significantly following deployment Long term speed reductions between 1 and 3 mph observed
Sorrell, et al.	Rural, 2-lane highway and interstate	South Carolina	n/a	45 - 55 mph (two-lane) 45 mph (interstate)	7 - 9 mph reduction (interstate) 5 - 7 mph reduction (two-lane)	85th percentile speeds reduced 6 - 9 mph (interstate) 2 - 4 mph (two-lane)
Post-Mounted Sign						
Study	**Application**	**Locale**	**Traffic**	**Speed Limit**	**Mean Speed Change**	**General Effectiveness**
Maze	Rural 4-lane divided interstate in advance of a crossover	Iowa	n/a	55 mph	3 mph reduction	85th percentile speeds reduced by 5 mph

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TABLE 2 Summary of School Zone Radar Speed Sign Results

Trailer Based						
Study	**Application**	**Locale**	**Traffic**	**Speed Limit**	**Mean Speed Change**	**General Effectiveness**
Casey and Lund	Urban 2-lane	Santa Barbara, CA	n/a	25 mph	Mean speeds fell between 1.5 and 5 mph	14% speed reduction when speeds exceeded limit by 10mph 7% speed reduction when speeds exceeded limit by 5mph
Permanent						
Lee et al.	Urban arterial	South Korea	n/a	20 mph	5 mph reduction (2 weeks) 3.5 mph reduction (12 months)	Before - 26.5% speeding After (two weeks) - 9.9% speeding After (12 months) - 5.5% speeding
Ullman and Rose	Unspecified 2-lane	Texas	n/a	35 mph	School zone - 9 mph (short term) and 9 mph (long term) Transition zone - 2-3 mph (short term) and 1 mph (long term)	Primary reduction observed in school zones 85th% speeds reduced 10 mph (short term) and 8 mph (long term)
Thompson, et al.	Suburban local roads	Maine	n/a	15 mph	2 to 4 mph reduction	Vehicles exceeding the speed limit fell by 4 to 20%, depending on site Over 70% of vehicles still exceeded the speed limit
Saito and Ash	Urban/suburban two and multi-lane roads	Utah	n/a	20 mph	1 to 3 mph reduction	85th percentile speeds reduced by 2 to 4 mph
KLS Engineering	Urban two and multi lane arterials	Washington D.C.	10000 - 30000 (ADT)	15 mph	1 to 7 mph reduction Some minor increases observed (1-3 mph)	Speed reductions found to be statistically signifcant in only 25% of cases
Garden Grove	Arterial streets	California	8000 - 29000 (ADT)	35 - 40 mph	Mean speeds not examined	85th percentile speeds reduced by 1.5 to 9.8 mph
Hallmark, et al.	Semi-rural two lane	Iowa	2343 (ADT)	25 mph	5.4 mph reduction after 3 months	85th percentile speeds reduced 7 mph (3 months)

No evaluations of portable post-mounted devices have been made to date.

TABLE 3 Summary of Additional Locations (Residential, Commercial, Speed Transition Zones) Radar Speed Sign Results

Trailer Based						
Study	**Application**	**Locale**	**Traffic**	**Speed Limit**	**Mean Speed Change**	**General Effectiveness**
Casey and Lund	Urban residential, commercial and undeveloped 2- and 4-lane roadways	Santa Barbara, CA	200-1200 vph	30 - 45 mph	10% mean speed reduction alongside trailer and 7% downstream	Reductions brief; speeds rose once trailers removed
Bloch	Urban, residential 2-lane roads	Riverside, CA	800 - 2400 (veh/ln/day)	25 mph	6.1 mph reduction beside trailer 2.9 mph reduction downstream 0.6 mph reduction downstream following removal	Minimal changes in speeds one week following removal
Donnell and Cruzado	Transition zones on 2-lane highways	Pennsylvania	n/a	45 - 55 mph (initial) to 25 - 40 (transition)	4.6 - 7.9 mph reduction (1 week) Reductions measured downstream of signs similar	3.1 to 9.2 mph increase 1 week following removal
Permanent sign						
Study	**Application**	**Locale**	**Traffic**	**Speed Limit**	**Mean Speed Change**	**General Effectiveness**
Traffic Engineering Division	Urban, arterials, collectors and local roads	Orange County, CA	n/a	n/a	4 mph reduction on all roads	Statistically significant reductions in 85th percentile speeds observed No carryover effects observed
Ullman and Rose	Sharp horizontal curve Approach to signalized intersections	Texas	n/a	30-55 mph	Signal approach - 3 mph (short term) and 0-4 mph (long term) Curve - 2-3 mph (short term) and 0-2 mph (long term)	85th percentile speeds reduced 2-4 mph (short term) and 0 -4 mph (long term)
Sandberg, et al.	Speed transition zones (rural to urban)	Minnesota	4000 - 12000 (ADT)	45 - 55 mph (initial) to 30 - 45 (transition)	1 week - 6 - 7 mph reduction 2 months - 3 - 8 mph reduction 7 months - 3 - 7 mph reduction 1 year - 6 - 8 mph reduction	85th percentile speeds 1 week - 6 - 8 mph reduction 2 months - 5 - 11 mph reduction 7 months - 5 - 7 mph reduction 1 year - 5 - 9 mph reduction
Hallmark, et al.	Transition zones on two lane highways	Iowa	300 - 2300 (ADT)	55 mph (initial) to 25 (transition)	1 month - 1 mph reduction 3 months - 0 mph reduction 9 months - 1 to 5.2 mph reduction 1 year - 1 to 3.4 mph reduction	85th percentile speeds: 1 month - 2 mph reduction 3 months - 1 mph reduction 9 months - 1 to 4 mph reduction 1 year - 2 to 3 mph reduction
Chang, et al.	Collector and arterial streets	Washington	2700 - 4900 (ADT)	25 mph	1.19 and 2.21 mph reduction	Only one site found to have statistically significant speed reduction
Tribbett, et al.	Rural Interstate	California	7650-9300 (AADT)	50 - 60 mph	1 to 5 mph reduction	Results were mixed, as some sites saw significant speed reductions, while others saw increased speeds

Safety Impacts

A review of literature found no published research findings on the safety impacts of radar speed signage. This is not surprising as the primary intention of radar speed signage is to slow motorists down. In slowing motorists down, there should be a corresponding benefit to safety, particularly in sign applications targeted in pedestrian issues. In reality, the temporary nature of many applications (e.g., radar speed trailers and CMS in work zones) limits the period during which crash reductions may occur. However, if motorist behaviors are changed as a result of the signage, it is possible that longer-term safety improvements could be observed. If this is the case, permanent radar speed sign installations in school zones, residential areas and the like may offer potential to observe crash trends over time.

Only one study was identified that examined any relationship between radar speed signage and crashes. Work by the California Highway Patrol found that speed trailers produced a 9.8 percent reduction in crashes. However, this study was flawed in that it did not use comparison sites or controls for long-term crash trends (28). Consequently, its results should not be considered reliable in terms of the expected impacts of radar speed signs on safety.

Existing Guidance

A final research project, completed by the Enterprise Program, developed warrants for Dynamic Speed Display Signs (DSDS) for application to transition zones, posted speed adherence and intelligent work zones (29). The warrants are presented on a website, with the user presented with a series of questions to answer. Based on the user's response to each question, the website informs them whether or not a sign is warranted. The website and approach it presents are still considered to be in a research state, and it is stressed that "Visitors to the website shall not use the warrants for any purpose other than assisting this research effort and contributing to the project. The warrants have not yet been validated and therefore should not be used to make any formal assessments about the validity of, or need for technology devices (29)."

The warrants developed ask a series of questions related to the application type of interest. These questions included:

- Does the 85th percentile speed (as determined by a speed study) exceed the posted speed limit by at least 5 mph, or by at least 3 mph in a school zone? (Transition Zone and Posted Speed Adherence Warrants)
- Does the zone experience a posted speed limit reduction of at least 10 mph? (Transition Zone Warrant)
- Is the area within 500 yards of a major pedestrian generator (e.g. school, park, library, senior center, office building)? (Posted Speed Adherence warrant)
- Is the area primarily a residential area or a heavily traveled pedestrian area? (Posted Speed Adherence warrant)
- Is the posted speed limit 35 mph or less? (Posted Speed Adherence warrant)
- Is the work zone currently in operation and observations suggest that the 85% speed at a location within the work zone exceed the posted speed limit by at least 5 mph? (Intelligent Work Zone Warrant)
- Will workers be located adjacent to the open traffic lane? (Intelligent Work Zone Warrant)
- Are there hazardous roadway conditions, such as a temporary unusually tight curve, or a rough road surface, requiring extra driving precaution? (Intelligent Work Zone Warrant)

- Are there other Dynamic Speed Display Signs along the route encountering the speed transition, within 5 miles in either direction (excluding DSDS within school zones)? (29)

Depending on application selected, more than one of these criteria needs to be met before a sign is justified. One aspect of the warrants worth noting is the inclusion of criteria regarding the distance between radar speed signs (5 miles). While the basis for this distance is not provided, it is of interest in that it addresses the concern for the potential overapplication of radar speed signs along a route or in proximity to one another.

While the warrants posted on the Enterprise Program website appear to agree with many of the research results and discussions provided in the previous sections, no documentation is provided to explain how they were developed. These warrants were developed based on available information related to the purpose and application of such devices and the critical factors associated with their use (ex. speeding), as well as engineering judgment (30).

California Guidance

As this work was being conducted for application in California, it was necessary to investigate what current guidance might be provided by the state, specifically through its amended version of the Manual on Uniform Traffic Control Devices (MUTCD) (31). The California MUTCD refers to radar speed signs as Vehicle Speed Feedback Signs (referenced by the Federal edition of the MUTCD as a type of changeable message sign (32)).

Option:

- A Vehicle Speed Feedback sign that displays to approaching drivers the speed at which they are traveling may be installed in conjunction with a Speed Limit (R2-1) sign.

Standard:

- If a Vehicle Speed Feedback sign displaying approach speeds is installed, the legend shall be YOUR SPEED XX.
- The numerals displaying the speed shall be white, yellow, yellow-green or amber color on black background.
- When activated, lights shall be steady-burn conforming to the provisions of CVC Sections 21466 and 21466.5.
- Vehicle Speed Feedback signs shall not alternatively be operated as variable speed limit signs.

Guidance:

- To the degree practical, numerals for displaying approach speeds should be similar font and size as numerals on the corresponding Speed Limit (R2-1) sign.

Option:

- When used, the Vehicle Speed Feedback sign may be mounted on either a separate support or on the same support as the Speed Limit (R2-1) sign.
- In lieu of lights, legend may be retroreflective film for flip-disk systems.
- The legend YOUR SPEED may be white on black plaque located above the changeable speed display.

Support:

- Driver comprehension may improve when the Vehicle Speed Feedback Sign is mounted on the same support below the Speed Limit (R2-1) sign.

- Vehicle Speed Feedback Signs are appropriate for use with advisory speed signs and with temporary signs in temporary traffic control zones.

The information provided by the California MUTCD established the foundation on which the guidance developed by this work was based. The California MUTCD indicates radar speed signs may be appropriate for use in conjunction with ordinary speed limit signs, advisory speed signs or as temporary signs in traffic control zones. Interestingly, no mention of the use of such devices in school zones was made, although such use could be considered implied in conjunction with speed limit signs.

GUIDANCE

Based on the review of the information discussed in previous sections, guidance related to the deployment of radar speed signs under various conditions were developed. Note that before deploying a radar speed sign, speed studies and appropriate modifications to speed limits should first be undertaken. One should keep in mind the important role that 85th percentile speeds play in the establishment of the posted speed limits at any site. In some cases, the failure of drivers to obey the speed limit stems in part from it being inappropriate for the site. In such cases, the correct engineering solution is to increase the posted speed limit, especially if it is non-statutory. A study of 85th percentile speeds at a site can provide the information needed to make such a determination and change. Additionally, changes to roadway geometry can often be accomplished for less than the cost of such signage, and with greater benefit to vehicle speeds.

Traditionally, radar speed signs have been deployed to address concerns in school zones, work zones, residential and commercial areas, and in general applications (speed transition zones, etc.). Based on the deployment applications identified, various guidance for when radar speed signs may be deployed was developed. The reader must keep in mind that the discussion in these sections *does not constitute a standard, specification or regulation. It is not intended to replace existing Caltrans [or other agency] mandatory or advisory standards, nor the exercise of engineering judgment by licensed professionals* (emphasis added). The information presented in the following section instead is intended to serve as a reference which synthesizes information and concepts from various agencies and organizations faced with similar transportation issues.

General Basis for Guidance

The development of guidance for the use of radar speed signage varies by the specific application. For example, the development of guidance/warrants related to the use of protected left turn signal phasing as opposed to permitted/protected phasing at signalized intersections would typically entail data collection activities and modeling at multiple sites. In the case of the guidance developed here, the varied distribution of potential sites, as well as different applications, precluded extensive site-based performance studies. Rather, existing study results and practitioner feedback were employed along with engineering judgment to develop general guidance related to the application of radar speed signs in California. The following paragraphs discuss the approach employed in developing radar speed sign guidance.

Consideration of the various application locations first had to be made. This was done through the literature review and a survey of practitioners in California communities throughout the state regarding their past and current use of radar speed signs. Based on the general language of the California MUTCD, radar speed signage—at least on state-controlled roads—is permissible anywhere when used in conjunction with existing speed limit signage or advisory

speed signage. Additionally, the use of radar speed signs in work zones is explicitly called for by the California MUTCD. Finally, the California MUTCD could be considered to allow the use of radar speed signs in school zones by permitting their use in conjunction with existing speed limit signage or advisory speed signage in the following passage: "Vehicle Speed Feedback Signs are appropriate for use with advisory speed signs and with temporary signs in temporary traffic control zones." A school zone may be considered such a temporary (in length) zone. Based on this information, as well as the deployments discussed in past research, the applications to be considered by this work were identified. Identified applications of radar speed signs included addressing excessive mean and 85th percentile speeds, safety concerns, traffic issues, posted speed compliance, pedestrian presence, school zones, work zones, residential and commercial applications, and general applications (speed transitions zones, signalized intersection approaches, etc.).

The next step in developing guidance was consideration of the factors and characteristics that may require the use of radar speed signs. In other words, in what specific cases should radar speed signs be used? In general, radar speed signage is employed when a speeding problem is identified or perceived. Another rationale for the use of radar speed signs is when an excess of speed-related accidents or pedestrian–vehicle collisions occur in a location. The argument could be made that the speed-related crashes are the result of an overall speeding problem rather than a separate problem involving crashes. Nonetheless, this could be considered an useful metric.

Once the various factors and characteristics associated with the historical applications of radar speed signs were identified, objective criteria that can be methodically applied in evaluating potential deployments were developed. These criteria were developed based on the results of prior research, which, overall, had focused on quantifying the problem (excessive speeding), as well as the impact that the radar speed sign application had on it.

No examination of the impacts radar speed signage had on crashes was found in any literature, nor did the practitioners surveyed indicate any general observations. Instead, conservative criteria have been established by the researchers for practitioners to follow should they wish to use crash experience in justifying radar speed sign use. However, the predominant justification for using radar speed signs is a measured or perceived speeding problem. This application has been extensively examined, and that research has provided a foundation on which to build objective, measureable criteria. These criteria are primarily related to changes in mean speeds and 85th percentile speeds observed by various studies following deployment.

Based on the literature review and survey, two levels of guidance were developed for the use of radar speed signs. The first was general guidance. This level of guidance was developed to direct the use of radar speed signs in addressing general concerns. For this type of guidance, criteria were developed for mean speeds, 85th percentile speeds, Average Daily Traffic (ADT), speed limit compliance issues, accident history, pedestrian presence, and posted speed limits. The second level of guidance focused on location-specific applications of radar speed signage. This level of guidance was developed to direct the use of radar speed signs in addressing concerns specific to different sites, such as school zones. To this end, criteria were developed to describe the characteristics of school and park zones, work zones and street conditions that would be applicable for the use of radar speed signs.

The format and presentation of the guidance is based on that issued by the City of Bellevue, Washington (33). This format was selected following input from Caltrans personnel. It concisely summarizes conditions for radar speed sign usage. The following sections provide the specific guidance developed for the different levels of use.

General Guidance

The following guidance applies to general cases where the application of a radar speed sign may be of interest. These general cases include excessive 85th percentile and mean speed issues, ADT levels, speed limit compliance issues, accident history, pedestrian presence, and posted speed limits. The application of this guidance should be made following the completion of appropriate engineering studies. These may include spot speed studies, traffic counts, accident investigations, or pedestrian counts/observations, depending on the application case. The specific type of deployment (trailer-based, permanent sign, etc.) is at the discretion of the agency and will depend on the problem being addressed, power availability, and so forth. Note that footnotes related to the development of this guidance are provided for reader clarification following the table.

TABLE 4 General Guidance

Criteria	Guidance
85th percentile speed	A radar speed sign may be considered when the observed 85th percentile speeds at a site exceed the posted speed limit by 5 mph or more (a).
Mean speed (b)	A radar speed sign may be considered when the observed mean speeds at a site exceed the posted speed limit by 5 mph or more (c).
Average daily traffic (ADT)	A radar speed sign may be considered when ADT exceeds 500 vehicles (d).
Accidents	A radar speed sign may be considered at sites exhibiting a correctable speed-related accident history within a recent time period (e).
Pedestrians	A radar speed sign may be used at sites with a pedestrian-related accident history.
Posted speed limit	A radar speed sign may be considered in conjunction with other guidance when the posted speed limit at a site is 25 mph or greater.

Footnotes:

a. The threshold of 5 mph has been established based on the nature of 85th percentile speeds. These speeds indicate the percentage of the traffic stream that is exceeding a given speed. In the case of this guidance, it is reasonable to expect that only a small proportion of vehicles will be traveling more than 5 mph over the posted speed limit if the posted speed limit was truly set at the 85th percentile speed. Note that mean speeds may fall below the posted speed limit at a site, but a speeding problem may still exist in the 85th percentile.

b. Typically, the 85th percentile speed is employed by traffic engineers to determine the proportion of the vehicle population that is exceeding the speed limit. However, it is recognized that some of the users of this work may not be from the traffic engineering discipline. In that case, mean speed guidance has been provided as such users may be more comfortable with that metric for their particular application.
c. The threshold of 5 mph is recommended based on the observed impacts of radar speed signage in past applications. In general, the mean speed reduction produced by signs is between 1 and 12 mph. Consequently, it is logical to employ a minimum threshold for mean speeds exceeding the posted speed limit of 5 mph before the application of a radar speed sign should be considered.
d. The threshold of 500 vehicles per day ADT is based on the variability of rural ADTs, which tend to be low. This does not mean that such deployments cannot occur below 500 ADT. Note that a limited number of evaluations/applications were made for traffic levels below 1,000 vehicles per day. Most reported applications were made at sites with high ADT.
e. The time period considered recent is at the discretion of the agency considering use of a radar speed sign.

Location-Specific Guidance

In addition to general guidance, information on specific past applications of radar speed signs made it possible to develop location-specific guidance in different cases. The following guidance applies to locations where the application of a radar speed sign may be of interest. These locations include school and park zones, work zones, and other roadway features including transition zones, in conjunction with curve warning signs, and signal approaches. The application of this guidance should be made following the completion of appropriate engineering studies such as spot speed studies. The specific type of deployment (trailer-based, permanent sign, etc.) is at the discretion of the agency and will depend on the problem being addressed, power availability, and so forth. Note that footnotes related to the development of this guidance is provided for reader clarification following the table.

TABLE 5 Location-Specific Guidance

Schools and parks	A radar speed sign may be considered for use within one half (1/2) mile of a school zone or park (a), and
	A radar speed sign may be considered when the posted speed limit in a school zone or park area is 15 mph or greater (b), and
	• A radar speed sign may be considered when the 85th percentile speeds in a school zone or park area exceed the posted speed limit by 5 mph or more (c), or • A radar speed sign may be considered when the observed mean speeds in a school zone or park area exceed the posted speed limit by 5 mph or more (d, e), or • A radar speed sign may be considered when ADT exceeds 500 vehicles (f), or • A radar speed sign may be considered to supplement an advisory or conditional speed limit already in place (e.g., a sign stating: Speed Limit 25 when Children Present)
Street conditions (g)	Transition zones—A radar speed sign may be considered in conjunction with other guidance where a speed transition zone exists (high to low speed limits).
	Curve warning—A radar speed sign may be considered in conjunction with other guidance where a curve speed warning advisory sign exists (high to low speed).
	Signal approach—A radar speed sign may be considered in conjunction with other guidance for high-speed signalized intersection approaches where the speed limit exceeds 45 mph (h).
Work zones	A radar speed sign may be considered when the posted speed limit in a work zone is 35 mph or greater (i), and
	• A radar speed sign may be considered when the observed mean speeds in a work zone exceed the posted speed limit by 10 mph or more (j). • A radar speed sign may be considered when the observed 85th percentile speeds in a work zone exceed the posted speed limit by 10 mph or more. • A radar speed sign may be considered when there have been speed-related accidents in a work zone

Footnotes:

a. The threshold of a half-mile proximity is based on the criteria employed in past sign applications. Mean speeds in school zones fell by 1.5 to 9 mph short term and 1 to 9 mph long term following deployment within this specified distance of schools. Note that a sign must be programmed to only operate when the conditional speed limit is in effect; in the case of schools and parks, this should be when children are expected to be present.

b. The threshold of a posted speed limit of 15 mph is based on the minimum reported posted speed limit of past sign applications.
c. The threshold of 5 mph has been established based on the nature of 85th percentile speeds. These speeds indicate the percentage of the traffic stream that is exceeding a given speed. In the case of this guidance, it is reasonable to expect that only a small proportion of vehicles will be traveling more than 5 mph over the posted speed limit if the posted speed limit was truly set at the 85th percentile speed.
d. The threshold of 5 mph is recommended based on the observed impacts of radar speed signage in past applications. In general, the mean speed reduction produced by signs is between 1 and 12 mph. Consequently, it is logical to employ a minimum threshold for mean speeds exceeding the posted speed limit by 5 mph before the application of a radar speed sign should be considered.
e. Typically, the 85^{th} percentile speed is employed by traffic engineers to determine the proportion of the vehicle population that is exceeding the speed limit. However, it is recognized that some of the users of this work may not be from the traffic engineering discipline. In that case, mean speed guidance has been provided as such users may be more comfortable with that metric for their particular application.
f. The threshold of 500 vehicles per day ADT is based on the variability of rural ADTs, which tend to be low. Note that a limited number of evaluations/applications were made for traffic levels below 1,000 vehicles per day. In general most reported applications were made at sites with high ADT.
g. Caltrans policy is that radar speed signs must be placed below the permanent (black on white) speed limit sign in such applications.
h. The threshold of a posted speed limit of 45 miles per hour is based on the minimum reported posted speed limit of past sign applications.
i. The threshold of a posted speed limit of 35 miles per hour is recommended to include lower speed work zones.
j. The threshold of 10 mph is recommended based on the observed impacts of radar speed signage in past work zone applications. In general, the mean speed reduction produced by signs is between 1 and 12 mph. Consequently, it is logical to employ a minimum threshold for mean speeds exceeding the posted speed limit of 10 mph before the application of a radar speed sign should be considered.

DISCUSSION

The primary purpose of this work was to develop guidance for the deployment of radar speed signs which could be employed in a systematic manner. In other words, sign deployments would follow the guidance for the applications developed by this study. To a large extent, the guidance presented cover a wide range of the deployment settings already pursued in California and elsewhere. The authors believe that this guidance could be applied nationally based on the fact that the results used in establishing the guidance were drawn from studies performed throughout the U.S. and internationally. That said, local conditions, speed limit criteria and requirements would need to be taken into consideration and adjusted before these guidelines are applied outside of California. Where the guidance likely differs from current practice is in the call for different thresholds to be met before deploying signage. For example, mean speeds should be measured at a site of interest and be observed to exceed posted limits by five miles per hour *before* a deployment is considered. Currently, 85^{th} percentile or mean speed measurement is

likely not occurring; rather, a sign is deployed to address a resident complaint or a problem perceived by the public (or police or traffic engineers), but not confirmed. Employing the guidance developed in this work will lead to a more systematic approach to the use of radar speed signs and, potentially, greater acceptance of and compliance with posted speed limits by the driving public.

CONCLUSION

Radar speed signs have seen increased applications in recent years in communities across the United States. The application of radar speed signs has typically been made in a haphazard, unscientific manner, usually involving subjective judgment and only rarely supported by engineering studies. The devices are typically placed where there is a perceived problem, yet decisions to place the devices are rarely accompanied by efforts to quantify or otherwise understand the problem itself, let alone the potential effectiveness of a radar speed sign in addressing it. The excessive use of signage to solve any speeding-related problem, real or perceived, could lead motorists to disregard the signage in the long term. Consequently, this paper has presented the results of an effort to develop criteria regarding when and how radar speed signage should be deployed to address safety and speed issues effectively. This included what situations may be applicable for the use of radar speed signs, whether they have been effective in similar applications, and where such signs should be located (setting). It is important to note that other countermeasures should also be considered before deploying radar speed signs, including low-cost traffic calming, especially in residential neighborhoods.

Results of past research on radar speed sign deployments indicated that signs were used in a number of common applications, including work zones, school zones, residential and commercial areas, and speed transition zones (signal approaches, rural-to-urban transitions, curve approaches, etc.). The problems that radar speed signs were typically employed to address included excessive mean and 85^{th} percentile speeds, safety concerns, traffic issues, posted speed compliance, pedestrian presence, and safety/speeding concerns in school zones, work zones, and residential and commercial areas. The research indicated that radar speed signs often achieved their objective of a reduction in speeds. Depending on the application and problem being addressed, changes in speeds ranged from small to significantly large. The long-term impact of such signage varied; in some cases it was reported to have a positive impact over time (e.g., many months), while in other cases radar speed signs were reported to lose effectiveness within weeks of their deployment. No rigorous statistical or even basic evaluations examined the impacts of radar speed signs on reducing speed-related crashes—a significant research void.

The guidance for the use of radar speed signs in California was developed based on the literature review and consultation with practitioners. The first step in developing guidance was consideration of application locations. Based on the general language of the California MUTCD, radar speed signage was permissible anywhere when used in conjunction with existing speed limit signage or advisory speed signage. Next, purposes for their deployment were identified, including addressing excessive mean and 85^{th} percentile speeds, encouraging compliance with posted speed limits; alerting drivers to the presence of pedestrians; addressing vehicle speed issues in school zones, work zones, and residential and commercial areas; and applications such as speed transitions zones, signalized intersection approaches, etc. This was followed by a consideration of the factors and characteristics associated with the historical applications of radar speed signs. These were identified through the literature review and practitioner survey as speeding and crash problems.

Once these various factors and characteristics were identified, objective criteria were developed that can be methodically applied in evaluating potential deployments. These criteria were developed based on the results of previous research that focused on the impact radar speed sign treatments had on vehicle speeds. These criteria were primarily related to changes in mean speeds and 85th percentile speeds observed in various studies following deployment. In the absence of any data regarding impact on speed-related crashes at a site, conservative criteria were developed for that area of interest. Based on the work completed to this point, two levels of guidance were developed: general guidance and location-specific guidance.

General guidance applies to cases where a radar speed sign may be used to address excessive mean speed and 85th percentile speed issues, ADT levels, speed limit compliance issues, accident history, pedestrian presence, and existing posted speed limits. Location-specific guidance applies to the use of radar speed signs in school and park zones, work zones, and general street locations such as transition zones, curve warning sign locations, and signal approaches.

Future Research

A recommendation for future research is the need to evaluate the safety impact of radar speed signage. No work was identified that examined the effectiveness of radar speed signs in reducing crashes, aside from that of the California Highway Patrol, which only looked at general trends. This is logical since the primary intention of such signs is to reduce speeds; consequently, examining the impacts of these signs on speeds has been the focus of all the literature identified. However, previous research indicated that radar speed signs have been deployed to address safety concerns in addition to speed-related problems. In instances where signage has been deployed to address a safety issue, evaluations of its impact on crashes are necessary. To date, no such evaluations have been performed. Consequently, one avenue of useful research would be to measure what, if any, impacts radar speed signs have on crashes, both in the short term and over time.

In addition, it would be useful to evaluate the proposed guidance as it is applied in the field. This would consist of a case study presenting an application using these guidelines. Budget and time limitations prevented from such a case study from being completed as part of the work presented here. Additional research is also needed to determine the effectiveness of speed displays, flashing speed displays, flashing speed feedback displays, blank-out signs with any combination of speed or speed feedback display, and other types of displays. Furthermore, research into benefit-cost analyses of various treatments, depending on roadway function and characteristics should be pursued so that criteria developed here can be validated with a rigorous statistical analysis that focuses on a reduction in user costs, those being incurred by crashes, delay, and fuel consumption.

Finally, no work reviewed during this project discussed the specifics of sign placement, such as distance from the roadway edge, the impacts of viewing angles, etc. In relation to this work, Caltrans has permitting requirements that must be met when placing items such as signs and trailers on the roadside on state-controlled routes, but these may vary from those imposed by local authorities for locations off state routes. Consequently, further research is required to determine whether the guidance outlined at the state level (in California and other states) is optimal in relation to radar speed signage. Such research would determine whether placement distances and angles produce more significant speed-reduction results than other strategies. Such

work could lead to the development of more specific physical placement guidance for future deployments.

DISCLAIMER

The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the data herein. The contents do not necessarily reflect the official views or policies of the State of California, the California Department of Transportation or the Federal Highway Administration. This report does not constitute a standard, specification, or regulation. This report is not intended to replace existing Caltrans mandatory or advisory standards, nor is it intended to supplant or supersede the exercise of engineering judgment by licensed professionals.

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