The Use of 'Your Speed' Changeable Message Signs in School Zones – Experience from the North Carolina Safe Routes to School Program

Sarah Worth O'Brien (corresponding author)
Bicycle and Pedestrian Program Manager
Institute for Transportation Research and Education (ITRE)
North Carolina State University
Centennial Campus Box 8601
Raleigh, NC (USA) 27695-8601
Phone: (919) 515-8703
Fax: (919) 515-8898
skworth@ncsu.edu

Carrie L. Simpson
Traffic Safety Project Engineer
North Carolina Department of Transportation
Transportation Mobility and Safety Division – Traffic Safety Unit
1561 Mail Service Center
Garner, NC (USA) 27699-1561
Phone: (919) 662-4607
Fax: (919) 771-2745
clsimpson@ncdot.gov

Submission Date: August 1, 2011
Word Count: 4,858, including abstract
2 Tables and 5 Figures: 1,750
Total Word Count: 6,608

ABSTRACT

The Safe Routes to School (SRTS) program seeks to enable children to walk and bicycle to school through a variety of tools. One such tool recently implemented through the North Carolina Department of Transportation's (NCDOT) program is the use of speed feedback signs (Your Speed signs) to reduce vehicle speeds in school zones. NCDOT has no policy or standard for the use of these signs within school zones, and research illustrating the value of using permanently installed Your Speed signs in school zones is sparse. The Eastern Carolina Injury Prevention Program (ECIPP) applied for SRTS funding to install these signs as part of their education, encouragement, and enforcement project. NCDOT therefore initiated a study on the use of these signs in conjunction with ECIPP's larger SRTS project. Significant findings of this study include a 3.0 ($p < 0.0001$) to 4.5 mph ($p < 0.0001$) reduction in speed sustained over a 12-month post installation period, suggesting that responses to Your Speed signs may not diminish as drivers become accustomed to their presence. Based on these promising results, NCDOT is considering additional research needs to fully inform policy considerations for the future use of these signs. This research may be useful for organizations seeking innovative SRTS program tools to improve speed compliance in school zones, for those contemplating the use of speed feedback signs in school zones who need sign assembly guidance and information on their effectiveness, and for those interested in a different way to evaluate their own SRTS projects.

INTRODUCTION

Lower regulatory speed limits are often established around schools during arrival and dismissal times. These reduced-speed school zones are designated due to the expectation of an increase in pedestrian activity and vehicular activity (eg. traffic, higher proportions of turning vehicles, and longer queues) resulting in an increased risk of potential conflicts. Slow driving speed increases the likelihood of avoiding a crash or at least minimizing the severity of injury if a crash occurs (*1*), which is particularly important in a school setting where there is an expectation of or desire for more child pedestrians. Therefore, the concept of establishing reduced speed limits in school zones is logical.

Unfortunately, past studies on the effectiveness of these special speed zones suggest that driver compliance is poor (*2*). This makes sense when considering the typical context in which drivers come upon a school zone. In some cases, there are no visual cues beyond the school zone paint markings and signage to indicate the need to slow down – nothing about the road's geometry, number of lanes, or other features change. These specialized reduced-speed zones often set up a situation that is unnatural to the driver based on the road's characteristics and environmental setting (e.g. urban, rural), which are more compatible with the speed limit that governs its operation 90% of the time. The driver's behavior when moving through a reduced-speed school zone is therefore largely unchanged.

Another visual cue traditionally expected around schools is largely missing today – child pedestrians. In 1969, 48% of children walked or bicycled to school; in the subsequent 40 years that proportion has dropped to 12% (*3*). Safe Routes to School (SRTS) programs seek to reverse this decline in active travel by encouraging and enabling children to walk and bicycle to school through implementation of the "Five E's": engineering, education, encouragement, enforcement, and evaluation. One of the primary reasons parents do not let their children walk or bike to school is traffic-related danger (*4*), particularly traffic speed (*5*).

In North Carolina, several applicants for SRTS funding proposed the use of permanently installed changeable message signs displaying approach speeds (Your Speed signs) as an engineering treatment to assist in enforcement of speed limits within school zones. The state Department of Transportation (NCDOT) has no policy, standard, or specification to address the use, assembly, location or operation of a Your Speed sign in this application. Other studies conducted to determine the effectiveness of portable speed trailers (*6, 7*) or speed display signs in work zones (*8, 9*) suggest a general trend that changeable message signs are effective in reducing speeds while they are operating, but once removed, driver compliance decays. Besides research conducted by Ullman and Rose, who found that dynamic speed display signs permanently installed in one school zone improved driver compliance for at least 4 months after installation (*10*), scarce research illustrates the value of using permanently installed Your Speed signs in school zones, particularly as part of the School Speed Limit assembly. Based on a previous study showing flashing beacons as an ineffective tool to improve speed compliance in school zones (*11*), NCDOT felt it prudent to determine the long-term effectiveness of using Your Speed signs in this setting.

Objectives

The primary objectives of this paper were to:

- Determine if Your Speed signs located in the school zone decrease speeds and increase speed compliance compared to before conditions.

- Compare vehicle speeds and compliance rates during reduced-speed school zone hours (school time) versus hours when the reduced speed limits were not in effect (non-school time).
- Summarize lessons learned and develop recommendations for future evaluations across North Carolina and other states.

C. M Eppes Middle School was identified as the study location through the SRTS program. The NCDOT studied the effectiveness of using permanently installed Your Speed signs for school zone speed compliance at this school**.** This paper documents the use of Your Speed signs within C.M. Eppes' school zone and their resulting impact on speed compliance which, combined with other enforcement, education and encouragement programs and activities, contributed to a successful SRTS project.

SITE DESCRIPTION

C.M. Eppes Middle School is located in Greenville, North Carolina near the campus of East Carolina University (ECU). Surrounded by an elementary school, a neighborhood, a park, and residence halls and athletic facilities of ECU as shown in Figure 1, the school sits on South Elm Street, a 4-lane road divided by a tree-lined median with unmarked bike lanes, on-street parking,

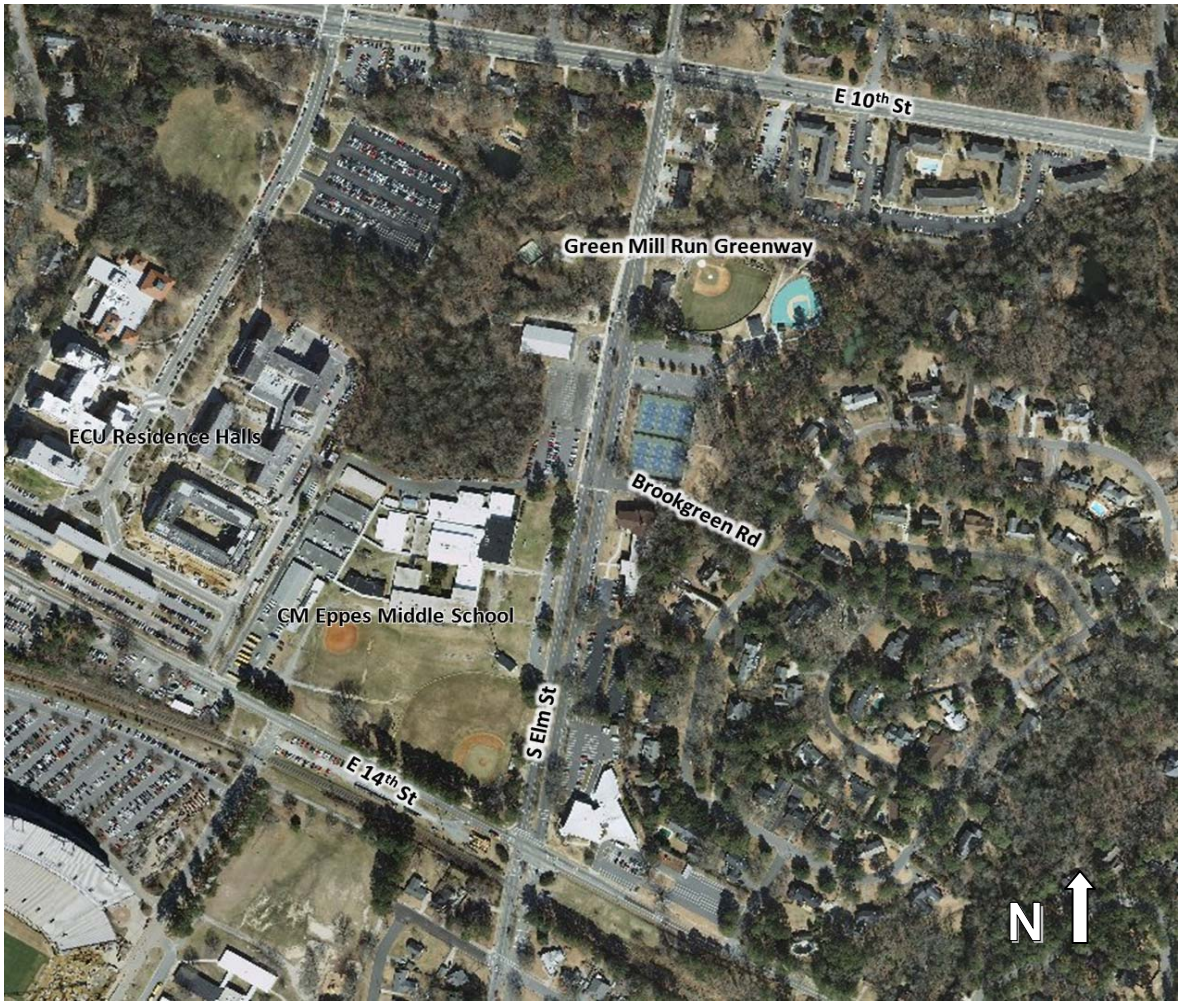

FIGURE 1 Aerial view of CM Eppes Middle School and surrounding neighborhood.

and sidewalk on both sides through the school zone. South Elm Street's ADT is 11,000 vpd (*12*), and the speed limit is 35 mph during non-school time. The designated school zone along South Elm Street extends for approximately 1,500 ft (457.5 m) in front of the school. From 8:00 am to 9:00 am and 3:25 to 4:45 pm (i.e. school time) the speed limit is reduced to 25 mph. Just outside the school zone to the north of the school the Green Mill Run Greenway crosses South Elm Street at a mid-block crossing. Another marked crosswalk traverses South Elm Street at the intersection of Brookgreen Road and the school driveway, which is within the school zone. The school is also bounded by Fourteenth Street, which is a 2-lane road with a speed limit of 35 mph and an ADT of 14,000 vpd (*12*). There is no designated school zone on Fourteenth Street.

Due to the surrounding land uses and available pedestrian facilities in the immediate area, pedestrian activity occurs at this site. NCDOT observed non-motorized activity while collecting motor vehicle speed data and captured rough counts: data collectors counted an average of 19 pedestrians or bicyclists per hour with approximately 63% of this activity seen during school time. Additionally, an average of 6 pedestrians per hour crossed South Elm Street (regardless of whether at a legal crossing) with approximately 63% of the crossings observed during school time.

C.M. Eppes Middle School SRTS Project

The Eastern Carolina Injury Prevention Program (ECIPP) has coordinated a pedestrian safety task force in Pitt County since 2006. Via the ECIPP, the task force applied for and was awarded SRTS funding to incorporate educational, encouragement, and enforcement programs at C.M. Eppes Middle School to build on distracted driving research and a photojournalism project already underway at the school. Part of their proposal was the use of Your Speed signs as an enforcement tool.

Upon authorization in February 2009, the ECIPP implemented their SRTS project over a 12 month period by:

- Conducting a photojournalism project in which students identified unsafe pedestrian scenarios around campus,
- Participating in International Walk to School Day (WTSD) in October 2009,
- Initiating a frequent walker/cyclist program, and
- Conducting a citation study and a speed study with the local police department to determine the effectiveness of the Your Speed signs once installed.

The Your Speed signs were installed in both directions of travel on South Elm Street on September 29, 2009 and were operational the week of October 5, 2009. The ECIPP worked with the City of Greenville to ensure that the signs were operational in time for the WTSD events held on October 7 and the subsequent frequent walker/cyclist program.

METHODOLOGY

School Zone Speed Limit Sign Assembly and Operation

In order to evaluate the use of the signage, NCDOT gave recommendations for placement, assembly and operation of the Your Speed signs. Figure 2a shows the suggested arrangement of the Your Speed sign as part of the School Speed Limit assembly, in compliance with sections 2B.13, 2L, and7B.15 of the MUTCD (*13*). NCDOT recommended that this assembly replace the existing School Speed Limit assemblies at the study location for both directions of travel. Recommended features of the Your Speed sign include:

- Displaying amber-lighted steady numerals for speeds below and up to 5 mph over the posted speed limit, flashing numerals for speeds between 6 mph and 20 mph over, and flashing a pattern (no numeral) for speeds 21 mph or more over.
- Operating only during the designated reduced school speed limit times documented with a legal traffic ordinance.
- A strong yellow-green color for the sign backing.
- Compliance with breakaway standards if installed where there is no curb & gutter.
- The capability to collect speed data over an extended time period to be used by local law enforcement and/or NCDOT for data collection purposes.

The City of Greenville installed their assembly to include flashing beacons in conjunction with the signage, as shown in Figure 2b. This choice was made because the original assembly being replaced included flashing beacons. NCDOT recommended that the beacons connect to the Your Speed sign so that their operations were in sync and ultimately flashed only

(a) **(b)**

FIGURE 2 (a) School Speed Limit Sign assembly incorporating the Your Speed sign, as suggested by NCDOT. (b) Image of installed assembly on South Elm Street. (C.M. Eppes Middle School is on right).

during the school times programmed in the Your Speed sign.

Speed Data Collection

A Lidar gun was used to collect speed data in both directions of travel. Data were collected before the signs were installed and at 1, 3, 6, and 12 month intervals post-installation from November 2009 through October 2010. For each interval, speed data were collected for the duration (approximately 1 h) of each school time (morning and afternoon) on a given day. At least 100 speed samples or 1 h of data collection were obtained in each direction of travel in the morning and afternoon during non-school time on the same day. The non-school time data were collected beginning (ending) at least 30 min after (before) the school time speed limit was in effect.

Speed data were collected on a Tuesday, Wednesday or Thursday when school was in session (i.e. teacher workdays and early release days were avoided.) All attempts were made to

collect data under similar weather conditions and from an inconspicuous spot so as not to influence drivers' speeds.

Data collectors targeted only unimpeded vehicles that were setting their own speed. Vehicles in platoons were avoided, as they were not actively choosing the speed at which they travelled. This made it possible to determine if the sign assembly had an effect on drivers selecting their own speeds.

RESULTS

Speed data were organized by school time and non-school time sets for analysis. Various speed characteristics were calculated for each group analyzed, including the percentage of vehicles exceeding the speed limit, average speed, 85th percentile speed, standard deviation, and pace speed. As the percentage of vehicles exceeding the speed limit goes down, the more drivers are in compliance. Average speed was calculated as a time mean speed – the mean of all individual speeds at a point or short section of roadway – and reflects a measure of drivers' tendencies (*2*). The differences in average speeds between before and after conditions were calculated and tested for statistical significance using two-sided *t*-tests. The 85th percentile speed is the speed at or below which 85% of the vehicles are going and is commonly used by traffic engineers to set speed limits (*2*). Speed dispersion parameters (standard deviation, pace speed) measure the potential safety of a road, as the more vehicles that fall outside of the average or pace speed (or the broader the spread of speeds) the higher the likelihood of crashes (*2*).

School Time Findings

Table 1 and Figure 3 provide a summary of speed data collected in both directions of travel on South Elm Street during school time. As shown in Table 1, for each speed characteristic measured there was a beneficial effect from installing the Your Speed signs when comparing pre- to post-installation measurements.

TABLE 1 Summary of School Zone Speed Data Collected During School Time on South Elm Street

		Observations	Vehicles Exceeding SL[a] (%)	Average Speed Above SL[a] (mph)	Standard Deviation (mph)	85th Percentile Speed Above SL[a] (mph)	Pace Speed Above (+) or Below (-) SL[a] (mph)	Drivers within Pace Speed (%)
Northbound	Pre-Installation	292	89	6.7	5.0	11.7	+1 to +10	67
	1 Mo. After	207	64	2.2[b]	4.3	6.4	-2 to +7	74
	3 Mo. After	207	67	2.8[b]	4.4	6.3	-2 to +7	84
	6 Mo. After	240	66	2.6[b]	3.9	6.1	-3 to +6	83
	12 Mo. After	230	65	2.2[b]	4.2	5.3	-3 to +6	77
Southbound	Pre-Installation	255	85	5.5	5.1	10.8	0 to +9	72
	1 Mo. After	201	62	2.6[b]	4.5	7	-3 to +6	76
	3 Mo. After	218	59	1.9[b]	4.2	5.3	-3 to +6	82
	6 Mo. After	227	76	2.6[b]	3.0	5.1	-2 to +7	92
	12 Mo. After	223	62	2.5[b]	4.3	6.3	-3 to +6	86

[a] Denotes 25 mph speed limit

[b] Denotes a post-installation average speed that is statistically significant ($p < 0.0001$) from pre-installation conditions.

During school time the average speed significantly decreased by at least 2.9 mph and at most 4.5 mph. Indeed, at the 12 month after interval, average speeds maintained a 3.0 ($p < 0.0001$) to 4.5 mph ($p < 0.0001$) decrease for southbound and northbound travel respectively. The 85th percentile speed decreased by at least 3.8 mph and at most 6.4 mph after installation

when considering either direction of travel, and 85th percentile speeds maintained a 4.5 to 6.4 mph decrease at the 12 month after interval. In other words, average speeds above the school time speed limit of 25mph were reduced by at least 9.8%, and 85th percentile speeds above the speed limit decreased by at least 12.6% after the Your Speed signs were installed.

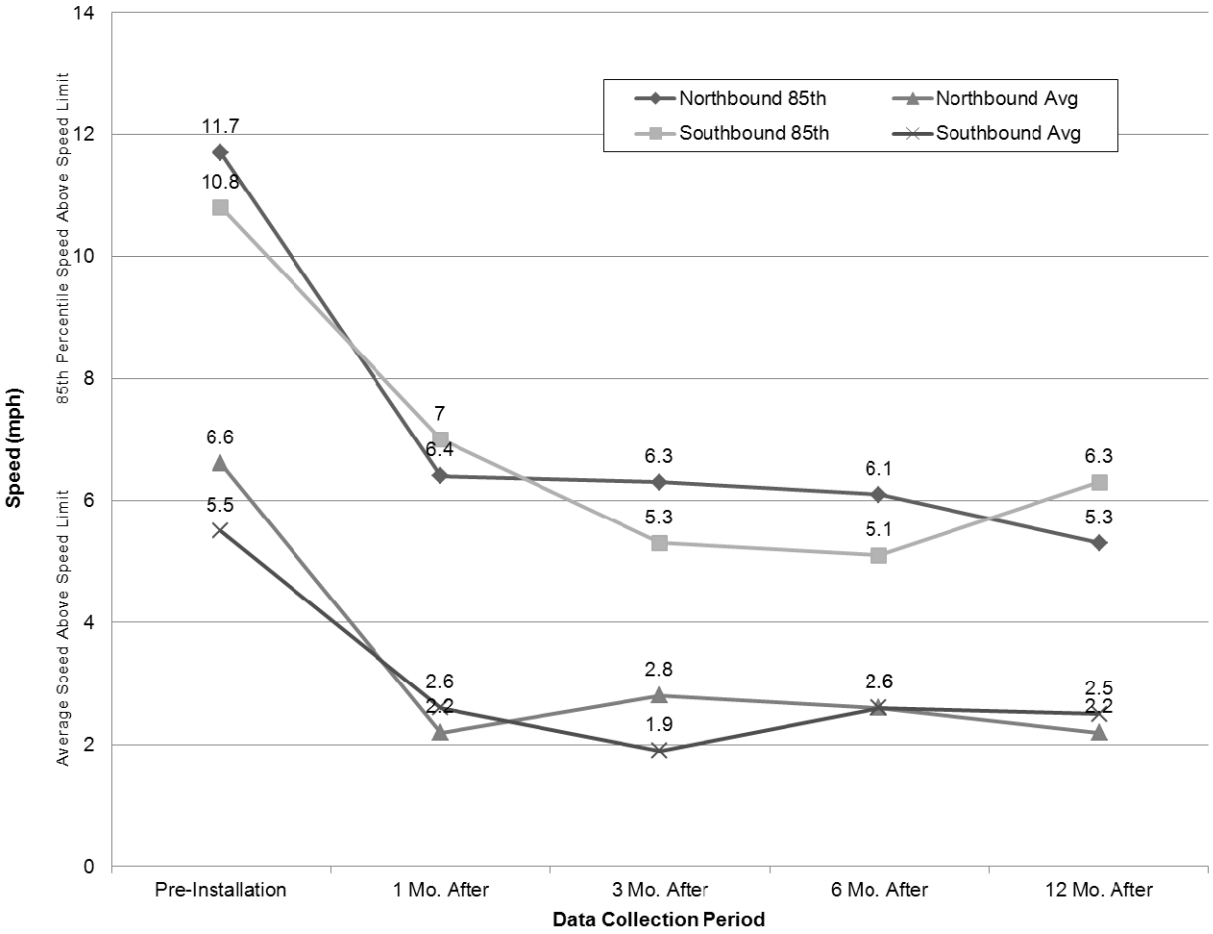

FIGURE 3 South Elm Street school time speeds above 25 mph speed limit.

Although driver compliance increased after sign installation, on average, drivers exceeded the school time speed limit before and after the Your Speed signs were installed. Therefore, speed dispersion factors indicating the road's safety were also analyzed. As visually depicted in Figure 3, the difference between the average speed and 85th percentile speed, which can be a rough indicator of speed dispersion, decreased for both directions of travel, with the widest spread (5.3 mph) observed before and the narrowest spread (2.5 mph) observed after installation of the signs in the southbound direction of travel. Standard deviation results also indicate that speed dispersion is reduced in after conditions. The percentage of drivers within the pace speed also increased by at least 4% (from 72% of drivers within 25-34 mph to 76% of drivers within 22-31 mph) and at most 20% (from 72% of drivers within 25-34 mph to 92% of drivers within 23-32 mph) after the Your Speed signs were installed.

When the direction of travel is not taken into account, a range of 16% to 24% with an average of 21.9% more vehicles complied with the school time speed limit once the Your Speed signs were installed. Most importantly, the significant reductions in speed appear to be sustained

over time, suggesting that responses to the permanent Your Speed signs do not diminish at this location as drivers become accustomed to its presence.

Non-School Time Findings

Data were collected outside the reduced-speed school zone hours as an additional point of reference to examine differences in vehicle speeds and compliance rates between the before and after data. Table 2 and Figure 4 provide a summary of speed data collected in both directions of travel on South Elm Street during non-school time. Results of speed compliance after the installation of Your Speed signs were mixed. In general, as shown by each measured speed characteristic in Table 2, drivers going northbound appear to be more compliant with the 35 mph speed limit after the Your Speed signs were installed, even though the signs did not operate during non-school times.

TABLE 2 Summary of School Zone Speed Data Collected During Non-School Time on South Elm Street

		Observations	Vehicles Exceeding SL[a] (%)	Average Speed Above SL[a] (mph)	Standard Deviation (mph)	85th Percentile Speed Above SL[a] (mph)	Pace Speed Above (+) or Below (-) SL[a] (mph)	Drivers within Pace Speed (%)
Northbound	Pre-Installation	287	47	0.7	4.8	4.9	-5 to +4	76
	1 Mo. After	228	29	-1.7[b]	4.4	1.9	-7 to +2	78
	3 Mo. After	324	39	-0.4[b]	3.6	2.7	-5 to +4	87
	6 Mo. After	209	40	-0.3[b]	3.5	3.1	-5 to +4	86
	12 Mo. After	214	42	0.1	3.9	3.9	-5 to +4	80
Southbound	Pre-Installation	267	29	-1.6	4.2	1.9	-6 to +3	79
	1 Mo. After	240	35	-1.0	4.5	2.9	-5 to +4	76
	3 Mo. After	349	29	-1.6	4.0	1.6	-7 to +2	81
	6 Mo. After	207	43	-0.4[b]	3.6	2.8	-5 to +4	84
	12 Mo. After	234	42	0[b]	3.9	3.8	-5 to +4	79

[a] Denotes 35 mph speed limit

[b] Denotes a post-installation average speed that is statistically significant ($p < 0.05$) from pre-installation conditions.

During non-school time the average speed results varied by direction of travel. In the northbound direction, average speed decreased between 0.6 mph ($p = 0.12$) and 2.4 mph ($p < 0.0001$). Southbound speeds increased over time. At 1 and 3 months after installation, the modest increase in average speeds going southbound were insignificant ($p = 0.09$ and $p = 0.88$, respectively. However, the largest increase of 1.7 mph in average speed was extremely significant with a *p*-value less than 0.0001, and it occurred 12 months after the Your Speed signs were installed.

The 85th percentile speeds also varied by direction of travel from a decrease of up to 3.0 mph (northbound) to an increase of up to 1.9 mph (southbound) after installation. It is interesting to note that neither average speed nor 85th percentile speed went above the pre-installation measures for northbound travel, but both parameters were modestly yet consistently higher for the 12 month post-installation period for southbound vehicles.

In general, the percentage of drivers within the pace speed increased an average of 6.8% for northbound vehicles, yet remained relatively unchanged with a 1% increase for southbound travelers, when comparing pre- and post-installation measures.

As visually depicted in Figure 4, the overall difference between the average speed and 85th percentile speed decreased when combining data from both directions of travel during non-school time, with the widest spread (3.85 mph) observed before and the narrowest spread (3.15 mph) observed 3 months after installation of the signs. The standard deviation measures also

suggest a narrowing of speed dispersion post-installation, when comparing an average of northbound and southbound measures for each data collection period to before conditions.

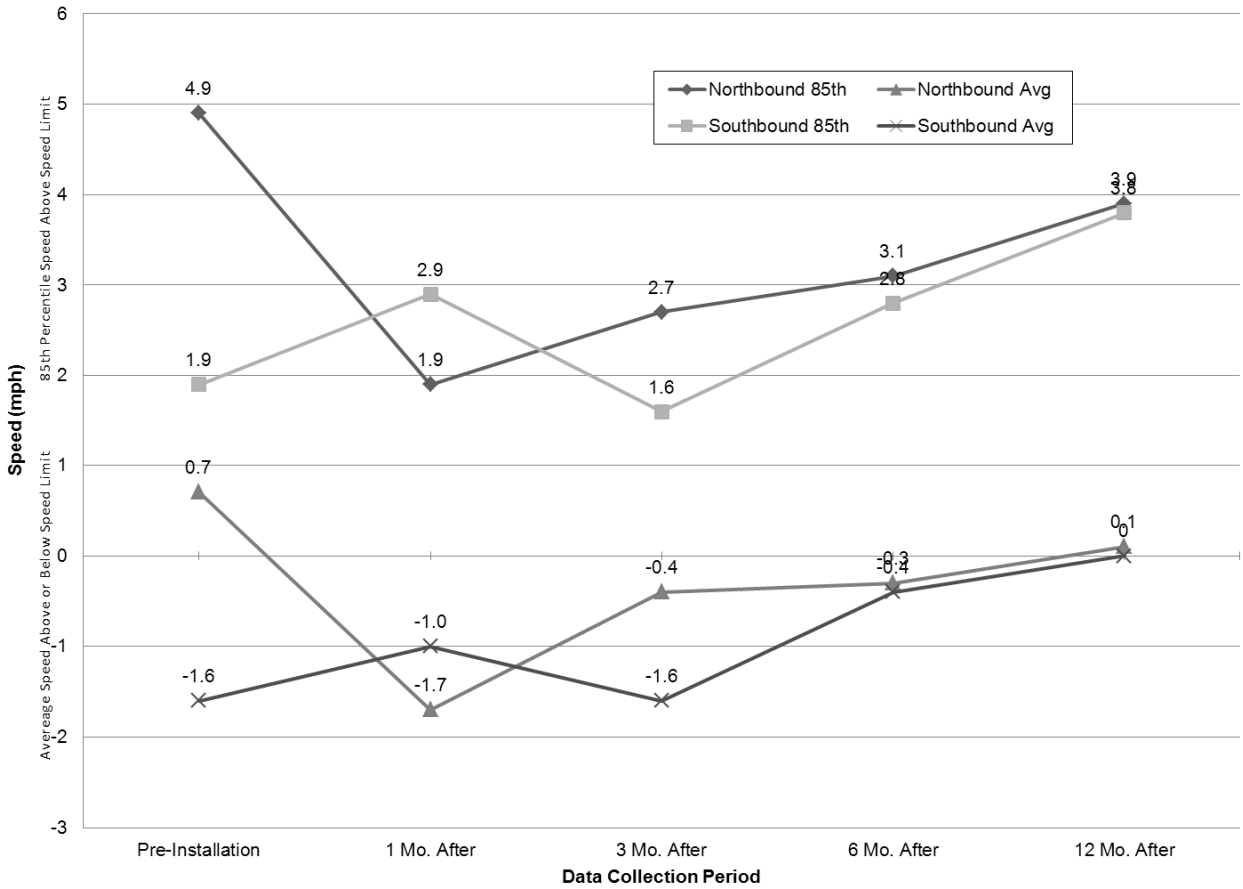

FIGURE 4 South Elm Street non-school time speeds above (below) 35 mph speed limit.

Comparison of School Time and Non-School Time Results

Non-School time data served as a control group, and no significant variation in speed measures were expected when comparing before and after data for this group, primarily because the Your Speed signs were not operational during non-school time. Also, when considering before conditions, the majority of drivers complied with the 35 mph speed limit so there was less need for improvement during non-school time compared to school time.

Figure 5 graphically displays a comparison of each speed parameter for school time versus non-school time data. On average, the percentage of vehicles exceeding the speed limit during non-school time changed minimally (<1%) while the same measure decreased by 21.9% when the Your Speed sign was operating during school time. The increase in driver compliance during school time as shown in Figure 5a suggests that the Your Speed sign produced the desired impact on getting drivers' attention.

School time data indicate with an average reduction of 85th percentile speeds over time (5.5 mph) compared to a negligible average reduction of 0.6 mph during non-school time, as shown in Figure 5b. The sharp rate of decline in 85th percentile speeds during school time supports the finding that the Your Speed signs are effective.

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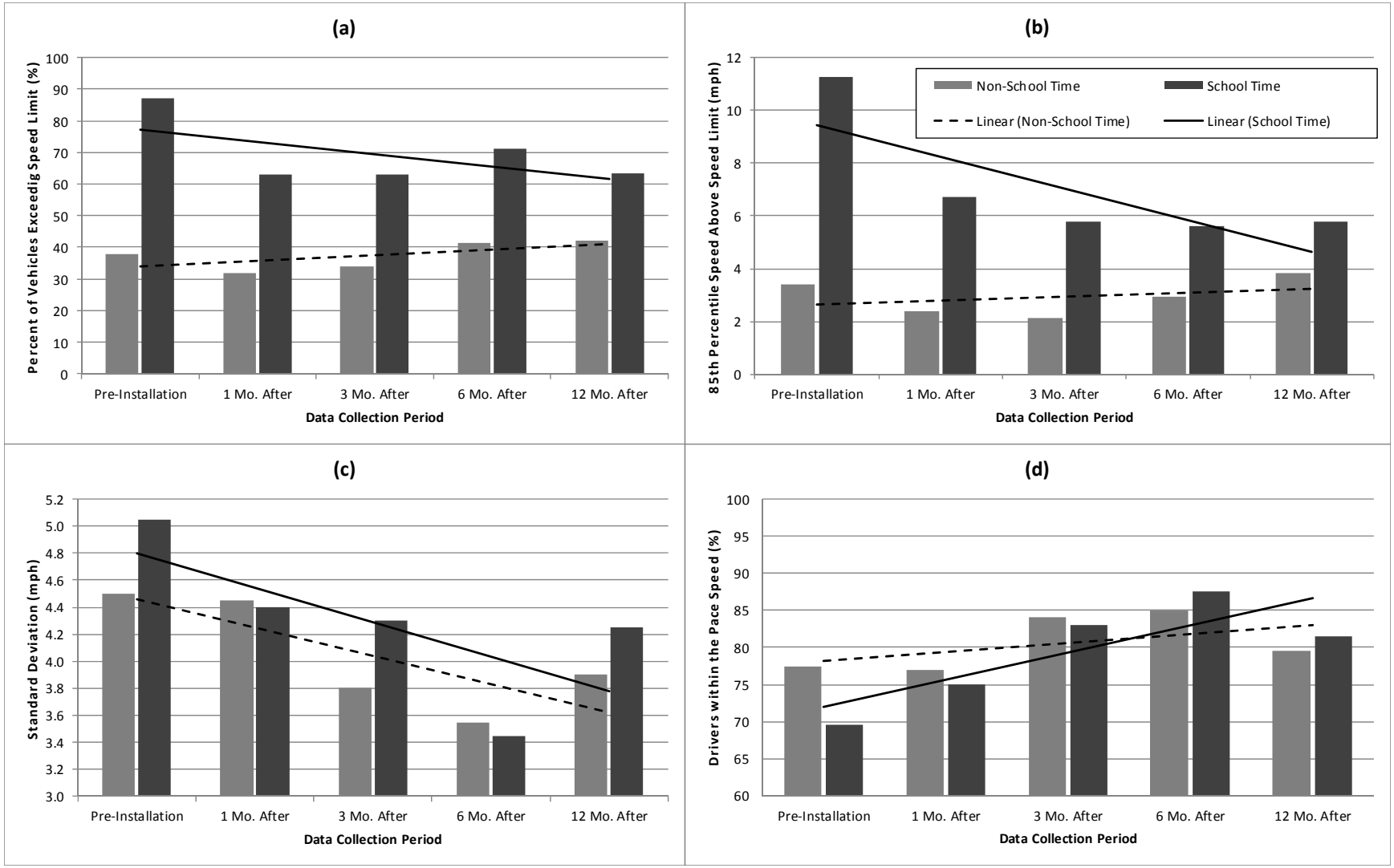

FIGURE 5 School time versus non-school time comparisons. (a) Comparison of the percentage of vehicles exceeding the speed limit. (b) Comparison of 85th percentile speeds above the speed limit. (c) Comparison of standard deviations. (d) Comparison of the percentage of drivers within the pace speed. (School time speed limit is 25 mph; non-school time speed limit is 35 mph.)

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A comparison of speed dispersion parameters may suggest that other variables impacted driver speeds besides the Your Speed sign. On average, standard deviations modestly decreased after sign installation for both school (0.95 mph) rates. Also, the percentage of drivers within the pace speed increased for both school (12.3%) and non-school time (3.9%); however, a higher rate of increase was observed during school time, as depicted in Figure 5d

DISCUSSION

Since the installation of the Your Speed signs as a part of the School Speed Limit sign assembly, there have been significant, sustained reductions in speed during the school time hours in both directions of travel for the year-long period over which observations were recorded. In fact, when direction of travel is not considered, the average speed was about 3.7 mph (or 12%) lower 12 months after the signs were installed. In addition to being statistically significant, the speed results may be considered practically significant in terms of crash avoidance. Lower speeds equate to shorter reaction and stopping distance, which is important in an environment where children may be entering the roadway. To put the results into perspective, a decrease in speeds from 35 mph to 30 mph can result in a vehicle being able to stop about 50 ft (15.3 m) sooner. The percentage of drivers within the pace speed was consistently higher, and there was a drop in the dispersion of vehicle speeds during school time hours post-installation, which also suggest that safety is enhanced.

This study at C.M. Eppes Middle School looked at a very specific application for the Your Speed signs as a part of a targeted enforcement strategy for the school's SRTS project. The signs may have greater potential to reduce vehicle speeds in this application due to their limited periods of operation. They target motorists only during the designated reduced school speed limit times, which equates to approximately 2 h per weekday when school is in session. It was assumed that the same driving population travels that segment of South Elm Street on any given day. In other words, local commuting traffic with typical trip patterns and drivers familiar with the area would expect the presence of the school. Permenantly installed Your Speed signs that only operate during school time have potential for achieving better compliance with reduced speed limits in school zones by heightening drivers' awareness when it is most critical for them to adjust their driving behavior, while not desensitizing drivers with the sign's presence.

During non-school times when the Your Speed sign did not operate, there was not an equivalent, consistent and sustained reduction in vehicle speeds as observed during school times. In fact, if more drivers complied during non-school time over the same data collection period, it would strongly suggest that other variables may be impacting vehicles speeds besides (or instead of) the Your Speed sign. Vehicle speeds varied by direction of travel with a slight increase in the southbound direction and a slight decrease in the northbound direction. When direction of travel is not considered, the average speed actually increased slightly (0.53 mph) 12 months after the signs were installed. The mixed results during non-school time may suggest that other factors were at play; and indeed, other activities conducted through the ECIPP SRTS project may have strengthened the results observed during school time and affected non-school time results, too.

For example, the city's police department conducted a citation study from September to October 2009, which overlapped with the initial data collection period of this study. Indeed, NCDOT data collectors documented a heavy law enforcement presence in the northbound travel direction during the 1 month after collection interval. Their presence may have contributed to the sharper decline in speeds for northbound travelers compared to southbound travelers for both school and non-school times. The police department's citation study revealed that the number of citations for speeding in the school zone decreased from an average of 2 per day to 1 every 2

days. However, the law enforcement presence alone cannot explain the sustained increase in driver compliance during school time 12 months after installation of the Your Speed signs.

A policy consideration in the use of Your Speed signs in school zones is that of data collection capabilities. While the data collection capability of the signs installed at C.M. Eppes Middle School was not tested or used as a part of this study, these signs can collect speed data over an extended period of time, providing a way for long-term monitoring of speed compliance. As was presented by Casey and Lund, engineering treatments most effectively influence speed compliance when combined with local law enforcement presence (*6*). By monitoring speed data collected through the Your Speed signs, law enforcement can conserve resources, improve efficiency, and only provide a physical presence when a pre-determined threshold of driver non-compliance is reached.

The data collection capability can also provide information to SRTS programs where speeding is still a problem even with a committed police presence, as that may suggest that additional engineering treatments (i.e. traffic calming strategies) need to be considered. Further study of the Your Speed sign's use in conjunction with police activities could be valuable to determine if there are standard lengths of time over which the sign's effectiveness decays, the threshold at which driver compliance is so poor that it warrants police presence, and the frequency of police activity needed to optimize speed enforcement using both techniques.

In North Carolina, many schools were built in once rural locations that are now urbanizing. This particular study occurred at a school well-established in a suburban setting with local commuter traffic. It will be important to conduct further study of the Your Speed sign as part of the School Speed Limit assembly at different school settings to determine whether the sign is effective for universal use in school zones, or whether its application should be limited to those with certain characteristics or factors. Given that flashing beacons proved to be ineffective at reducing speeds in school zones (*11*), additional research is needed to determine whether comparable results can be obtained at similar site locations with a modified School Speed Limit assembly that utilizes Your Speed signs without flashing beacons.

Due to the promising results from this research, NCDOT plans to study the use of Your Speed signs at 9 additional schools in North Carolina, which are also implementing SRTS-awarded projects. Results from a more robust case-controlled study of these signs may have potential policy, standards, or design implications for NCDOT and will help the department determine what, if any, support it may provide to communities or schools with an interest in using Your Speed signs in school zones.

ACKNOWLEDGEMENTS

The original work done under this research effort was funded through North Carolina's Safe Routes to School Program. The authors would like to thank the North Carolina Department of Transportation's Traffic Safety Unit, the SRTS Program, and Signing and Delineation, specifically Brian Mayhew, Shawn Troy, Joel Cranford, Ed Johnson, and Ron King, for their help and guidance throughout this project. Special thanks also to Ellen Walston with the Eastern Carolina Injury Prevention Program for supporting CM Eppes Middle School in launching a successful SRTS program.

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