Reducing Pediatric Traffic-related Casualties in Ohio with Flashing Warning Beacons:

A Quasi-experimental Study

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Introduction

Motor vehicle crashes are one of the leading causes of death for children in the United States (Cunningham et al., 2018). Currently, Ohio law mandates that schools use posted signs to designate a school zone, which requires vehicles to reduce speed during times when children are present. This mandate, however, only sets the standard for the bare minimum and allows for privately funded enhancements to draw additional attention to school-zone traffic signs. This has created disparities in traffic control measures across the State; schools with more resources are better able to afford enhanced safety features (i.e., flashing beacons). Furthermore, inconsistent traffic signage creates confusion, leading to poor motorist decision-making and traffic accidents (Ohio Department of Transportation, 2012).

These inconsistent traffic control measures, and the paywall limiting access to enhanced safety features, impact some schools more than others. This represents a health and safety disparity for Ohio school children because the presence of traffic control measures is directly tied to local resources. Often operated by non-profit organizations, schools that serve disabled children are disproportionately (negatively) impacted by the variation in how school zones are marked. These discrepancies compromise the safety and wellbeing of students in need of additional support, especially when motorists become accustomed to the high-visibility, enhanced safety features that mark other school zones.

To demonstrate the efficacy of enhanced safety features, emphasize the importance of consistent traffic control measures, and advance the wellbeing and equity in a local region, the current project assessed the impact of introducing flashing beacons at a local school that serves deaf children. The intervention is represented by the addition of flashing beacons to the selected school zone. The expectation is that the addition of the flashing beacon will heighten motorist awareness and student safety, thus reducing motorists' speeds and eventually reducing the risk of crashes, injuries, and deaths.

Prior Literature

Motor vehicle crashes represent 20% of all pediatric deaths (Cunningham et al., 2018). Each year, approximately 800 school-aged children are killed in motor vehicle crashes during normal school travel hours. This figure represents about 14% of all child deaths that occur annually on U.S. roadways (Transportation Research Board, 2002). Moreover, approximately 25,000 children are injured and 100 are killed each year in school zones across the United States (Transportation Research Board, 2002). These statistics demonstrate the need for enhanced safety features on roadways that service Ohio schools.

This raises an important question: what is the best way to address traffic safety concerns in local school zones? Fortunately, there is a growing body of research into traffic mitigation strategies. Studies show that motorists may be forgetful when it comes to the temporary changes in speed that school zones offer (Gregory et al. 2015; 2014). As a result, drivers initially slow down, but eventually return to regular speeds before leaving the school zone. While some attempts have been made to remind drivers of the temporary speed change, only specific interventions have been found to be effective. For example, simple signage was not found to be effective (Gregory et al., 2015), while narrowing lanes and including a warning light in the center of the lanes did successfully reduce driver speed (Ratanavaraha and Watthanaklang, 2013).

Two approaches have guided policymakers and engineers when attempting to address concerns and safety challenges in school zones. The first relies on large engineering projects that attempt to alter the behavior of drivers on a subconscious level. Common examples of these interventions include narrowing roads, implementing raised center medians, or completely changing the shape of roads to include more curves (Ratanavaraha & Watthanaklang, 2013; Rahman et al. 2019; Miyazaki and Morimoto, 2016). While these engineering-focused interventions were found to be effective at reducing driver speed, they require relatively large and expensive changes to the surrounding area. Additionally, these changes may not be possible because of space or zoning restrictions, or simply because the municipality lacks the resources to implement them.

The second approach relies on signage and beacons to ensure drivers are continuously and actively aware of the school zone and its designated speed. Such mitigation strategies (e.g., signs, pavement markings, flashing beacons, speed boards) have been implemented over the years in efforts to slow vehicle speeds and heighten motorist awareness in school zones. Of these, research shows that flashing beacons effectively reduce motorist speeds in active school zones and, therefore, are expected to provide a variety of safety benefits (Khattak & Kang, 2020).

Forward-facing beacons are primarily used to highlight the “begin school zone” sign and are required in some states, but not in Ohio. Newer rear-facing beacons can now be placed near the end of a school zone to serve as a reminder, as drivers often do not understand when they are in the school zone or not (Rahman et al., 2019). Rear-facing flashing beacons can reduce speed in a school zone (Hawkins, 2007), but additional research and replications are needed before we can be confident that the results of prior work would generalize to Ohio.

It is important to note that where and how these crash mitigation strategies are implemented is inconsistent. In Ohio, schools that are not along routes controlled by the Ohio Department of Transportation or that are within municipal limits are required to finance their own crash mitigation strategies. This ties traffic safety directly to school resources—some schools have the ability to enhance traffic safety around their facilities while others do not. Schools that are unable to enhance their traffic safety disproportionately serve children with special needs or disabilities (i.e., non-profit and underprivileged school systems).

The Ohio Department of Transportation's Manual of Uniform Traffic Control Devices Procedures (2012) notes that when traffic control devices are not uniformly implemented, it can cause confusion among pedestrians and other road users, prompt wrong decisions, and contribute to motor vehicle crashes. Inconsistent traffic control measures may be especially detrimental to motorist decision-making when the inconsistencies are geographically close to each other (i.e., one school using flashing beacons to mark the school zone, while a different, proximal school does not). In particular, motorists may come to expect enhanced safety features to designate school zones. When those features are absent, the motorist may incorrectly believe they are *not* in a school zone.

Although several studies have evaluated the effectiveness of various traffic control devices (e.g., sign, flashing beacon, lane modifications), there is a lack of research proposing modern, innovative operation and engineering countermeasures, which might have significant improvement of safety in school zones (Rahman et al., 2019). The present study addressed this gap by assessing, using a quasi-experimental design, the impact of rear-facing flashing beacons on motorists' speed in a local school zone. The focal school serves deaf children, so the need to slow traffic speeds was a high priority for local safety experts and school administrators.

The Current Study

The goal of this project was a practical one: to reduce the speed of motorists in a school zone. If we can achieve this goal, we believe there are a number of secondary outcomes that will also be realized, such as a reduction in traffic crashes and a reduction in the number of injuries and deaths of Ohio children and adolescents.

The research team set out to answer the following research questions:

1. The majority of the studies examining the effectiveness of forward-facing traffic beacons were conducted in traditional 35 mile per hour roadways. Given this, do the results of forward-facing beacons remain consistent on higher speed roadways?
2. Forward-facing beacons effectively reduce motorist speed—at least initially. However, it is unclear how long (and therefore, how far) speed reductions are effective. Given this, do rear-facing flashing beacons effectively reduce motorist speed throughout the school zone?

Methods

Setting

To answer these research questions, the research team conducted a quasi-experimental analysis by comparing pre- and post-intervention data from an "intervention school", Ohio Valley Voices school. Additionally, a second layer to this study further enhanced the robustness of the results. Prior to the addition of the speed beacons (i.e., the intervention), the study team identified another local school to serve as a "matched comparison". The matched comparison school, McCormick Elementary, is similar to the Ohio Valley Voices in that it serves the same age-range of students and it is geographically situated near the Ohio Valley Voices school (i.e., the intervention school).

Both of the schools selected for this project are located on a main road marked as a 40 mile per hour zone when school is not in session. When school is in session, motorists are instructed to decrease their speed to 20 miles per hour. The two schools are located within 2 miles of one another. This means that the two schools have similar traffic conditions and are geographically proximal to one another. The traffic control measures used by these two schools, however, differ significantly. Prior to the current study, the Ohio Valley Voices school used only the mandated minimum of a black and white sign to designate the change in speed upon entering the school zone. The matched control school, McCormick Elementary school, used the mandated black and white sign along with forward-facing flashing beacons to help draw motorists' attention to the change in speed. These beacons were activated regularly in both the morning and afternoon, from 7:15am to 8:00am and again from 3:15pm to 4:00pm.

Figures 1 and 2 display the differences between the two schools and their surrounding areas. Both schools reside in very similar suburban areas. Figure 1 also displays the details and changes that were made as part of the intervention at Ohio Valley Voices. As well as the installation of the multiple school zone beacons, road markings and signs were moved to accommodate the beacons and to bring the area in line with Ohio Traffic Code. This included moving the "School Zone" pavement markings and signage to warn drivers of the upcoming School Zone warning beacons while taking into account the added beacons. Images of the added beacons are displayed in Figures 3.

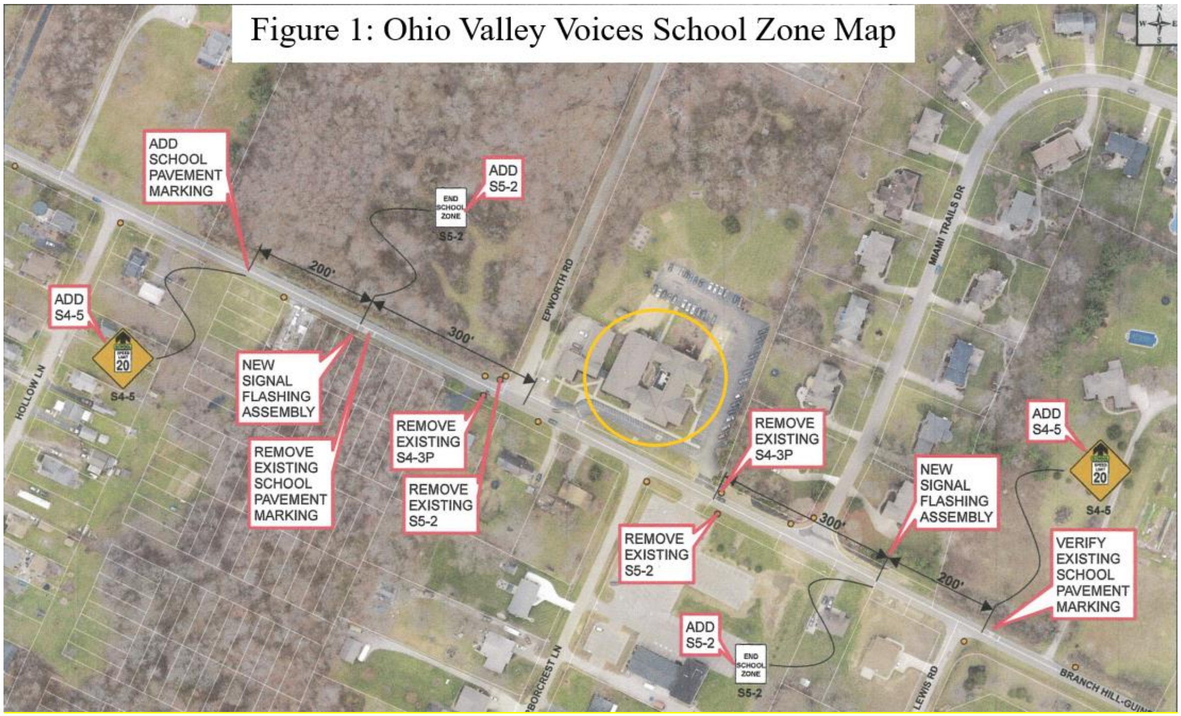


Figure 1: Ohio Valley Voices School Zone Map

Note: Ohio Valley Voices is marked by a yellow circle
S4-3P refers to a black and yellow sign “School” sign.
S4-5 refers to a black, white, and yellow “School Speed Limit 20 [MPH]” sign.
S5-2 refers to a white and black “End School Zone” sign.
Examples of each of these signs are available as Figures 4 through 6 in the appendix

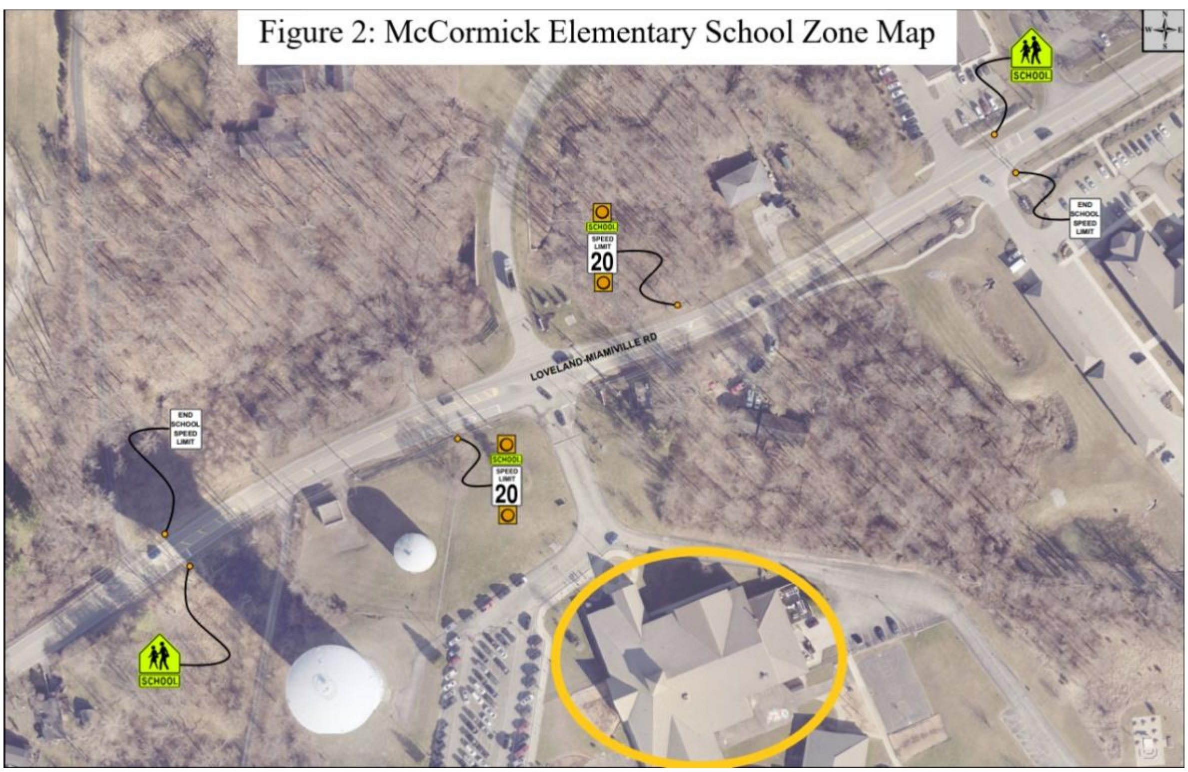


Figure 2: McCormick Elementary School Zone Map

Note: McCormick Elementary is marked by a yellow circle

Figure 3: Image displaying the front-facing (left) and rear-facing (right) school zone beacons

Note the key difference between the two schools that existed prior to the study: the matched control school already had forward-facing speed beacons in place. Ohio Valley Voices did not have any speed beacons. By comparing speed data from Ohio Valley Voices (the intervention school) to those gleaned from McCormick Elementary (the matched comparison school), this study is able to speak to two different factors: 1) the impact of adding speed beacons to a school that previously had none and 2) the impact of the rear-facing beacon versus forward-facing beacons.

Data Collection

To gather the requisite data, the Miami Township Police Department used traffic study collection tools, specifically VIAS TrafficX road tubes, to collect traffic data. This technology is capable of capturing speed and volume data as vehicles enter and exit the school zone in both directions. Miami Township Officers placed data collection equipment at both the beginning and end of the school zones for both of the selected study schools. Data collection occurred during the same time window at both sites. Specifically, pre-intervention data were captured between April 15th and May 15th, 2022.

The Miami Township Police Department worked with the Clermont County Engineer's Office to obtain the necessary permits and accepted a bid from A&A Safety to complete the installation of the solar-powered, triple beacon school safety lights. The improvements to the school safety zone began on August 4th, 2022, and the triple beacon school safety lights went active on September 19th, 2022.

Post-intervention data was collected one year after the initial traffic study, between April 13th and May 1st, 2023. We relied on roughly the same date ranges that were used during the pre-intervention phase so as to reduce the impact of seasonality and/or weather conditions on the post-intervention data. Data was also recorded on dates several months after the installation of the additional warning beacons to avoid driver behavior that would be reacting to a new driving experience in the school zone.

During the study period, Miami Township officers were careful to avoid police patrols in the area in order to avoid contaminating the study results by artificially lowering speeds in one area (as a result of the patrol) and not the other.

Descriptive statistics are provided for base-level comparisons of the two sites and their drivers. Both pre- and post-intervention data were analyzed using R version 4.3 and Stata version 15.1. Comparisons of average speeds of both locations were performed using *t*-tests and regression analysis. For the purposes of this study, observations are defined as a motor vehicle. Motor vehicles that were traveling 70+ miles per hour were removed from the sample prior to analysis. This decision was made after a careful examination of outlier cases. There were only a small proportion of cases clocked at speeds greater than 70 miles per hour (~200 cases per school).

Upon initial analysis of the speed data, the research team became aware of inconsistencies in the timing of the observations. Specifically, we observed very clear decreases in average speed (see: Figures 2 and 3 below) that do not match with the beacon activation times provided by each school. Because of this, the timing of the beacons being *on* was manually selected based on observation of the patterns in Figure 2 and Figure 3.

Results

Univariate statistics are displayed in Table 1. Overall, the sample contained a large volume of information. As shown in the table, a total of 355,651 motor vehicles were included in the analysis. The large number of observations for both schools lends credibility to the upcoming analyses and reduces concerns about random noise impacting the results.

Table 1. Descriptive statistics

	N	Average Speed (mph)	SD
Full Sample	356,651	37.16	10.20
Ohio Valley Voices	214,751	36.93	9.34
McCormick Elem.	141,900	37.50	11.38

Note: SD = standard deviation.

The average speed of all motor vehicles was 37.16 miles per hour. Vehicles at McCormick Elementary had a slightly higher average speed (37.50 mph) compared to Ohio Valley Voices (36.93 mph). There are also important differences in the weekend driving behaviors, with drivers at McCormick Elementary driving approximately 3-4 miles per hour faster than at Ohio Valley Voices.

The next step to the analysis was to assess the impact of adding the flashing beacons to the Ohio Valley Voices School. Data that can speak to the impact of the intervention are shown in Table 2.

Table 2. Descriptive statistics by site and time.

	Pre-Intervention			
	Ohio Valley Voices		McCormick Elem.	
	Average Speed (mph)	SD	Average Speed (mph)	SD
Beacons off	37.23	9.75	38.02	10.80
Beacons on	--	--	26.53	9.99
Weekend	39.38	8.46	42.65	9.67
	Post-Intervention			
Beacons off	37.05	8.47	38.09	11.39
Beacons on	26.49	8.96	28.52	11.51
Weekend	38.67	7.78	42.75	9.32

Note: SD = standard deviation.

Looking at the average speed (mph) during times when the beacons are *on* reveals that motor vehicles traveling through McCormick Elementary's school zone had an average speed between 28 and 29 mph. Vehicles traveled at slightly slower speeds at Ohio Valley Voices when the beacons were on (between 26 and 27 mph). Results of a *t*-test shown in Table 3 suggest that this small difference is statistically significant. Overall, the beacons being *on* resulted in an average decrease in speed of over 10 miles per hour.

Turning to Table 4, we see the results from a multiple regression analysis. The outcome for the analysis is vehicle speed in miles per hour. We see the Intercept value was estimated at 38.05. That value represents the average vehicle speed at McCormick when the beacons were off. The next row of the table shows the impact of turning the beacons on. The results show the beacons reduced the speed of drivers by approximately 10.63 miles per hour. The next row in the table shows the difference in speeds, when the beacons were off, between McCormick and Ohio Valley Voices. As can be seen, speeds at Ohio Valley Voices were 0.91 miles per hour slower, on average, than they were at McCormick during times when the beacons were off. This decrease in speed, albeit very small, was found to be statistically significant. Finally, we see in the final row, the impact of the beacons at Ohio Valley Voices. This effect shows the impact of the beacons, *above and beyond*, the effect of the beacons that was noted above. As shown in the table, the beacons at Ohio Valley Voices further reduced speeds when compared to the beacons at McCormick. Specifically, the beacons at Ohio Valley Voices—which, recall, included a rear-facing beacon—reduced speeds by only a small amount more (0.02) than the beacons at McCormick. This difference was not statistically significant ($p > 0.001$).

Figures 2 and 3 below display these significant and almost immediate decreases in speed that occur once the beacons are turned on. Comparing these to the average speed when the beacons are on and off shows that while the McCormick beacons can results in lower speeds of drivers at some points, the beacons at Ohio Valley Voices appear to sustain the decreases in speed for longer times.

There also appears to be a difference in the effects of the beacons depending on the time of day, with motorists driving approximately 0.62 miles per hour slower in the morning compared to the afternoon. Results of additional two-sample *t*-test and regression models shown in Tables 5 and 6 also suggest that this relationship is statistically significant.

Table 3. Results of *t*-tests comparing average speed and beacon status

	N	Mean (mph)	SE	SD
Beacons Off	366,720	37.67	0.02	10.34
Beacons On	42,549	27.14	0.05	10.25

Note: All relationships statistically significant ($p < 0.001$), $t = 198.9573$, $df = 409{,}267$,
SE = standard error, SD = Standard Deviation

Table 4. Regression of speed (mph) on site and beacon status

	b	SE
Intercept	38.05*	0.022
Beacons on = 1	-10.63*	0.064
Ohio Valley Voices = 1	-0.91*	0.035
Ohio Valley Voices * Beacons on	-0.02	0.115

Note: *b* = unstandardized regression coefficient, SE = standard error, $N = 409{,}269$.
*$p < 0.001$

Table 5. Results of t-tests comparing average speed with beacons on across time of day

	N	Mean (mph)	SE	SD
Morning	11,856	26.69	0.09	9.68
Afternoon	30,693	27.31	0.06	10.46

Note: All relationships statistically significant ($p < 0.001$), $t = -5.5950$, $df = 42547$.
SE = standard error, SD = Standard Deviation

Table 6. Results of regression of lights and time of day

	b	SE
Intercept	37.23*	0.022
Beacons on = 1	-10.54*	0.096
Afternoon = 1	1.79*	0.031
Afternoon * Beacons on	-1.17*	0.114

Note: *b* = unstandardized regression coefficient, SE = standard error, $N = 503{,}563$, *$p < 0.001$

Figure 4: Average speed across sites, by beacon status

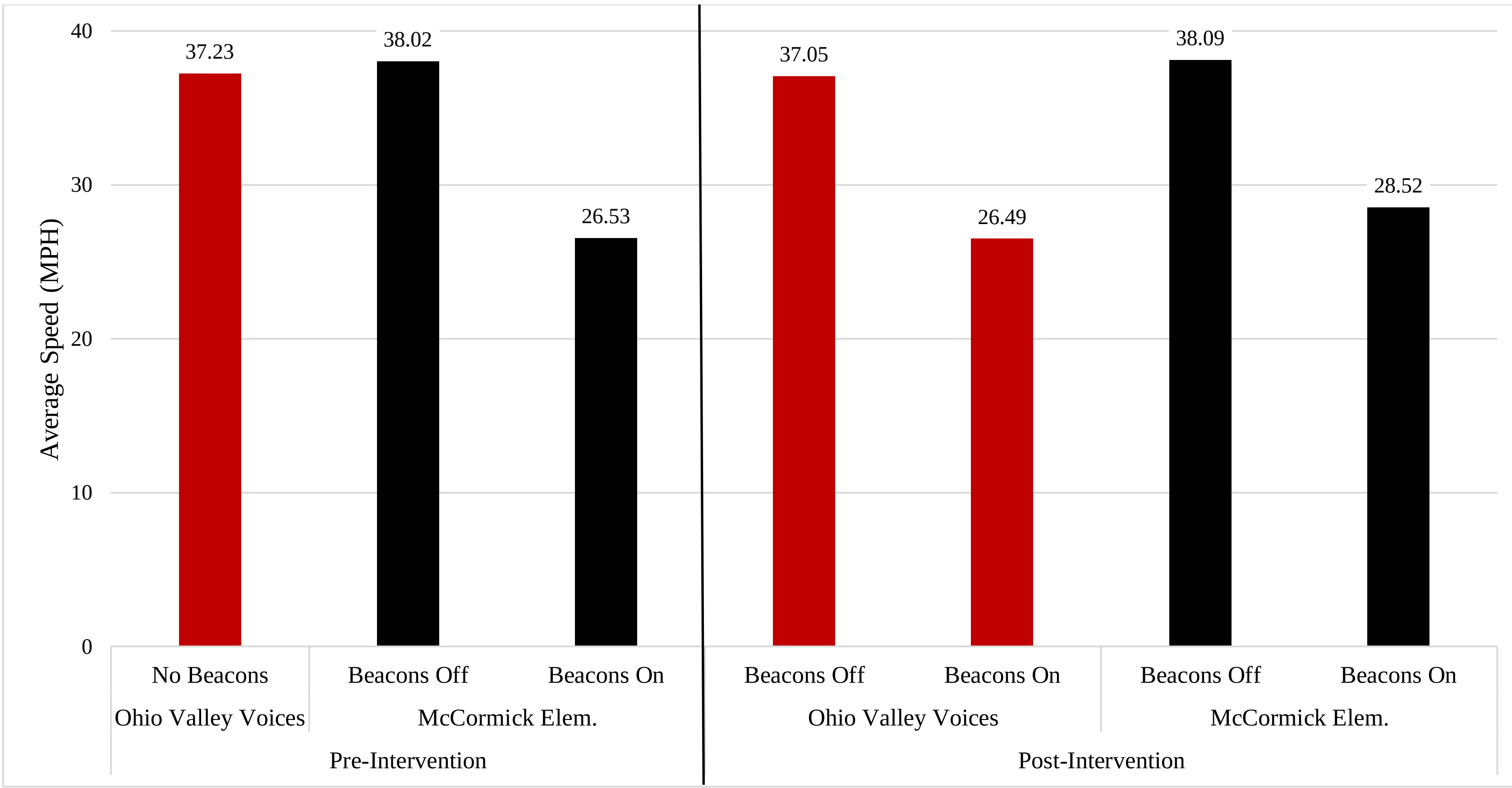
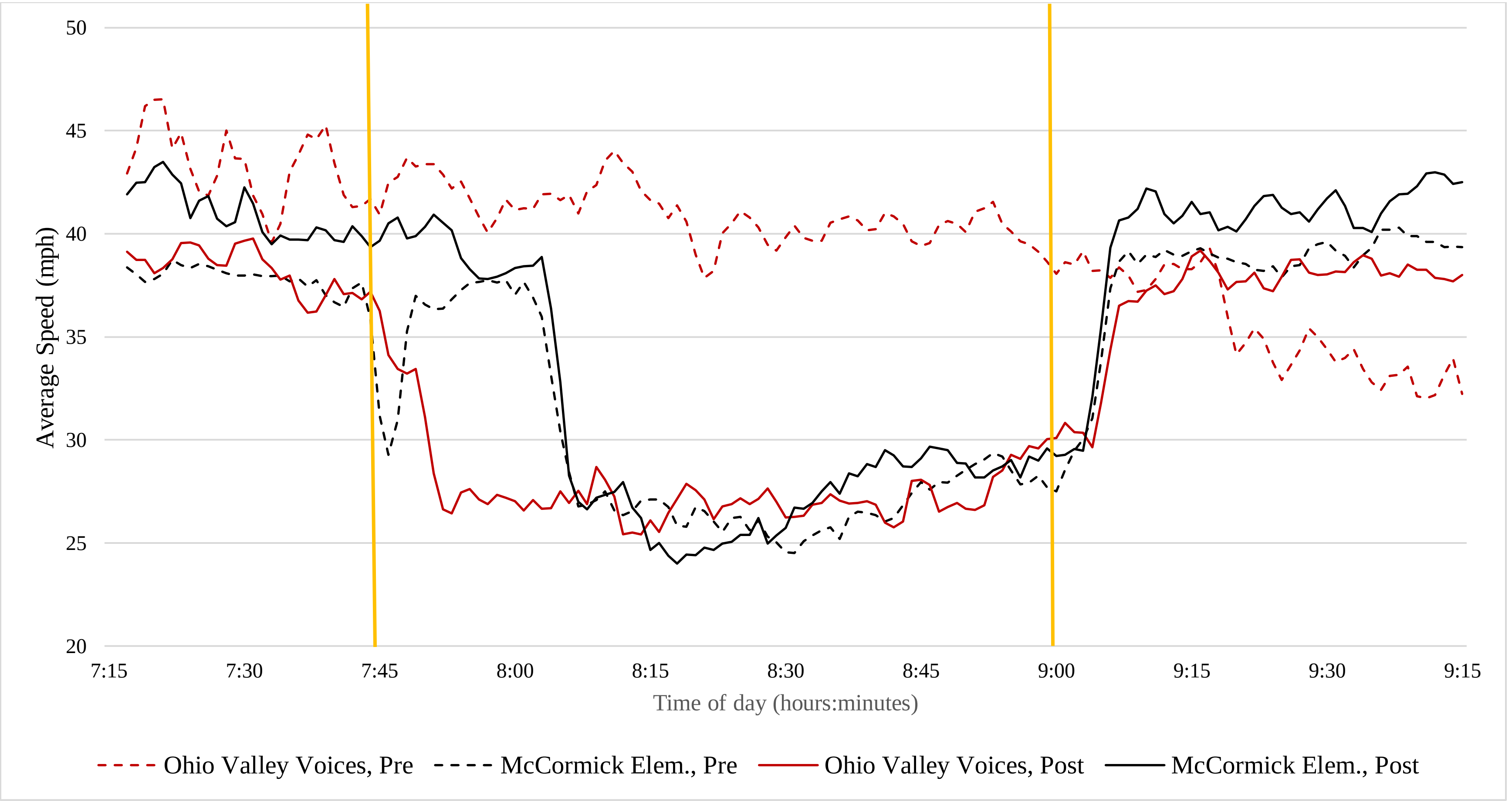
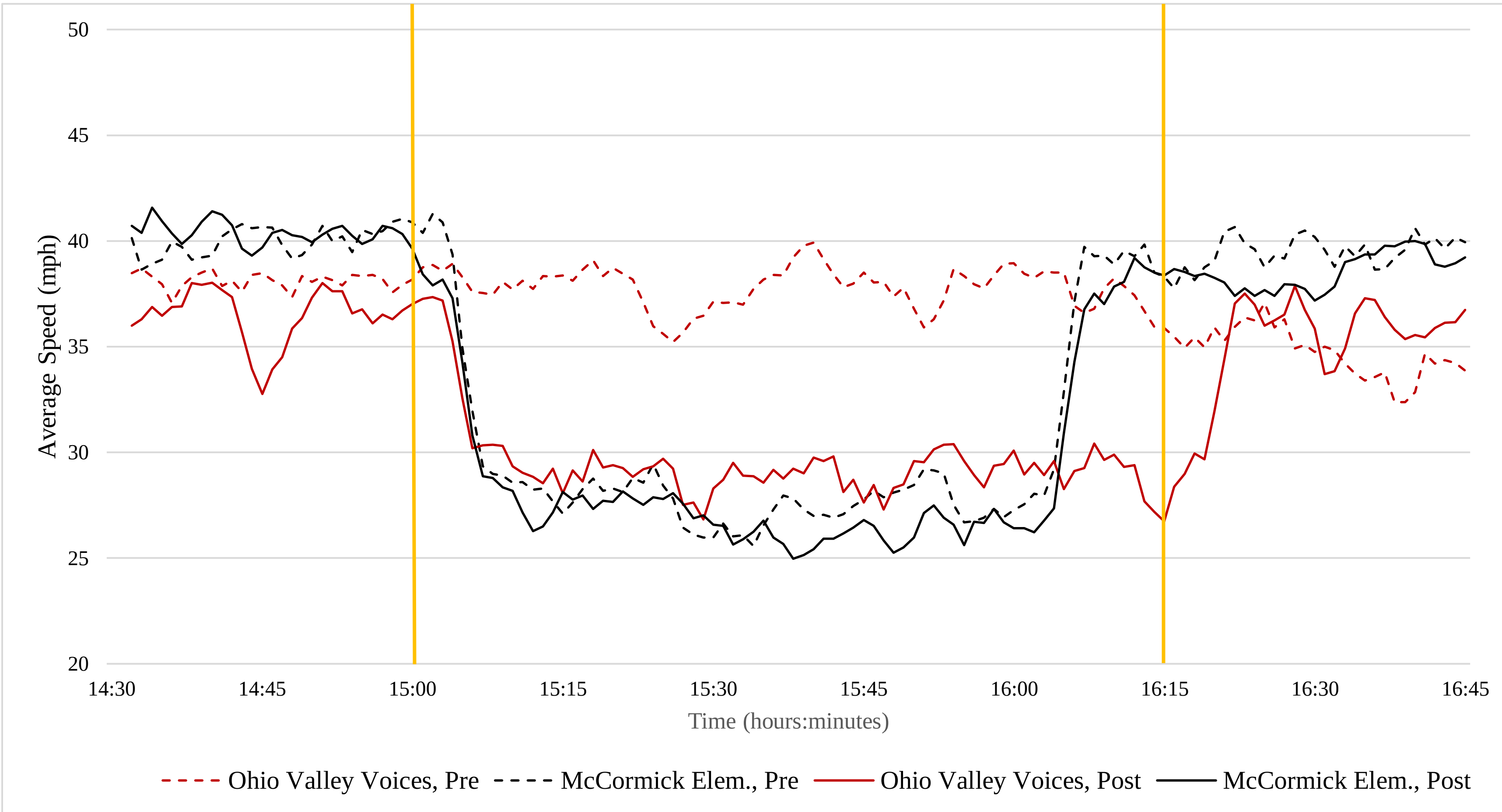


Figure 5: Average speed in the morning, by site



Note: Yellow bars indicate when beacons were activated.

Figure 6. Average speed in the afternoon, by site



Note: Yellow bars indicate when beacons were activated

Discussion

Examining the evidence presented in the current study suggests that adding warning beacons to a school zone results in drivers traveling at lower speeds. Additionally, while the third beacons did not result in any statistically significant reductions in driver speed, it may be helping sustain lower speeds over a longer amount of time. Additional studies are needed to fully understand the effects that these third beacons may be having on driver behavior.

The beacons did not reduce driver speeds to that of the posted speed limit during active hours: 20 miles per hour. While this may look like a failure from a strict legal perspective, this is certainly a success when viewed from a perspective of safety and public health. Simply put, *any* reduction in speed will have positive effects when it comes to school zones. Even a few miles per hour can allow for drivers to have increased reaction times and braking distance. Additionally, the reduction in speed could also turn a pedestrian collision into an injury rather than a death.

There is also some evidence that the status of the beacons can have differing effects depending on the time of day. This relationship appears significant, with drivers in the afternoon driving at higher speeds despite there being more motorists on the road. This also opens up potential conversations about potential effects that other variables may be having on the overall model. This also clearly identifies the need for additional replications of this type of intervention in additional school zones that are both similar and different to those used in the current study.

Limitations

The current study is not without its limitations. The first is that the sample only includes two suburban schools. Additionally, the current study was able to provide data on 12 days, only 9 of which were school days. These points limit its generalization and applicability in both time and space. For example, driver behavior may change depending on seasonal weather or if they are in an urban or rural school zone. The differences in driving speeds during the day also adds questions about the impact that other variables may be having on the model.

The need for the research team to manually identify the status of the beacons adds a level of uncertainty to the accuracy of our specific results. While the impact of adding any warning beacon to the school zone is quite clear, the impact of the third beacon is small and could have partially been the result of other factors described above. There are also concerns about the number of actual changes that were made to the intervention school. Specifically, it is possible that the changing of signage location could have had an impact on driver behavior, rather than the beacons. Follow-up studies that examine the effects of adding a third beacon to a currently two beacon school are currently being planned.

Conclusion

Despite the limitations, the current study offers evidence that adding warning beacons could be useful in reminding drivers that they are in a school zone. Adding the third additional beacon still may be useful in reducing both fatalities and injuries, with further research needed to re-examine its effectiveness. This solution may be especially useful because of its relatively low cost in both funding and physical space. Because of this, many schools, regardless of the space and funding available to them, may be able to reduce driver speeds and increase the safety of their students. That being said, additional studies should be conducted in order to properly understand the effects that adding a reminder beacon can have on different types of schools or during different seasons.

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Appendix

Figure 4: Example of an S4-3P School Zone Sign

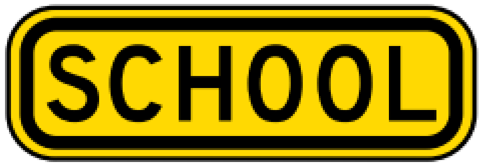

Figure 5: Example of an S4-5 School Zone Speed Limit Sign

Figure 6: Example of an S5-2 End School Zone Sign