Evaluating the Effectiveness of Portable Stop Signs

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About

This report was developed by the New Jersey Bicycle and Pedestrian Resource Center of the Alan M. Voorhees Transportation Center (VTC) at Rutgers, The State University of New Jersey.

The Alan M. Voorhees Transportation Center (VTC) is a national leader in the research and development of innovative transportation policy. Located within the Edward J. Bloustein School of Planning and Public Policy at Rutgers University, VTC has the full array of resources from a major research university on transportation issues of regional and national significance.

The New Jersey Bicycle and Pedestrian Resource Center (BPRC) assists public officials, transportation and health professionals, and the public in creating a safer and more accessible walking and bicycling environment through primary research, education and dissemination of information about best practices in policy and design. The Center is supported by the New Jersey Department of Transportation through funds provided by the Federal Highway Administration.

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Introduction / Objective

The New Jersey Bicycle and Pedestrian Resource Center (NJBPRC), with funding from the New Jersey Department of Transportation, uses research to investigate ways to improve traffic safety and decrease traffic fatalities on New Jersey roadways. Particular importance is being placed on improving safety for bicyclists and pedestrians, which are the most vulnerable roadway users. Unfortunately, the steps that have been taken over the past few years have not resulted in a meaningful reduction to the number of roadway fatalities. As of December 1, 2019, 162 pedestrians and bicyclists had been killed on New Jersey roadways. In addition, pedestrians now make up a greater share of roadways fatalities than in previous years[1].

As a densely populated state, New Jersey has many urban roadways where closely-spaced intersections are controlled by "STOP" signs. Considering that most pedestrian activities are in dense, urban areas, this puts them at a greater risk of injury or death if drivers fail to stop as required. In New Jersey, stop-controlled intersections saw 30,754 collisions in 2018, which resulted in 41 fatalities and 8,651 injuries. While the majority of those crashes only involved motor-vehicles, 375 pedestrians and 308 bicyclists were injured[2]. Previous studies have found that 70% of collisions at stop intersections are the result of driver violations, particularly failing to stop as required[3].

A variety of proven counter-measures exist to improve safety at intersections. Traffic signals, for example, can give pedestrians an exclusive phase to cross the street, but the installation of new signals is expensive and is not always warranted by traffic volumes. In some cases, traffic signals can result in higher crash rates than their stop-controlled counterparts[4]. Roundabouts have been studied and built as another approach to improve safety at intersections by changing the roadway geometry, but they can require the acquisition of property to be built. The space requirement makes them difficult to build in established cities. Lower-cost countermeasures aim to decrease crashes at stop-controlled intersections by increasing the visibility of the stop sign. Some of these measures include adding advance signage, flashing LED lights, supplemental pavement markings, and rumble strips. However, many of these measures have been tested in rural areas or wide suburban arterial roadways, and may not be appropriate or effective in urban residential neighborhoods or downtown districts.

In 2018, NJBPRC researchers observed multiple New Jersey municipalities deploying portable stop signs to supplement existing stop signs at intersections, as a way to increase driver compliance. A review of the available literature indicated that this innovative method of traffic control had not been studied to understand its effectiveness. Additionally, the Federal Highway Administration (FHWA) has not approved of this technique as a way of improving safety at intersections.

The research team decided to evaluate the effectiveness of supplemental portable stop signs in improving driver compliance at stop controlled intersections by evaluating the existing installation at an intersection in Central New Jersey. Fortunately, due to nearby construction, the portable stop sign was temporarily removed, which allowed the research team to compile baseline driver compliance statistics for the intersection. The portable stop sign was then reintroduced to the intersection, and driver compliance was also measured. This report compares the findings to see if portable stop signs should be recommended as a way to improve driver compliance and increase driver and pedestrian safety in New Jersey and beyond.

[1] Fatal Accident Statistics. https://www.njsp.org/info/fatalacc/index.shtml.

[2] New Jersey Division of Highway Traffic Safety https://njdhts.numetric.com/roads/crash-query#/

[3] Retting, R. A., H. B. Weinstein, and M. G. Solomon. Analysis of motor-vehicle crashes at stop signs in four U.S. cities. Journal of Safety Research, Vol. 34, No. 5, 2003, pp. 485–489.

[4] Persaud B, Hauer E, Retting RA, Vallurupalli R, Mucsi K. Crash reductions related to traffic signal removal in Philadelphia. Accid Anal Prev. 1997;29:803–810.

Background

The FHWA mandates national standards for traffic control devices in the Manual on Uniform Traffic Control Devices for Streets and Highways (MUTCD). This manual defines and standardizes traffic control devices that can be used on all public streets. Specifications within the manual include colors, shapes, sizes, and fonts that can be used on signs and on road markings.

Regulatory signs are described as those that "shall be used to inform road users of selected traffic laws or regulations and indicate the applicability of the legal requirements." One of the most common signs, the stop sign, is "an octagon with a white legend and border on a red background." A standard stop sign is 30" x 30", although they can be as large as 48" x 48" in some areas[5].

The MUTCD places various restrictions on how stop signs can be displayed. For example, the only supplemental sign that may be installed with a stop sign is "ALL WAY" or "CROSS TRAFFIC DOES NOT STOP" (where applicable). Additionally, the MUTCD provides guidance on which intersections are suitable for stop signs, based on traffic volumes or crash history. This includes recommendations on when to use a two-way stop, where drivers of one roadway do not have to stop, and an all-way stop, where all vehicles must come to a complete stop.

While the MUTCD does allow for a second supplemental stop sign to be placed on the left-hand side of a multi-lane roadway to increase driver compliance, it does not allow for the use of a portable stop sign, except for "emergency and temporary traffic control zone purposes." Currently, the FHWA recommends the following improvements for situations in which "there is a history of drivers failing to heed stop signs that are clearly visible":

- Install STOP AHEAD sign.
- Increase size of STOP and STOP AHEAD signs.
- Install an additional stop and/or STOP AHEAD sign on the left-hand side of the road or in the median on the left side of the approach.
- Install an overhead STOP sign.
- Install intersection illumination.
- Install a red reflective strip or post insert on the STOP sign post.
- Consider adding a flashing red beacon in conjunction with the STOP signs mounted either on top of the sign or on an overhead span wire or mast arm.
- Place actuated red flashing beacons on the top of a STOP sign. A detector would be in the pavement in advance of STOP sign. As a vehicle approaches, the red beacons would begin to flash. This solution would address the driver expectancy problem and give more attention to the stop sign.
- Under rural road conditions, install two sets of transverse rumble strips in the approach lane (one in advance of the STOP AHEAD sign and the other before the stop sign). Consider installation of two additional sets of transverse rumble strips to supplement the first two locations[6].

[5] 2009 Edition Chapter 2B. Regulatory Signs, Barricades, and Gates. https://mutcd.fhwa.dot.gov/htm/2009/part2/part2b.htm.

[6] Intersection Safety Issue Briefs. https://safety.fhwa.dot.gov/intersection/other_topics/fhwasa10005/brief_4.cfm.

Regardless of this guidance, the research team has observed several municipalities in New Jersey placing a portable stop sign to supplement existing stop control. Typically, they have been seen in the center of the roadway, on the double-yellow lines that designate direction of travel (Figure 1). At the location studied in this report, the portable stop sign was placed on the white line dividing two lanes of traffic moving in the same direction along a one-way street.

Figure 1. Portable stop sign added to supplement standard signage and pavement stencils in Asbury Park, NJ.

These observed installations are similar to the way in which municipalities install In-Street Pedestrian Crossing signs (R1-6), which are permitted by the MUTCD in Section 2B.12. The MUTCD provides the following guidance for their use:

“If used, the In-Street Pedestrian Crossing sign shall be placed in the roadway at the crosswalk location on the center line, on a lane line, or on a median island. The In-Street Pedestrian Crossing sign shall not be post-mounted on the left-hand or right-hand side of the roadway,” and “unless the In-Street Pedestrian Crossing sign is placed on a physical island, the sign support shall be designed to bend over and then bounce back to its normal vertical position when struck by a vehicle.”

Figure 2. An in-street pedestrian crossing sign in Asbury Park, New Jersey..

A 2018 study published in the ITE Journal[7] looked at the effectiveness of R1-6 signs and compared them to an earlier study that cataloged yielding rates at uncontrolled crosswalks with Rectangular Rapid Flashing Beacons (RRFB) and Pedestrian Hybrid Beacons (PHB). Although the sample size of the study was small, it did find that the signs resulted in higher yielding rates at multiple installations. At most sites, yielding rates went from under 20 percent to over 60 percent. As such, it seems reasonable that a similar installation with a stop sign would produce positive effects.

[7] Houten, R. V., Hochmuth, J., Dixon, D., and McQuiston, C. Safety Benefits of the gateway R1-6 Treatment: An Examination of Effects on Drivers Yielding to Pedestrians, Speed at Crosswalks, and Sign Durability. ITE Journal, March 2018, pp. 31-41.

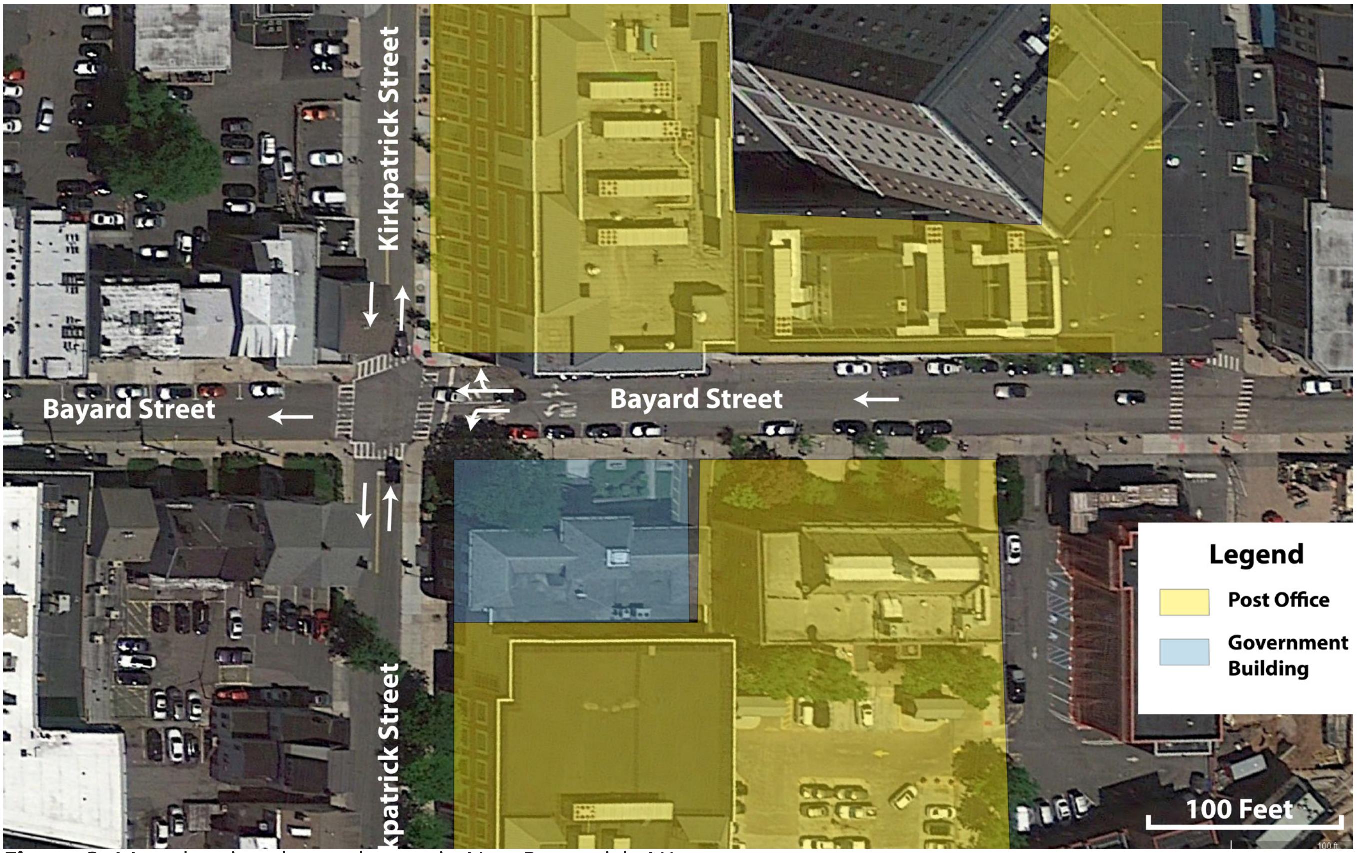

Figure 3. Map showing the study area in New Brunswick, NJ.

Study Location

As mentioned in the introduction, the study intersection was selected because the local municipality had already deployed a portable stop sign as a way to increase driver compliance. As seen in Figure 3, Bayard Street is a one-way road running to the west. It is 37 feet wide, with one lane of travel and parallel parking on each side. At the intersection with Kirkpatrick Street, one lane is added for left turning traffic, while another lane allows for right turns and through movements. In New Jersey, state law prohibits parking within 50 feet of a stop sign[8].

Figure 4. Study location, looking west.

The portable stop sign is normally placed on the center white line between the two lanes, as noted by the star in Figure 3. Two permanent stop signs are mounted on posts on each side of the roadway. The pavement is marked with a stop bar and a high visibility crosswalk. The municipality also uses plastic bollards to delineate the no-stopping zone and to prevent illegal parking at the intersection (Figure 4). Occasionally, the portable stop sign migrates to the side of the road, as seen in Figure 4. However, the municipality relocates it to the centerline. For this study, data was not collected when the stop sign was located on the side, as depicted in the photo.

The intersecting roadway, Kirkpatrick, is bi-directional with one lane in each direction. Each direction is controlled by a single stop sign on the right side of the roadway, along with a stop bar and a high-visibility crosswalk.

[8] 2009 New Jersey Code TITLE 39 - MOTOR VEHICLES AND TRAFFIC REGULATION 39:439:4-138 - Places where parking prohibited

Most stop-controlled intersections in New Jersey only require traffic on the minor street to stop, giving the right-of-way to the major street (two-way stop control). All-way stops, such as this one, are comparatively rare. Since Bayard Street has two lanes in the same direction, it gives the appearance that it is the major street with the right-of-way. This configuration may lead to some drivers not realizing they must stop. However, restricted visibility (as seen in Figure 4) and high pedestrian volumes warrant the use of an all-way stop configuration as installed by the municipality. In December 2018, a 63-year-old pedestrian was injured by a vehicle failing to stop before making a left turn.

Elevated pedestrian volumes exist at this intersection due to the presence of multiple civic buildings. The northeast corner of the intersection is home to county offices and the county court. The southeast corner hosts a post office, city hall, and city police headquarters. Non-employees visiting any of these buildings must use a public garage located north of the study area, or arrive using public transit. The neighborhood is also home to a variety of restaurants that attract large lunch crowds. Two blocks away, the city's main street has a vibrant retail scene that attracts pedestrians and visitors throughout the day.

Methodology

The research team conducted a literature review to identify similar studies and research methodologies. Two types of research are prominent in literature related to driver behavior and stop signs compliance. One type is empirical, using observational or experimental methods. Intersections observed by these studies are selected based on location, physical design and stop sign types. Another type is an overview of stop sign design principles and guidelines that discuss appropriate locations for stop signs, best practices of design, benefits and limitations.

The most common research method found was to observe driver compliance at different stop controlled intersections. In a study within the UCLA campus, researchers selected three intersections in heavily trafficked areas to observe driver compliance at stop signs[9]. The stopping behavior was categorized as one of three types: complete stop, where the tires of the vehicle stopped rotating and majority of the vehicle stayed behind the marked stop line; crosswalk stop, where the driver halted within the crosswalk lines; and rolling stop, where the driver slowed but never stopped.

Some studies conducted experiments that evaluated the impact of additional devices at intersections on driver compliance. One study installed a "LOOK BOTH WAYS" sign and an LED sign that featured animated eyes scanning left and right at three locations to prompt drivers to look left and right for approaching traffic. To evaluate the effectiveness, observations focused on whether the driver came to a full stop and whether the driver looked to the right before entering the intersection[10].

Another method observed in the literature review used the combination of an opinion survey and a longitudinal observation study. A study in Canada first surveyed participants on their estimation of the driver compliance or noncompliance at local stop signs under various conditions: in general, as a function of presence/absence of another vehicle, sex and age of the driver, and the type of vehicle. The survey offered three types of driver behavior: 1) complete stop, 2) slow, no stop, and 3) no slow or stop, and participants were asked to estimate the percentage of each behavior under the two circumstances. Then, researchers observed stop signs for five consecutive years around the same time of year. The variables collected are the same as the ones included in the survey: three types of driver behavior, presence/absence of another vehicle, sex and age of the driver, and the type of vehicle. Using responses from the survey, researchers tested perceived driver compliance against observed driver behavior[11].

[9] Deveauuse, N., K. Kim, C. Peek-Asa, D. Mcarthur, and J. Kraus. Driver Compliance With Stop Signs at Pedestrian Crosswalks on a University Campus. Journal of American College Health, Vol. 47, No. 6, 1999, pp. 269–274.

[10] Houten, R. V., and R. A. Retting. Increasing Motorist Compliance And Caution At Stop Signs. Journal of Applied Behavior Analysis, Vol. 34, No. 2, 2001, pp. 185–193.

[11] McKelvie, S. J. (1986). An opinion survey and longitudinal study of driver behaviour at stop signs. Canadian Journal of Behavioural Science/Revue canadienne des sciences du comportement, 18(1), 75.

Figure 5. Researcher, on bench, observes a truck at the study intersection.

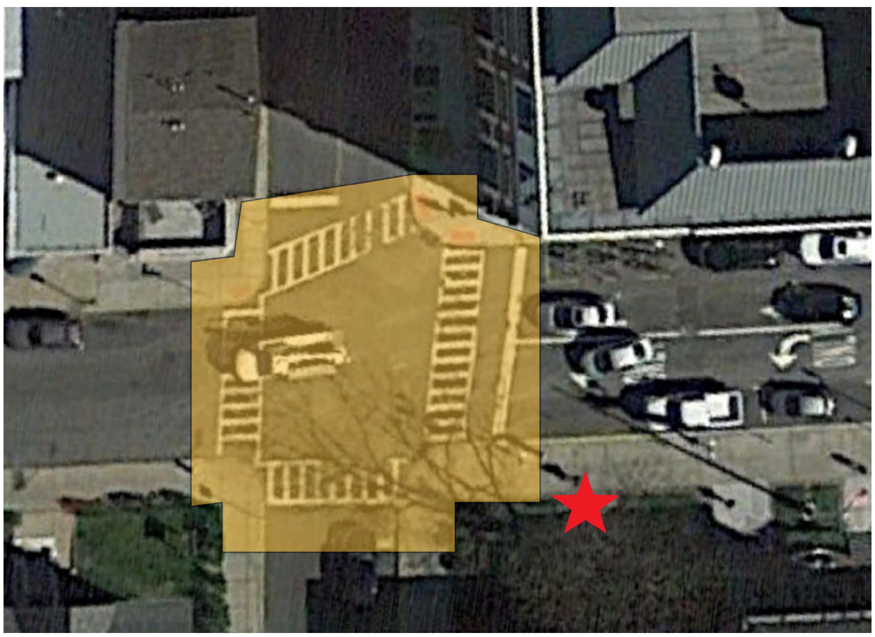

Figure 6. If a pedestrian was located within the orange area when the driver arrived at the stop bar, the interactionwas classified as occurring with a pedestrian. The observer sat at the location of the red star.

Most of the literature classified stopping behavior in either three or four buckets. Based on this review, our research team decided to classify drivers under the following categories for this study:

- Complete Stop: The driver comes to a complete stop on or before the crosswalk.
- Crosswalk Stop: The driver comes to a complete stop within the crosswalk.
- Rolling Stop: The driver slows down, but does not come to a complete stop.
- No Stop: The driver does not slow down at all.

In order to guarantee consistency in data collection and classification, a single trained researcher conducted every observation. The researcher sat on a conveniently located bench on the southeast corner of the intersection (Figure 5). Aside from classifying the stopping behavior, the researcher also noted if a pedestrian was located within the intersection at the time, at a location visible to the driver. Figure 6 shows the location of the observer and the bounding box for pedestrian activity.

Observations were taken on Tuesdays, Wednesdays, or Thursdays during sunny or cloudy weather over the course of a few weeks in summer and fall 2019. Observations were only taken during typical work days, with normal traffic patterns. Observation periods were 7am until 10am, 11am until 1pm, and 4pm until 8pm. Each time period was first observed two times without the portable stop sign, and then two times with the portable stop sign. Observations that were abandoned due to rain or other circumstances were not included in the data.

During the observation, it became clear that many drivers conducting a "crosswalk stop" were simply drivers who intended to do a "rolling stop" but were forced to stop late due to the presence of a pedestrian or other vehicle in the intersection. As the collected data did not include information on the presence of other drivers, the research team decided to combine those two behaviors. As such, this report classifies driver behavior in one of the following categories:

- Complete Stop: The driver comes to a complete stop on or before the crosswalk.
- Partial Stop: The driver slows down, but does not come to a complete stop, OR stops within the crosswalk.
- No Stop. The driver does not slow down at all.

Data

A total of 9,146 vehicles were observed over twelve different observation periods. In the morning, peak traffic

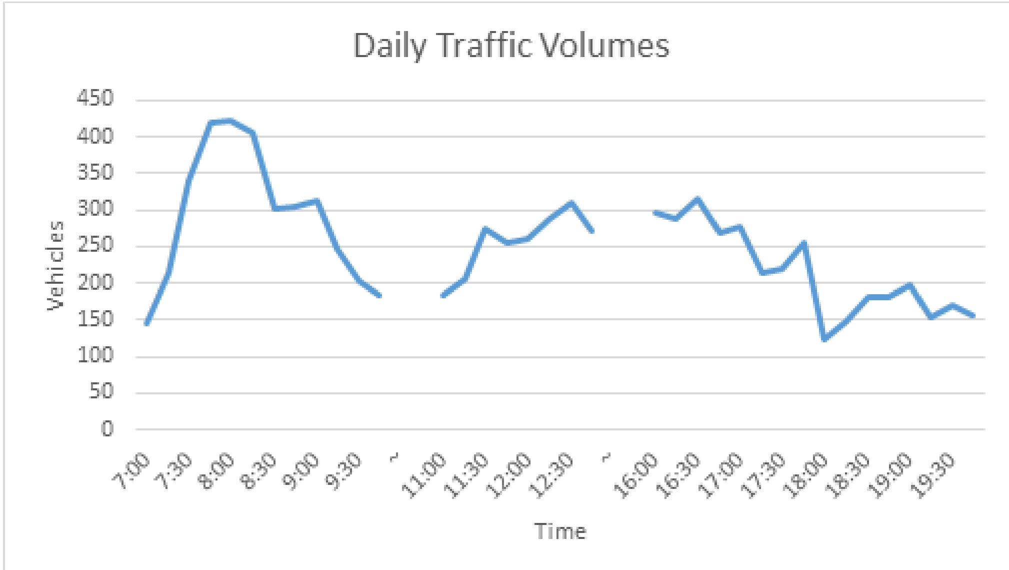

Figure 7. Vehicle counts on Bayard Street

was found to be between 7:45am and 8:30am. In the evening, consistent traffic volumes stretched from 4pm until 6pm. The lowest traffic volumes were observed between 7pm and 8pm. Figure 7 shows combined traffic volumes throughout the day.

These numbers match expectations. Many of the vehicles using the intersection are employees of, or have business with city government, county government, or the court system. These offices are generally open from 8:30am to 4:15pm.

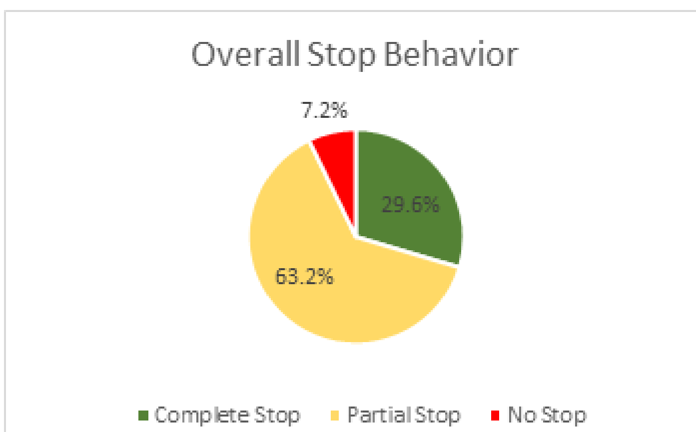

Figure 8. Stop behavior of all observed drivers, at all hours, with and without portable stop sign.

As discussed in the methodology section, driver behavior was classified as either coming to a 'Complete Stop," a 'Partial Stop," or "No Stop." At all hours of the day, before and after the portable stop sign was added, the most common observed behavior was a partial stop, exhibited by 63% of drivers. As seen in Figure 8, 30% of drivers came to a complete stop, while 7% did not stop at all.

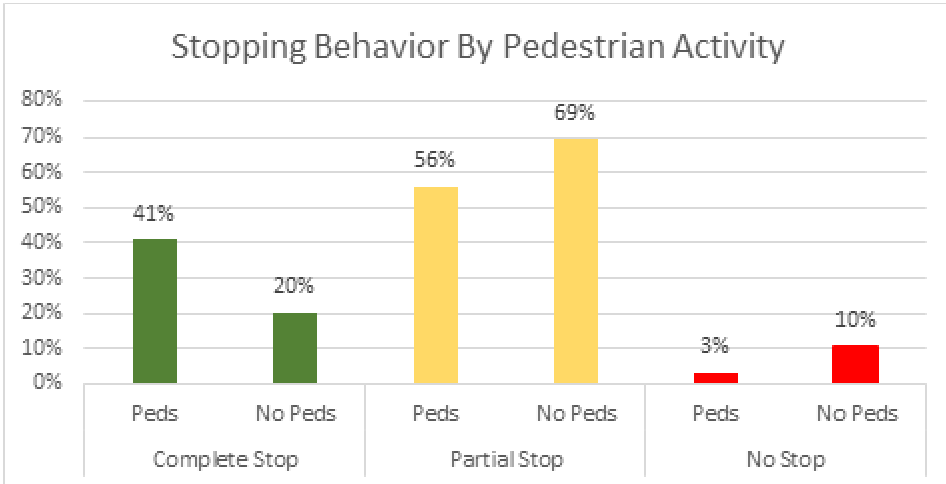

Figure 9. Stop behavior of all observed drivers related to pedestrian activity, at all hours, with and without portable stop sign.

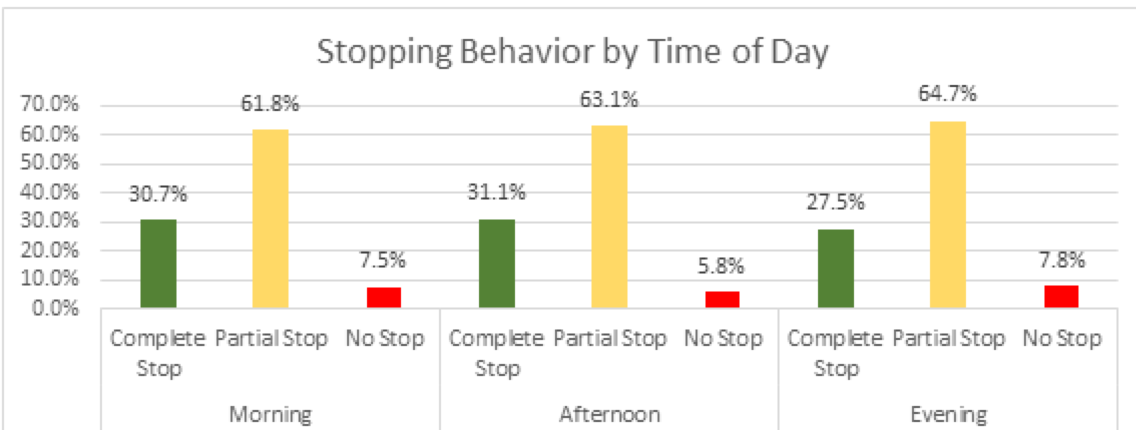

Figure 10. Stop behavior of all observed drivers by time of day.

Each observation included data if a pedestrian was located somewhere within the intersection. As seen in Figure 9, 56% of drivers enacted a partial stop when a pedestrian was present, compared with 69% when there were no pedestrians. 39% of drivers came to a complete stop when pedestrians were in the intersection, in contrast to only 20% of drivers who stopped when no pedestrians were visible. Only 3.5% of drivers did not stop at all when pedestrians were nearby, compared with 10.5% of drivers blowing through the stop sign when no pedestrians were visible.

This result may indicate that drivers failing to stop are not doing so because they did not see the stop sign, but because they felt that there was no need to stop, since the intersection appeared to be empty. This hypothesis could be better understood if the study was repeated with data about intersecting traffic.

At all hours of the day, the most common observed behavior was a partial stop (Figure 10). 62% of morning drivers, 63% of afternoon drivers, and 65% of evening drivers exhibited this behavior. In the morning and afternoon, 31% of drivers came to a complete stop, compared with just 28% in the evening. 7.5% of morning drivers did not stop at all, compared with 6% in the afternoon and 8% in the evening.

This change in behavior throughout the day was likely related to the presence of pedestrians, rather than having to do with the time of day. For example, 57% of drivers observed during the afternoon period arrived at the stop sign when a pedestrian was present. This is in contrast to only 39% of interactions featuring a pedestrian in the evening. Aside from drivers having to stop to avoid hitting a pedestrian in the crosswalk, the added eyes on the street during the afternoon hours might encourage more lawful behavior.

	Complete Stop			Partial Stop			No Stop		
	Peds Present	No Peds	Combined	Peds Present	No Peds	Combined	Peds Present	No Peds	Combined
No Portable Stop Sign	931	573	1504	1187	1531	2718	87	286	373
	42.2%	24.0%	32.7%	53.8%	64.1%	59.2%	3.9%	12.0%	8.1%
Portable Stop Sign	756	446	1202	1121	1942	3063	48	238	286
	39.3%	17.0%	26.4%	58.2%	74.0%	67.3%	2.5%	9.1%	6.3%
Difference	-2.9%	-7.0%	-6.3%	4.4%	9.9%	8.2%	-1.5%	-2.9%	-1.8%
Percentage Change	-7.0%	-29.2%	-19.3%	8.2%	15.4%	13.8%	-36.8%	-24.3%	-22.6%

Figure 11. Stop behavior before and after the portable stop sign was added, with and without pedestrian interactions.

Figure 11 shows driver compliance at the intersection before and after the portable stop sign was added. Each type of behavior (complete stop, partial stop, and no stop) is shown when pedestrians were present, when pedestrians were not present, and a combined total. For example, when pedestrians were present and before the portable stop sign was added, 42.2% of drivers came to a complete stop, 53.8% came to a partial stop, and 3.9% did not stop at all. When pedestrians were not present, only 24% of drivers came to a complete stop, while 64% came to a partial stop, and 12% did not stop at all.

The expectation of this study was that the addition of the portable stop sign would increase driver stop compliance at the intersection. Adding the stop sign did reduce the number of situations where the driver did not stop at all. Without the portable stop sign, 8.1% of drivers did not stop. This decreased to 6.3% of drivers after the portable stop sign was added. Viewed as a percentage change, the addition of a portable stop sign resulted in a 37% decrease of no-stopping behavior when pedestrians were present.

However, there was also a decrease in the number of drivers coming to a complete stop before the crosswalk. This observation was true both when pedestrians were present, and when they were not. Instead, more drivers conducted a partial stop. The largest absolute change was when pedestrians were not present. Prior to the portable stop sign, 64% of drivers completed a partial stop; this increased to 74% after the portable stop sign was added. These results were consistent at all times of the day.

[12] Dangers of Speeding https://www.nhtsa.gov/risky-driving/speeding.

[13] Richards, D. C. Relationship between Speed and Risk of Fatal Injury: Pedestrians and Car Occupants. Transport Research Library, September 2010.

[14] Arnold, D. E., Lantz, K. E. Evaluation of Best Practices on Traffic Operations and Safety, Phase 1: Flashing LED Stop Sign and Optical Speed Bars, June 2007.

[15] Feest, J. Compliance with Legal Regulations: Observation of Stop Sign Behavior. Law & Society Review 2, no. 3 (May 1968): 447-462

Discussion

The increase in partial stop behavior was not expected by the research team, but it may be explained by other behavioral change that were not measured. In particular, this study did not measure vehicle speeds before or after installation due to limitations on available equipment. However, vehicle speeds are of particular importance when it comes to roadway safety. In 2017, 26% of traffic fatalities were attributed to speeding . Higher rates of speed increase the stopping distance of vehicles and also result in more force applied during a collision. This in turn is especially dangerous to pedestrians who are more likely to suffer fatal injuries as speeds increase[13]. A 2007 study in Virginia recommended the installation of flashing LEDs at stop signs in rural intersections due to the decrease in driver speeds approaching the intersection[14].

It is possible that drivers arriving to the intersection at a slower rate of speed may have felt they complied with the purpose of the stop sign. It may also be true that overall safety at the intersection may have improved due to slower speeds. In order to confirm this hypothesis, the study should be repeated with vehicle speed data approaching the intersection before and after deployment of the portable stop sign.

A common method to evaluate the effectiveness of safety interventions is to compare three years of crash data before and after the modification. As these installations in New Jersey are recent, that data is not yet available. It is also unlikely that the data will be reliable. As seen in Figure 4, the portable stop sign has a tendency to migrate to the edge of the intersection, before it is returned to the middle by municipal staff. If a crash is reported, it will be impossible to know where the portable stop sign was at the time of the collision, as the police report is unlikely to mention that detail.

Most of the literature found during this study focused on improving safety outcomes by enhancing the visibility of the stop signs. That in turn is reflected by the recommendations made by FHWA which propose using larger signage, flashing lights, and other attention grabbing schemes to bombard drivers with information about the stop control. Indeed, adding the portable stop sign should provide yet another visual cue that the intersection is stop-controlled. Unfortunately, these interventions do not account for drivers who see and understand the stop sign, but make a conscious choice to ignore it. One study from 1968 concludes that behavior at stop signs is related to social pressure, which is distinct from legal pressure[15]. The study reached this conclusion by looking at the stopping behavior of drivers at the same intersection by age, race, sex, and the presence of passengers. That study found that 62% of drivers made a rolling stop, which is similar to the findings in this study. The report further concludes that as long as enforcement of partial stops is rare, behavior will not change.

To that end, more conclusive data on portable stop signs might be found if they are deployed at an intersection with a proven crash history, where drivers report that they did not see the stop sign. In that case, the deployment of a portable stop sign should be studied in place of an alternative (and likely more expensive) treatment, such as adding LED lighting to the signs.