Long-Term Effectiveness of Dynamic Speed Monitoring Displays (DSMD) for Speed Management at Speed Limit Transitions

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Abstract. Speeding continues to be a significant safety issue on today's roadways. Studies have demonstrated that increased compliance with properly established speed limits reduces crash incidence and severity. One of the outcomes of Intelligent Transportation System (ITS) technology is the development of practical tools to enable the traffic engineer to more effectively manage speed on their roadway system. The Dynamic Speed Monitoring Display (DSMD) sign is one such tool. These signs measure the speed of the approaching vehicles and then feed this information back to the driver in real time via a dynamic message display. Portable DSMD signs (a.k.a. speed trailers) have been shown to be an effective engineering countermeasure for short-term speed control. However, experience has shown that as soon as the device is removed, speeds soon return to their previous levels.

This paper reports the results of a long-term evaluation of DSMD signs at speed reduction transition zones, which are those locations where the speed limit changes from a higher speed to a lower speed. The study was specifically targeted at locations were a rural highway transitions into an urbanized area. The study found a statistically significant decrease in overall vehicle speed immediately after the installation of the DSMD signs. The average speed reduction across all of the study sites was seven mph and it was found that these speed reductions were maintained over the course of the one year duration of the study. DSMD signs were shown to be effective long-term for speed management at speed transitions zones.

INTRODUCTION

Drivers who exceed the posted speed limits have become a major concern for transportation agencies, cities and communities. These drivers, whether intentionally or not, place themselves and others in danger as well as reduce the overall quality of life for nearby residents and neighbors. Recent research suggests that safety can be improved by increased driver conformance to the posted speed (1).

The challenge agencies face is how to improve conformance with the posted speed limit. Many speeding drivers are local residents who are comfortable with the area. These motorists, many times, unconsciously speed through their own neighborhoods. The static speed limit sign alone, while effective in many areas, does not always create the conformance that is desired.

Generally, the concern related to speed conformance manifests itself at locations where the regulatory speed limit changes. These locations, generally involving changes from a higher speed (e.g., 50 mph) to a lower speed (e.g., 35 mph), are often related to a change in the characteristics of the roadway environment. For example, a two-lane highway may have a speed limit of 55 miles per hour. As the same highway enters into a more residential area, the speed limit may drop to 35 miles per hour. Although the amount of traffic is constant, the presence of homes, businesses, and pedestrians necessitates the need for a lower travel speed.

Historically engineers have looked to enforcement tools, either active or passive, as a solution to speeding. Active enforcement entails police vehicles patrolling the roadway writing tickets to speeding motorists. Passive enforcement relies on the motorists to correct their own driving behavior. An example of this is the use of a portable speed trailer placed along a roadway. In both cases, observations have show that once the police vehicle is out of sight or the speed trailer is removed, vehicle speeds return to their previous levels (2, 3).

Engineers have had a limited toolbox when it comes to improving speed limit conformance. Additionally, ideas that once worked, soon become obsolete or lose their effectiveness. Traffic characteristics of roads can change with time and development. Many locations that were once outlying low volume rural roads are seeing significant increases in traffic volume and vehicle speeds as urban areas grow. Conventional tools included the installation of signs and/or pavement markings and the use of high visibility sheeting to increase sign conspicuity. Even with these efforts, many drivers will still exceed posted speed limits.

One new tool that addresses speed issues by combining engineering and education is the Dynamic Speed Monitoring Display (DSMD) sign (Figure 1). DSMD signs are a practical outcome of advances in ITS technology. These traffic control devices are self contained ITS systems that measure the speed of an approaching vehicle using a radar embedded in the sign, then feeding this information back to the driver in real time via a dynamic message display. The DSMD sign encourages the driver to act more safely by adjusting their speed to come into compliance with the posted speed limit. The DSMD sign, permanently installed in conjunction with a standard static regulatory speed limit sign (MUTCD R2-1), provides information to the motorist of the speed at which they should be driving with the static sign and the speed at which they are driving with the DSMD sign – a total package of information that is easy for the driver to comprehend without distraction.

Figure 1 – Dynamic Speed Monitoring Display (DSMD) Assembly used in this study

THE STUDY

Studies have been conducted on the effectiveness of permanently installed DSMD signs in a number of applications, particularly for speed management in school zones and urban traffic calming (4, 5). The purpose of this paper is to report on the results of a long-term evaluation of these devices at speed reduction transition zones, which are those locations where the speed limit changes (transitions) from a higher speed to a lower speed. The study was specifically targeted at locations were a rural highway transitions into an urbanized area. An important objective of this study was to assess the long-term effectiveness of permanently installed DSMD signs. It is well documented that DSMD signs are an effective speed management tool, but the majority of the studies have only evaluated short term effectiveness – typically over the course of a few days to a few months (6, 7). Concerns have been raised that DSMD signs may lose their effectiveness over time as drivers become accustomed to seeing them on a regular basis.

STUDY DESIGN

The study was conducted as a Before-and-After with Control site design (8). This format was chosen due to the long-term nature of the study. Use of a control (untreated) site chosen randomly from the population of possible treatment sites overcomes the drawbacks associated with simple Before-and-After studies. A control site provides information on both seasonal and long-term variation in traffic. The criteria used to identify the test sites were:

1) Located on county controlled roads within Washington County or Dakota County, Minnesota.
2) Transition from a rural high speed highway to an urbanized area.
3) Reduction in posted speed limit of 10 mph or greater at the transition.
4) Existing history of speed related safety concerns.
5) No other engineering measures planned at the site for at least 12 months.

Five locations were chosen from among a number of potential locations meeting the criteria. Four locations were designated as experimental sites and one as the control site (Table 1). The three sites in Washington County (2 experimental, 1 comparison) were speed reductions from 50 to 30 mph, 55 to 40 mph and 55 to 30 mph (Control) on rural two lane highways as they entered urban areas. The Dakota County locations were located along a single stretch of highway where there were two successive speed transitions. The first transition was from 55 mph to 45 mph followed by a second transition 0.7 miles downstream from 45 mph to 35 mph. All the locations in this study were two lane roads. At each of the experimental locations, the existing R2-1 sign indicating the reduced speed was replaced with an assembly consisting of a DSMD sign mounted directly below the speed limit sign (see Figure 1). No changes were made at the Control site**.**

Table 1- Study Test Sites

Location	**Initial Speed Limit (mph)**	**Reduced Speed Limit at Transition (mph)**	**Average Daily Traffic (ADT)**	**Date DSMD Signs Installed**
Experimental Sites				
Hugo (CSAH 8) Washington County	50	30	12,000	Nov 2004
Bailey (CSAH 18) Washington County	55	40	4,000	Nov 2004
Hastings #1 (CSAH 46) Dakota County	55	45	11,000	May 2005
Hastings #2 (CSAH 46) Dakota County	45	35	11,000	May 2005
Control site (untreated)				
Stonebridge (CSAH 5) Washington County	55	30	5,000	--

Note: CSAH = County State Aid Highway

Dynamic Speed Monitoring Display Assembly

The DSMD signs used in this study were 3M Driver Feedback Signs operating on AC power. These signs conform to the requirements of the MUTCD for changeable message signs that display to approaching drivers the speed at which they are traveling (9). The dimensions of the speed limit sign and the DSMD sign were both 36 inch x 48 inch. This sign size is recommended in the MUTCD for use on higher speed rural highways. The signs used in the study utilize a NEMA TS4 Hybrid dynamic message display that combines Fluorescent Yellow-Green retroreflective pixels with integrated high-output 590 nm InGaAIP LEDs (10). Hybrid displays were chosen to maximize sign target value and legibility under all conditions – day, night and inclement weather. The frame surrounding the hybrid display as well as the face of the R2-1 Speed Limit sign was White ASTM Type IX retroreflective sheeting.

The DSMD used K-band radar embedded within the sign to measure the speed of the approaching vehicles. The signs were programmed to display the speed to the motorist in real time and to flash until that motorist slowed down to at or below the posted speed limit at the transition point. The DSMD signs were programmed with minimum and maximum speed display cut-off limits to discourage reckless drivers attempting to see how fast they could go. These signs also have the capability for vehicle speed data collection; however, this feature was not used for this study.

Data Collection

Limited data for analysis is a common problem in field research. Sufficient data must be collected in order to allow a thorough analysis of the results of the experiment. Vehicle speed and traffic volume data was collected at two positions at each location. The first position, denoted the Advance site, was one-third to one-half mile upstream of the speed limit reduction. The position of the Advance site was chosen such that the DSMD was inconspicuous in the distance. The Advance sites also function as comparison sites since speeds at these locations should not be influenced by the DSMD. The second set of data was collected adjacent to the DSMD sign, which is the point where the reduced speed limit officially begins and where the driver should now be traveling at the new lower speed.

The plan called for the signs to be installed at the same time at all of the sites. Data collection was then to be conducted at all sites simultaneously at defined intervals over the course of one year. These intervals were nominally:

- Before installation of the DSMD sign
- One week after
- Two months after
- Seven months after
- One year after

The original plan was adhered to at the Washington County sites (2 experimental sites and the control site) with only a few modifications due to the Minnesota weather. These signs were installed in November 2004. Installation of the DSMD assemblies at the test location in Dakota County that comprised of two consecutive speed transitions were delayed until May 2005 due to difficulty installing power for the signs during the winter. Due to logistical problems One Week After data was not collected for the Dakota County locations.

This study used commercial pneumatic tube traffic data recorders with electronic data collection to measure vehicle speed and volume. Vehicle speeds were binned in 1 mph increments at 15-minute intervals. All measurements were taken mid-week for 48 to 72 consecutive hours simultaneously at both the Advance and DSMD sign positions. Simultaneous data collection provided a counter balance for day–to–day variability.

STUDY RESULTS

In any long-term study, there is natural variation in traffic volume and speed. In order to draw conclusions on the persistent effectiveness of the DSMD signs, a review should be made to check for potential external influences other than the DSMD sign. Table 2 presents the average directional daily traffic volume through each of the sites during the measurement periods. The corresponding Average Daily Traffic (ADT) is approximately twice the volumes listed in the table. With one exception, the data shows the 24-hour average traffic to be relatively stable. The majority of the test sites showed only a two to four percent variation in traffic volume over time with no distinct trend. However, at the Bailey site, there is a consistent increase in volume over the course of the study, which is mainly due to completion of a nearby major construction project.

Table 2 - Average Directional Daily (24-hour) Traffic Volume through the Study sites

Location	Before	2 Months	7 months	1 year
Hugo Advance	6214	5614	6560	5899
Hugo DSMD	6115	5527	6385	6197
Bailey Advance	2107	2440	3506	2720
Bailey DSMD	2193	2450	3526	2788
Hastings Advance	5343	5342	4914	5507
Hastings #1 DSMD	5863	5747	--[1]	5924
Hastings #2 DSMD	5133	4940	4706	5281
Stonebridge Advance	2568	--[1]	2804	--[2]
Stonebridge Control	2511	2223	2754	--[2]

Notes: [1]Data lost due to equipment malfunction; [2]Data not collected due to installation of a DSMD sign at this site

The speed data was compiled, reduced and analyzed using both Microsoft ® Office Excel 2003 and Minitab ® Release 14.13 statistical software. A number of descriptive statistics were generated as a function of time and location, including:

- Average speed
- 50th (median), 85th and 95th percentile speeds
- 10-mph Pace

The 24-hour speed results for the control and study sites are summarized in Tables 3, 4 and 5. Statistical analyses were run on the data comparing changes in vehicle speed distributions as a function of time period and location. Significance testing included an analysis of Variance, Z-test, t-test and Odds Ratio. All statistical measures showed highly significant associations (alpha < 0.01) between the presence of a DSMD sign and speed reductions within the transition zone. The study sites with the DSMDs experienced reductions in the 50th, 85th and 95th percentile speeds averaging 6.3, 6.9 and 7.0 mph, respectively. The 10-mph Pace speeds also decreased at all the DSMD locations. These results indicate the DSMD shifted the entire speed distribution at the transition zone. At the Advance sites and the Control site, the corresponding speeds were either flat or increased slightly over the course of the research.

The data at the Stonebridge Control site was only collected through 7 months. Due to the need to address the existing speed related safety concerns at this location and based on the positive results of this study up to that point in time, Washington County installed a DSMD sign assembly just prior to the One Year After data collection period.

Table 3 - Results for the Control (untreated) Site

	Mean Speed (mph)	**Standard Deviation (σ)**	**Sample size**	**50th Percentile Speed**	**85th Percentile Speed**	**95th Percentile Speed**	**10 mph Pace (mph)**
Stonebridge Advance (55 mph)							
Before	52.6	6.6	7881	53	59	62	48-57
1 week	50.6	6.4	7547	51	56	60	46-55
2 months	--	--	--	--	--	--	--
7 months	53.5	7.0	8416	54	59	63	51-60
Stonebridge Control (30 mph)							
Before	40.2	6.8	7739	40	45	49	36-45
1 week	41.7	7.0	7397	42	48	52	36-45
2 months	39.2	6.7	5712	39	45	49	36-45
7 months	40.0	6.7	8290	40	45	49	36-45

Table 4 - Results for the Washington County Study Sites

	Mean Speed (mph)	Standard Deviation (σ)	Sample size	50th Percentile Speed	85th Percentile Speed	95th Percentile Speed	10 mph Pace (mph)
Hugo Advance (50 mph)							
Before	51.8	7.5	18403	52	58	60	46-55
1 week	54.0	7.5	17699	54	60	64	51-60
2 months	52.3	7.4	16979	53	59	62	46-55
7 months	52.8	7.9	19203	53	59	63	51-60
1 year	51.2	7.5	15199	51	57	60	46-55
Hugo DSMD (30 mph)							
Before	44.2	7.7	18085	44	50	54	41-50
1 week	37.1	8.4	17336	36	44	49	31-40
2 months	36.1	8.1	16613	35	42	47	31-40
7 months	37.0	8.5	18678	36	43	49	31-40
1 year	36.0	6.9	16025	36	43	45	31-40
Bailey Advance (55 mph)							
Before	50.6	6.4	6201	51	56	59	46-55
1 week	51.0	14.9	6360	55	63	67	51-60
2 months	51.3	6.9	7254	51	58	61	46-55
7 months	50.4	7.6	10451	51	57	60	46-55
1 year	50.1	7.0	5645	50	57	60	46-55
Bailey DSMD (40 mph)							
Before	50.9	7.2	6305	51	58	63	46-55
1 week	44.6	7.9	6048	44	50	57	41-50
2 months	42.3	5.4	7253	42	47	50	36-45
7 months	45.7	6.4	10521	45	51	55	41-50
1 year	43.3	6.4	5433	43	49	53	36-45

Table 5 - Results for the Dakota County Study Sites

	Mean Speed (mph)	**Standard Deviation (σ)**	**Sample size**	**50th Percentile Speed**	**85th Percentile Speed**	**95th Percentile Speed**	**10 mph Pace (mph)**
Hastings Advance (55 mph)							
Before	52.5	7.3	9782	53	59	62	46-55
2 months	49.8	7.4	10019	50	55	60	46-55
7 months	49.6	7.2	8995	49	55	60	46-55
1 year	50.2	7.9	10181	51	56	60	46-55
Hastings #1 (45 mph)							
Before	52.1	7.4	10667	52	58	62	46-55
2 months	47.1	6.9	10812	47	52	57	41-50
7 months	--	--	--	--	--	--	--
1 year	45.9	7.9	10984	47	52	55	41-50
Hastings #2 (35 mph)							
Before	39.0	8.6	9250	39	45	50	36-45
2 months	36.0	7.9	9318	36	40	45	31-40
7 months	36.0	7.9	9318	36	40	45	31-40
1 year	34.5	6.8	9658	36	40	44	31-41

DISCUSSION

There are two basic questions that must be answered in order to determine whether a new traffic control device will be a useful and reliable addition to the engineer's speed management toolbox:

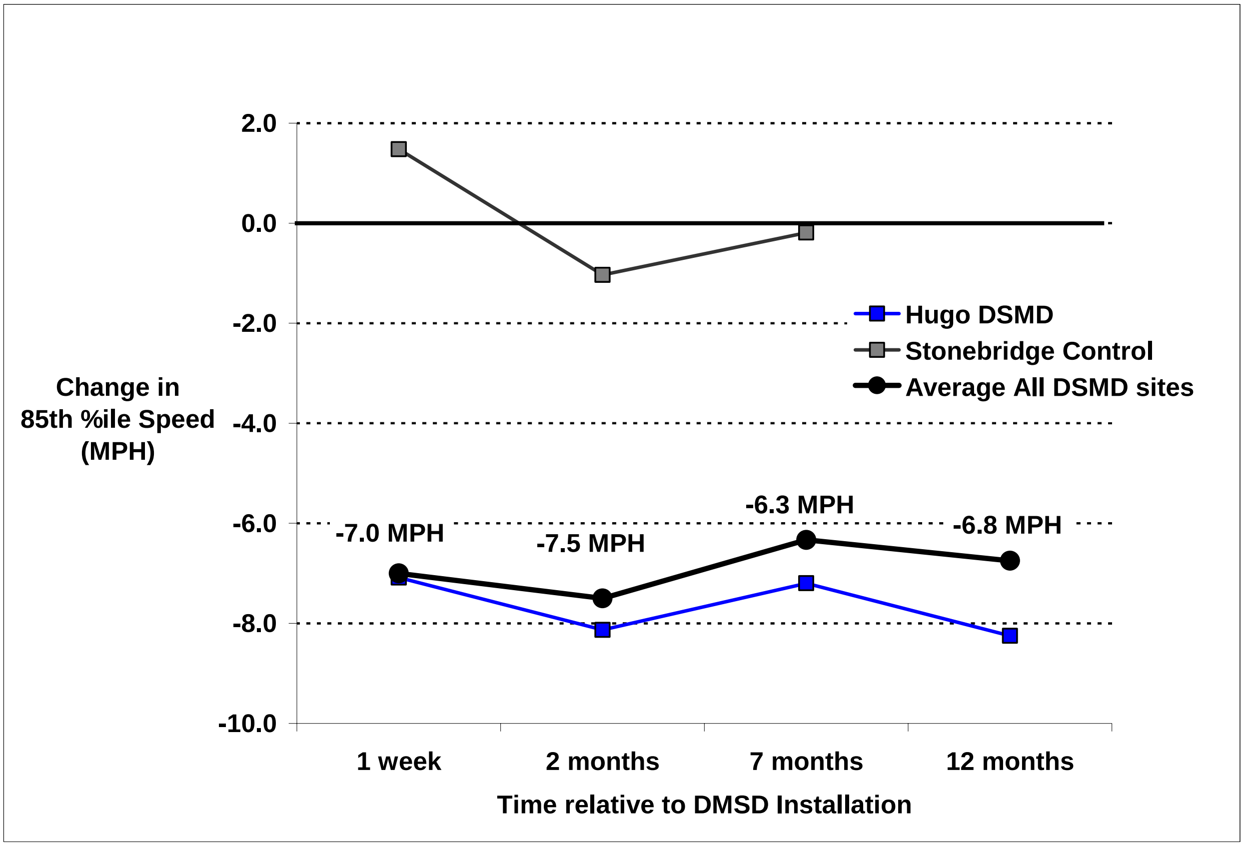
1) In what applications is it effective?
2) Does the device have a persistent effect on driver speed behavior?

The objectives of this study were to address both of these questions. The results of this study were very consistent across all test sites as demonstrated by the data in Tables 3-5. This discussion will use primarily the results from the Hugo locations in Washington County to illustrate the answers to these questions.

Effectiveness for the Application

Recent studies have shown DSMD signs to be effective for speed control at school zones and urban traffic calming. This project evaluated their effectiveness at speed transition zones, particularly where the DSMD sign is used in combination with the regulatory Speed Limit sign. The results of the study show the DSMD sign is an effective tool for reducing speed and increasing compliance at speed transition areas. Figure 2 illustrates the change in 85th percentile speed for the Hugo test site, the Stonebridge control site, and the average speed reduction over all the DSMD locations.

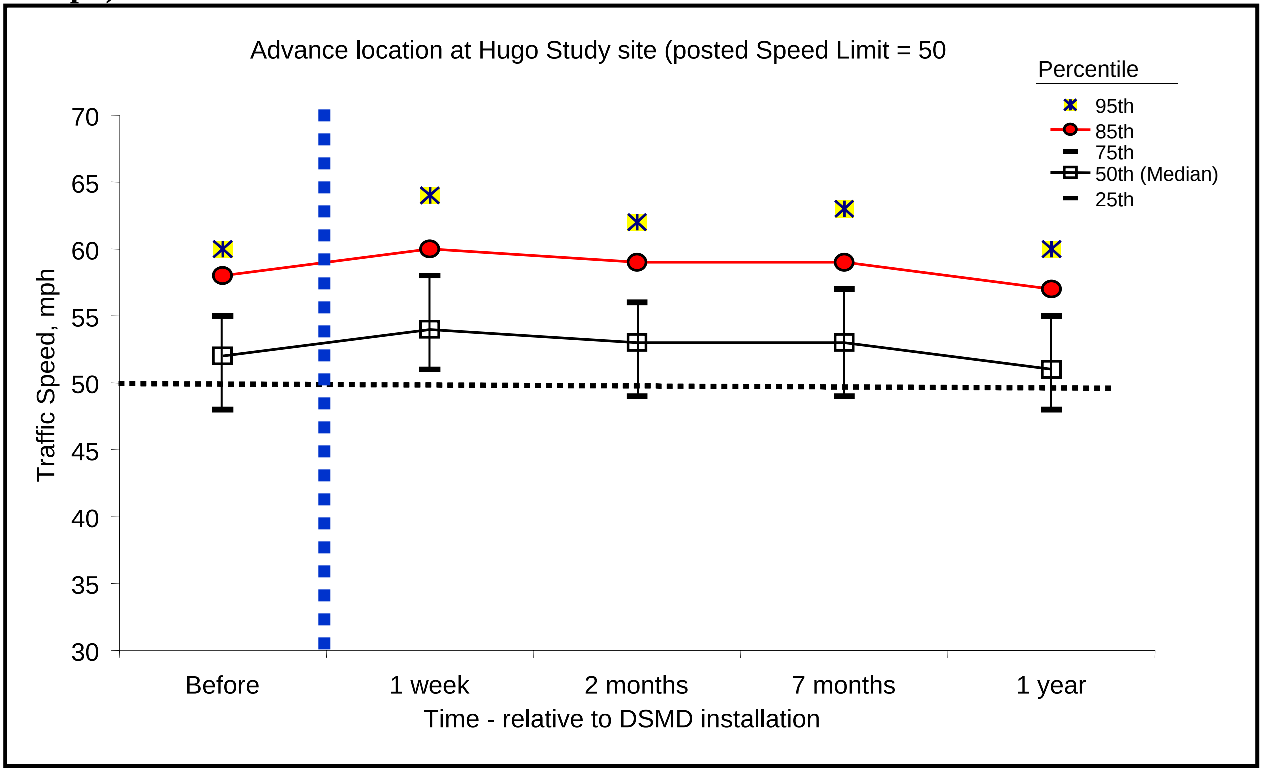
Figure 2 – Change in 85th Percentile Speed as a Function of Time period.



Persistent Effect on Driver Speed Behavior

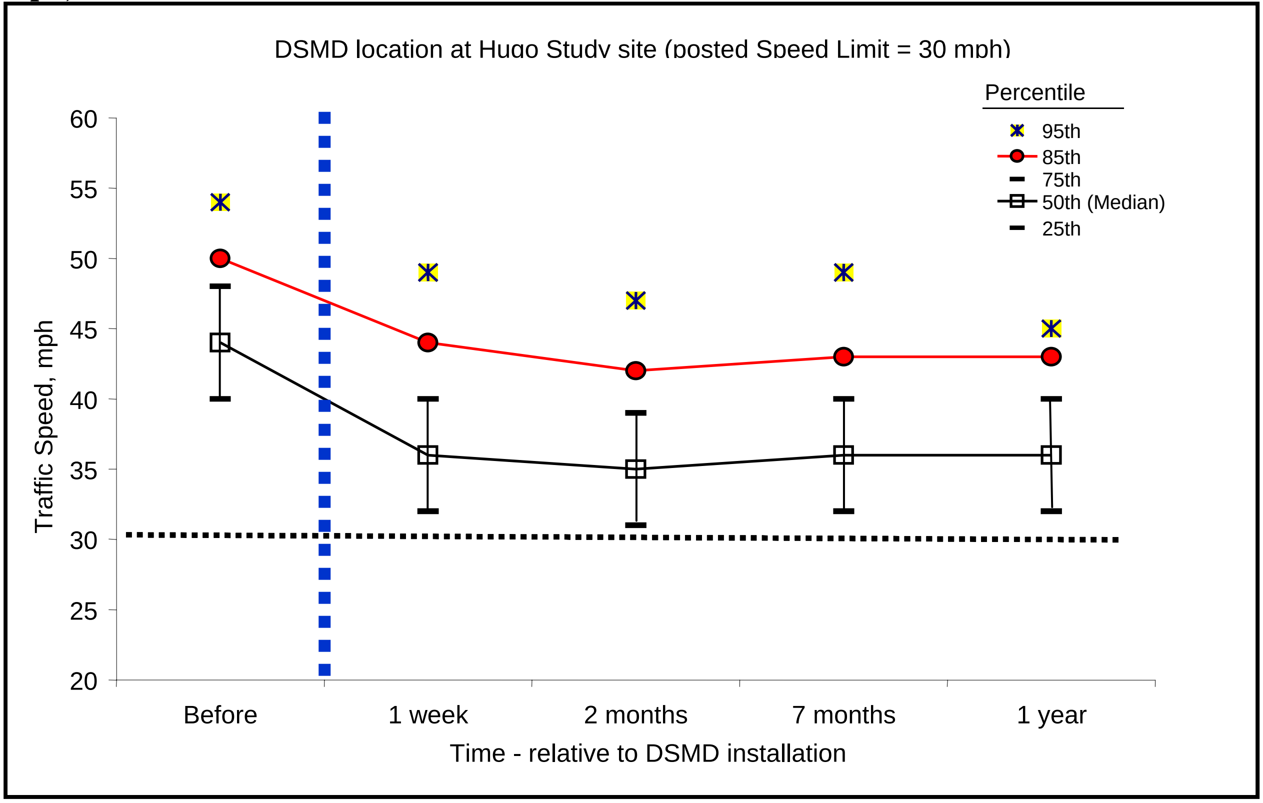
Data was collected over the course of one full year to assess the long-term effect of DSMD signs on drivers' speed. Speed and traffic volume data were collected in advance of the speed limit transition area and at the speed transition prior to installing the DSMD signs and at regular intervals afterwards. Analysis of the data showed both statistically significant and, more importantly, practically significant reductions in vehicle speeds associated with the use of the DSMD assembly. At the Hugo Advance location, the Before 85th percentile speed was 57 mph (posted Speed Limit of 50 mph) and the 10-mph Pace of 46-55 mph made up of 65 percent of vehicles. Over the course of the study period, the 85th percentile speeds remained relatively consistent at approximately 57 mph for each of the time frames (Figure 3).

Figure 3 - Changes in 24-hour Speed Distribution at the Hugo Advance site (Speed Limit 50 mph)



At the location of the existing speed limit sign indicating the new reduced speed limit, the 85th percentile speed in the Before period was 50 mph (the posted speed limit is 30 mph) with the 10-mph Pace of 41-50 mph made up of 63 percent of the vehicles. One week after the installation of the DSMD sign assembly, there was a six mph decrease in the 85th percentile speed, from 50 mph down to 44 mph (Figure 4). One year after installation, there was still a seven mph reduction in the 85th percentile speeds relative to the Before period. Not only did the 85th percentile speed decrease and stay down, but all speeds decreased, with the higher speeds (95th percentile) showing an even larger decrease of up to nine mph over time. Additionally, the 10-mph Pace dropped by 10 mph from an initial 41-50 mph to 31-40 mph within the first week and was still 31-40 mph at one year while maintaining essentially the same percentage of vehicles (63% Before versus 64 % After one year).

Figure 4 - Changes in 24-hour Speed Distribution at the Hugo DSMD Site (Speed Limit 30 mph)



The data showed the overall results across all the DSMD sign locations were fairly consistent. The study found:

- Speed reductions of approximately 6-8 mph in the 85th percentile speed.
- Decrease of 10 mph in the 10 mph Pace
- Consistent reductions through all time frames including the 24-hour data, AM peak hour, and PM peak hour.
- Consistent shift in the speed distribution to lower speeds.

CONCLUSIONS

Speeding is and will continue to be a safety concern for users on all roadways. From an Engineering perspective, the toolbox is relatively limited on how to address speeding on roadways. In the past, the use of law enforcement officials has been the main tool to "combat" speeders. An emerging technology, the Dynamic Speed Monitoring Display (DSMD) sign, now provides the Engineer with another tool to utilize. A DSMD sign in combination with a regulatory speed sign provides direct and relevant information to the motorist using the roadway. This information component provides the driver with immediate feedback on their behavior relative to the posted speed.

The goal of this study was to focus on reducing and managing speeds in transition zones where the speed limit changes from a higher speed (e.g. 50 mph) to a lower speed (e.g. 35 mph). The results of the study show that DSMD signs at transitions zones have a significant long-term (one year or greater) positive effect on driver speed. This study found overall decreases in speed of approximate six to eight mph at the transition point.

In addition to the improved speed conformance, the installation of these signs proved extremely popular with drivers, nearby residents and businesses, as well as with elected officials.

With the installation of the DSMD signs, expect:

- A reduction in overall speeds
- Increased conformance with posted speeds
- Positive public/elected official feedback

The DSMD sign in combination with a standard regulatory speed limit sign was found to be an effective long-term speed management solution at speed limit transitions.

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